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SCIENCE AND TRAFFIC DEVELOPMENT

TRANSPORT AND LOGISTICS INDUSTRY IN DIGITAL AGE

10th – 11th May, Opatija, Croatia

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AIR TRAFFIC CONTROLLER ASSESSMENT OF THE FREE ROUTE AIRSPACE IMPLEMENTATION WITHIN ZAGREB AREA CONTROL CENTRE

ABSTRACT

Current tools in air traffic control are not sufficient to support the advanced conflict detection that has arisen from implementation of free route airspace. Free route airspace has proven to be more efficient for airline companies, but the effects on air traffic controllers have not yet been tested in full. It is attempted to solve that problem in this paper and to see what kind of impact free route airspace has on the air traffic controllers. It is concluded that with the implementation of specific free route airspace (SEAFRA), traffic complexity is increased and that controllers have a hard time detecting conflict in advance since there are no more old "hotspots" to concentrate on. Hence, the whole airspace is considered as a hotspot. At the end of the paper, several steps have been proposed for future work and for solving some of the issues that the air traffic controllers have emphasized.

KEY WORDS

Free route airspace; air traffic controller; traffic complexity; conflict detection; workload;

1. INTRODUCTION

In accordance with contributing to the achievement of the Single European Sky ATM Research (SESAR) objectives, Free Route Airspace (FRA) started the path of development in 2008. European Union, through the Commission Implementing Regulation (EU) No 716/2014 commenced the ambitious plan of implementing FRA by 2021 in a majority of European airspace [1] and gave the FRA concept definition: "A specified airspace within which users may freely plan a route between a defined entry point and a defined exit point, with the possibility to route via intermediate (published or unpublished) waypoints, without reference to the ATS route network, subject to airspace availability. Within this airspace, flight remains subject to air traffic control." [2–4]. An example of points used in FRA is given in Figure 1 where FRA (I) represents intermediate point, FRA (A) arrival connecting point and FRA (E/X) entry or exit point. These new points have significant meaning to the Air Traffic Controllers (ATCOs) and the preponderant role for carrying out the traffic within FRA falls on them, therefore it is important to pay attention to their performance.

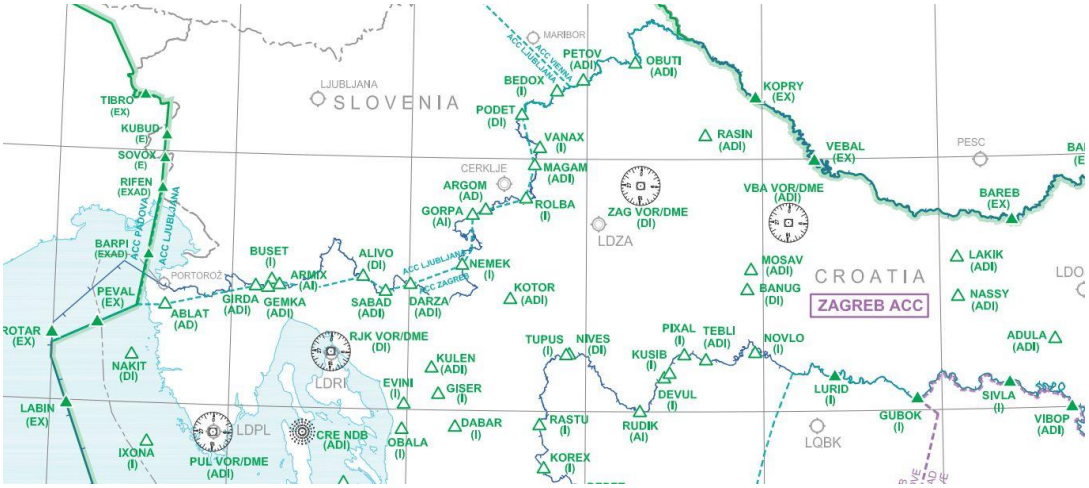


Figure 1 – Example of FRA points [5]

FRA presents a means of enhancing airspace performance in capacity, efficiency and environment [2]. The proliferation of average daily flights in EUROCONTROL area emphasizes the important role of airspace capacity. STATFOR observations showed an increase of 2.4% traffic in 2016 compared to data from 2015 (Figure 2) [6]. Further average annual growth from 2015 to 2023 is forecast to be 1.9% and in 2023 number of flights is expected to be 14% higher than in 2016 [6]. The latter year showed a decline of service quality that started three years before. The time of arrival within 15 minutes of the scheduled time was in 80.5% fights and compared to 2015 a decrease of 1.6% was noted. Departure delay increased from 10.2 minutes to 11.2 minutes per departure. The main reason for delays were reactionary delays that were caused by previous flight legs. Turn around delay is the next main reason for overall delays caused by operators such as airlines and airports although their share in delay shows a decline by 1% compared to 2015 [6].

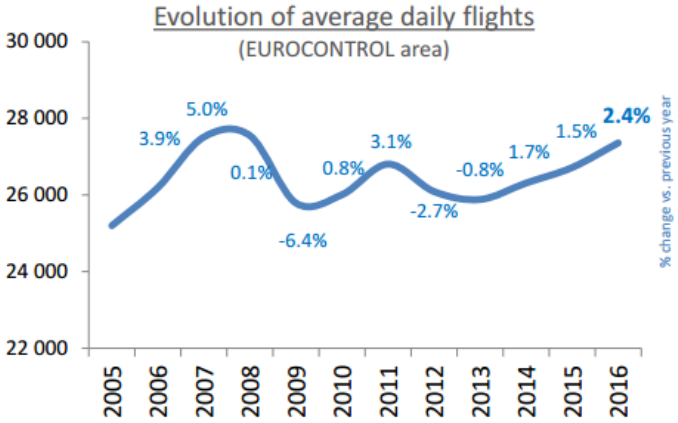


Figure 2 – Evolution of average daily flights [6]

The growth of the number of aircraft has an inevitable connection with emissions, costs and fuel burn. Enlarging the area of FRA directly influences the environment. The flight efficiency benefits brought by FRA are clearly presented in STATFORs analysis of trajectories. Comparison of flight plan trajectories and actual trajectories (Figure 3) distinguishes the States with full FRA implementation (red circle) and States who have implemented FRA partial or with no implementation (blue square). The latter States have flight efficiency of 1.6% points less than the full FRA implementation States and 1% points higher gap between actual and planned operation. The predictability, which is important for utilization of capacity and resources, is improved by leading the actual operations closer to the planned ones [6].

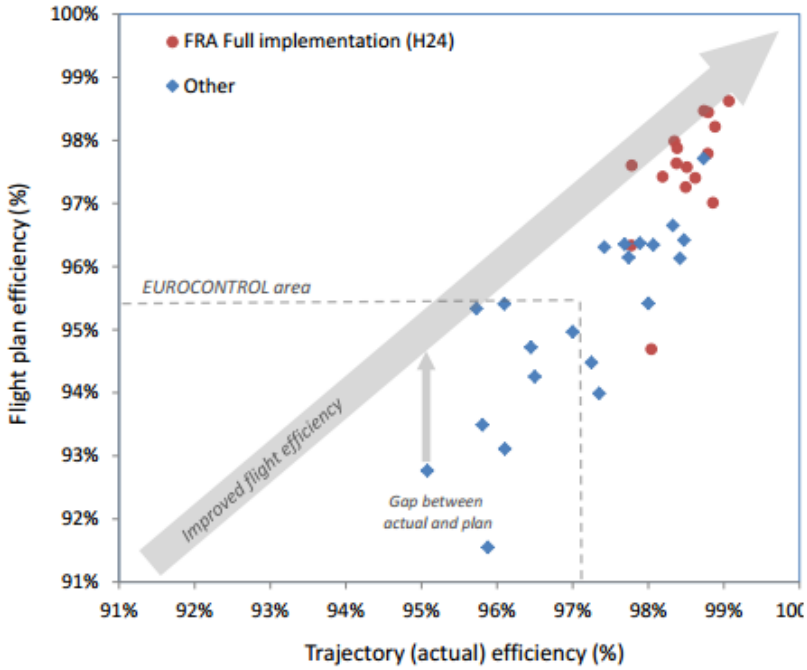


Figure 3 – Flight efficiency by State [6]

In order to achieve FRA all over Europe, cross-border implementation of FRA is or shortly will be done in larger parts of Europe: Croatia – Serbia – Bosnia and Herzegovina and Montenegro (SEAFRA); Romania – Hungary – Bulgaria (SEENFRA); Malta – Italy; Estonia – Latvia – Finland – Sweden – Denmark – Norway (NEFRA) and Austria - Slovenia (SAXFRA). It is expected that their work will improve natural harmonization of airspace design, operating procedures and rules with the addition to network flexibility [6]. Before the summer of 2018, the European airspace is expected to take shape as shown in Figure 4 [7].

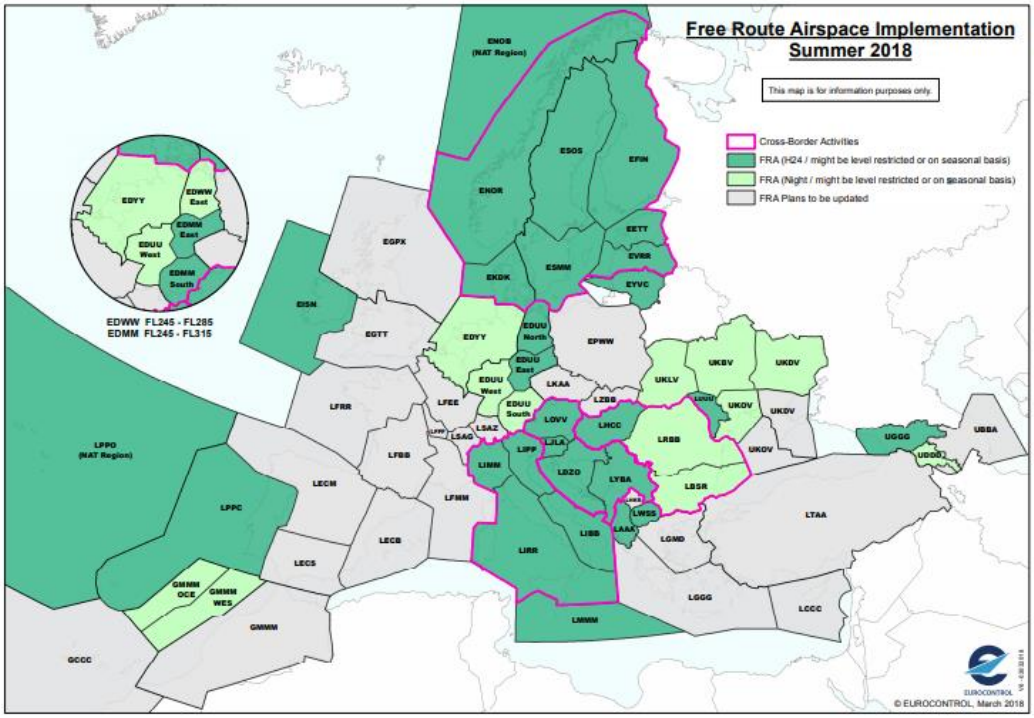


Figure 4 – Project plan for the implementation of FRA [7]

SEAFRA is one of the cross boarders FRA implemented and well on in operation. The airspace covers the area of four countries: Croatia, Serbia, Bosnia and Herzegovina and Montenegro being the first one in Europe by such a high number of states included. Three ANSPs: CCL (Croatia Control Ltd), SMATSA (Serbia and Montenegro Air Traffic Services SMATSA LLC), and BHANSA (Bosnia and Herzegovina Air Navigation Services Agency) are offering their costumers flight planning without the boarder's constriction but instead entry, exit and intermediate points into the whole airspace. SEAFRA operates 24 hours a day and has become a good milestone for the SECSI FRA [8].

In February 2018, South East Common Sky Initiative (SECSI) FRA was organized by joining Croatia – Serbia – Bosnia and Herzegovina and Montenegro (SEAFRA) and Austria - Slovenia (SAXFRA) (Figure 5). SECSI is brought to strengthen the South East Axis which has an important role in connecting the Central and South Europe. It gives more routing options and city pair connections. The estimation of potential saving per day are about 1.940 NM in flight distance, a reduction in fuel consumption of 8,000 kg, a reduction in CO2 emissions of 25,500kg and 285 minutes in flight time [9]. Therefore, the savings for airline operators are obvious and the profit for passengers lies in shorter duration of fight. SECSI FRA was one of the most ambitious projects in Europe regarding the airspace. It is an example of how two large already functioning FRA connect to one in order to achieve the common European FRA scheduled for 2022 [9,10].



Figure 5 – South East Common Sky Initiative Free Route Airspace (SECSI FRA) [9]

2. AIR TRAFFIC CONTROLLERS ASSESSMENT

For the purpose of this research, an anonymous survey was conducted on the 34 ATCOs within Zagreb Area Control Centre (Zagreb ACC) of the Croatia Control ltd. The survey was conducted one year after the implementation of SEAFRA during the summer season to help analyzing the new experience that came with the FRA traffic and how it influenced the ATCOs' work. From all the 34 participants, 26.5% had between 6 to 10 years experience in providing air traffic control service, the second most represented work experience was between 16 to 20 years with the 17.6%, Figure 6, left

chart. Exactly 50% of ATCOs stated that they have been working 12 months within the FRA environment and only 14.7% had experienced it for one month, Figure 6, right chat.

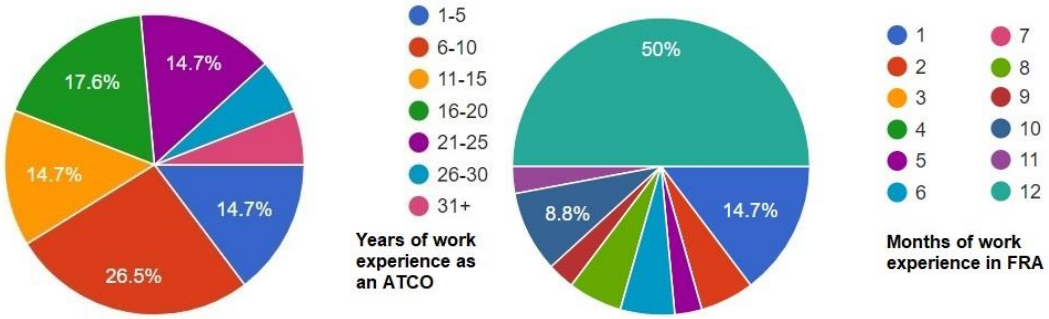


Figure 6 – Survey of years of experience as an air traffic controller (LEFT CHART), and period of work experience in FRA (RIGHT CHART)

When asked about the overall knowledge about the implementation of FRA in Europe, ATCOs responded very well, more than 70% were very well knowledgeable about FRA implementation in Europe, Figure 7, upper chart. But the interesting thing to notice is opposing opinions on the idea whether FRA is really necessary to be implemented, there were no high scores in answers for the need to implement nor for the need not to implement, the highest score was the middle one with 35.3%, Figure 7, lower chart.

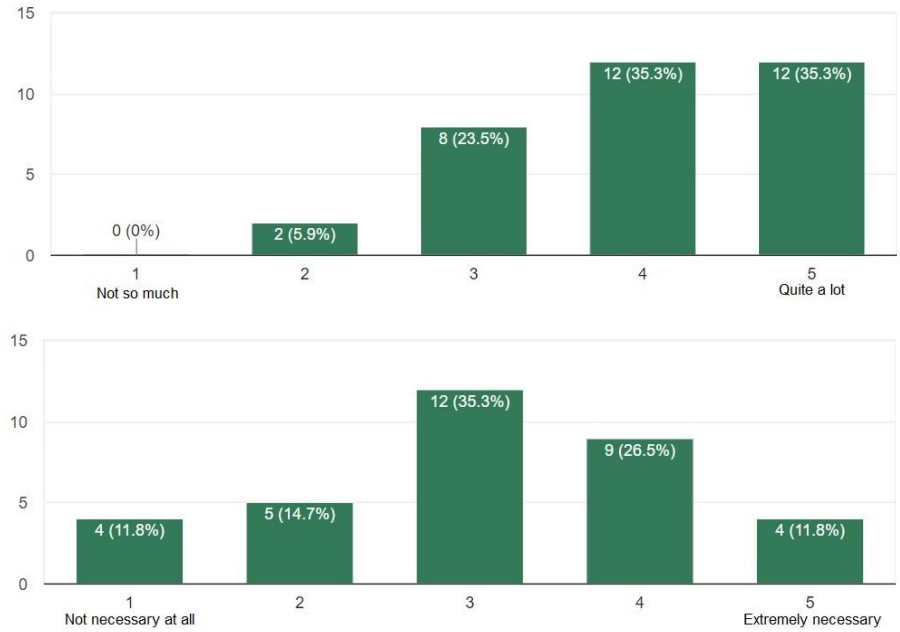


Figure 7 – Survey of how much ATCOs know about the implementation of Free Route Airspace in Europe (UPPER CHART), and what is the necessity of FRA implementation (LOWER CHART)

Main reasons for implementing FRA was well recognized among the tested ATCOs. More than 90% stated that reduced fuel consumption was one of the reasons and more than 85% stated that the main reasons are reduced flight distance and reduced flight time. Also, interesting to notice is that the low scores were received in the categories of reduced traffic complexity, reduced number of conflicts and reduced controller's workload. That could be a problem in the future ATC work since the traffic is only going to increase over the years [6]. On a side note here, there was an option for participants to enter other reasons for the implementation of FRA and they could be categorized into two types of answers. Environmental factor and emissions with 11.8% and 5.9% for the "Implementation rule", Figure 8.

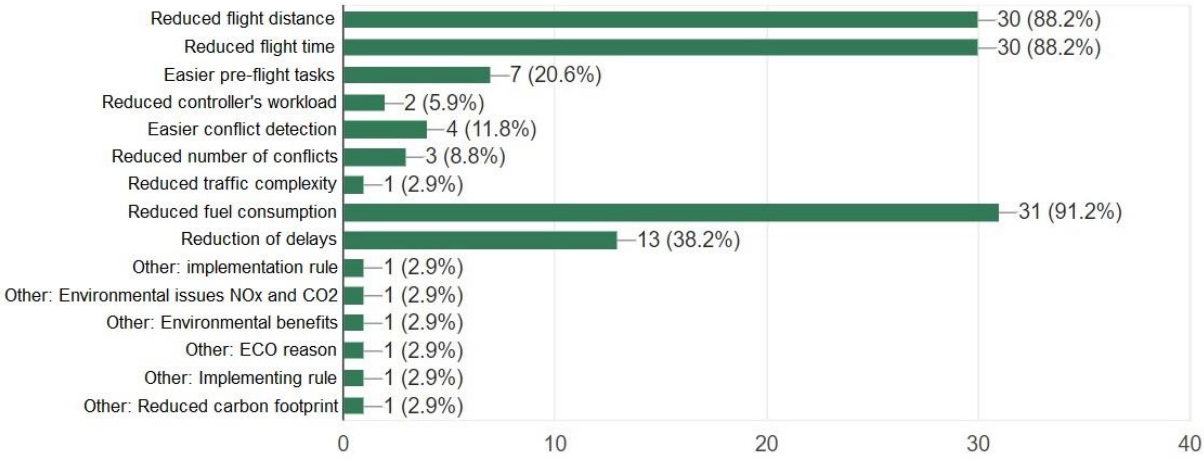


Figure 8 – Survey that shows what are the main reasons for FRA implementation

More than 60% of ATCOs stated that their work experience in FRA compared to the standard fixed routes changed a lot, Figure 9, upper chart. And when asked about a specific category and the level of change there were some interesting answers as well. For example, conflict detection received astonishingly high marks in drastic changes and in changed a lot answers, overall, more than 75% and more than 60% received the same marks for traffic complexity and situational awareness, Figure 9, lower chart.

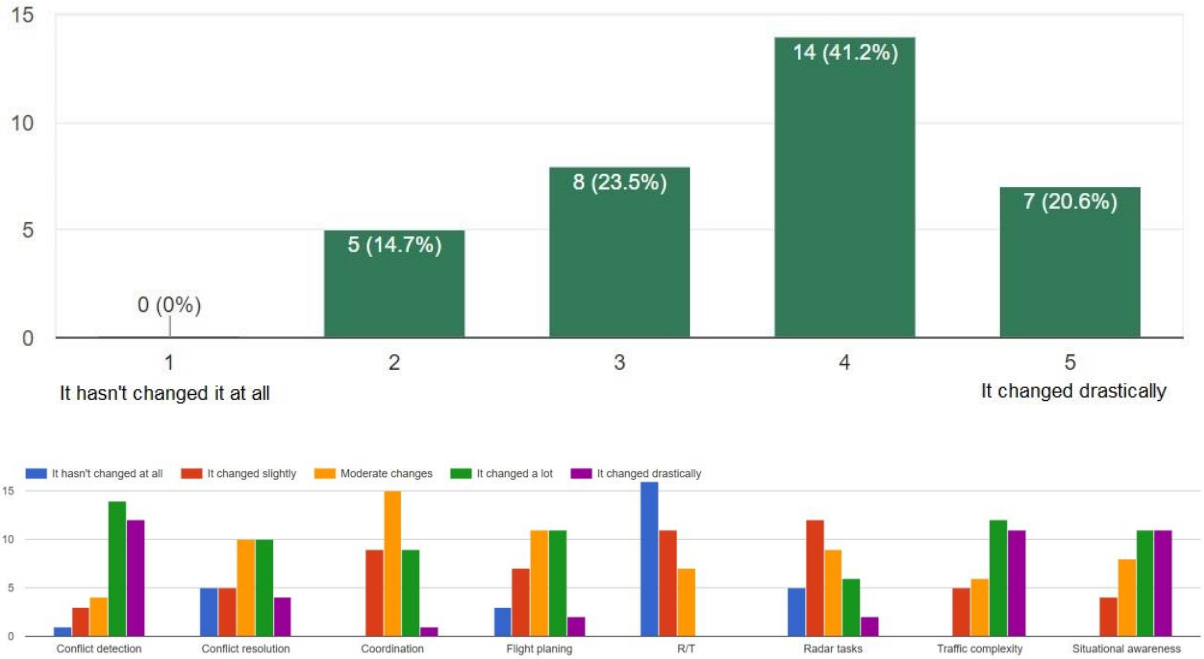


Figure 9 – Survey of how much has FRA changed ATCOs work experience compared to the standard fixed routes (UPPER CHART), and the ATCOs experience that has changed with FRA implementation (LOWER CHART)

Continuing on the change of the work within FRA, the next logical inquiry was to see how did the workload changed with the new FRA environment. Surprisingly, high marks received an increased workload with the new FRA environment, more than 70%, Figure 10, upper chart. Related to the specific workload tasks, yet again it can be noticed that conflict detection, traffic complexity and situational awareness are extremely high. For conflict detection, ATCOs answered more than 60%

increase with a high workload and more than 70% for the traffic complexity and situational awareness, Figure 10, lower chart.

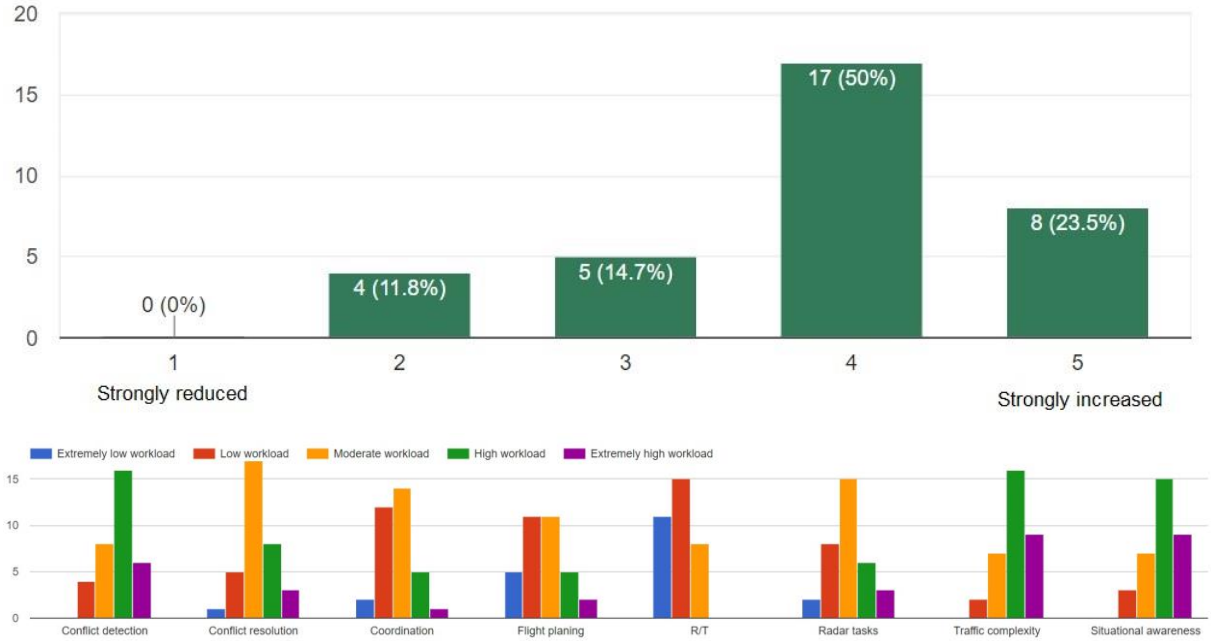


Figure 10 – Survey of ATCOs workload with FRA implementation (UPPER CHART), and the level of workload for the given ATCO categories with FRA implementation (LOWER CHART)

Compared to the conventional "fixed" ATS routes, more than 40% of ATCOs stated that they can handle the same amount of traffic within the FRA environment, but 35% of them stated that they can handle more traffic than before, unlike some that said that they can handle less, which makes for 20% of the candidates, Figure 11.

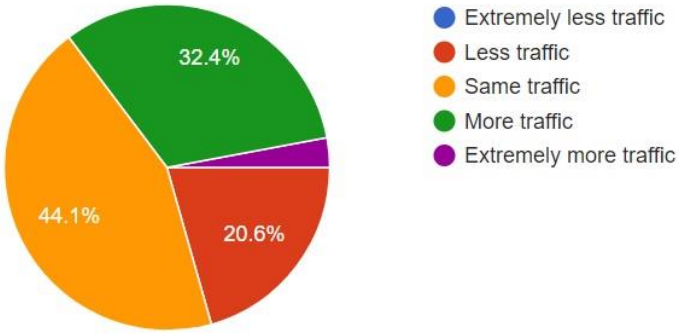


Figure 11 – Survey of traffic management within FRA compared to the conventional fixed routes

But regardless of the amount of traffic they can handle, the surprisingly high percentage of answers was received for complexity estimation: air traffic within FRA is more complex than before, approximately 80% of the ATCOs think that the air traffic is more complex compared to the conventional "fixed" ATS routes, Figure12, left chart. And alongside that, 70% stated they need more advanced tools for conflict detection when working within the FRA environment, Figure 12, right chart.

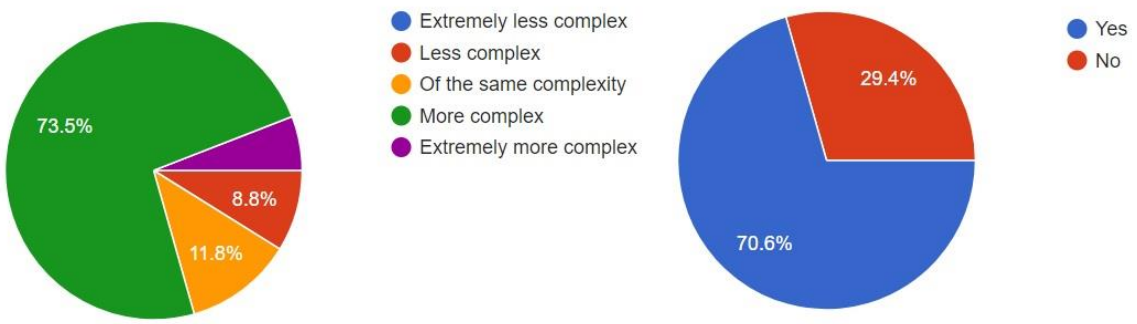


Figure 12 – Complexity comparison of conventional ATS routes to the ones within FRA (LEFT CHART), and the need for more advanced tools for conflict detection when working within FRA environment (RIGHT CHART)

Based on the answers on each particular ATC tool it can be concluded that existing tools are sufficient for their work and that there should be some sort of a new tool that could help ATCOs detect conflict in advance. Also, it could be seen that CARD (Conflict and Risk Detection) tool needs more changes, with 50% of ATCOs requesting its improvement, Figure 13. While STCA (Short Term Conflict Alert), QDM (Range and Bearing tool), Probe (tool for checking the conflicts if the flight route is changed), Level band highlight (filtering the flight levels), Flight leg embellishment (tool for checking the conflicts along the flight route), DAPs (feeding information from the aircraft FMS system) and SEP (Safety and Emergency Procedures) all have high percentages in marks that the tool does not require any changes or slight changes are required. Some other studies also indicate the need for new ATC tools when dealing within FRA environment [11].

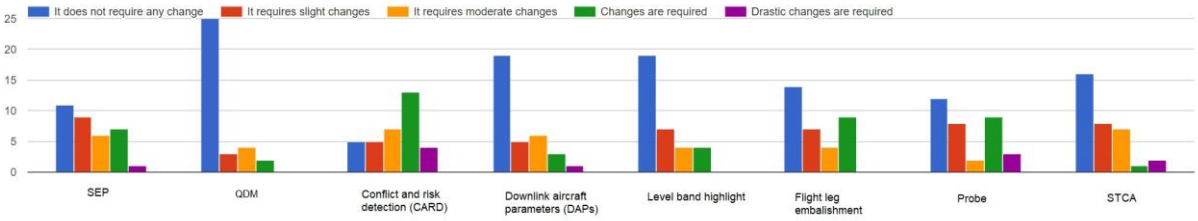


Figure 13 – Survey of to what degree do the ATCO tools need to be changed

3. DISCUSSION

The results have shown that with SEAFRA there has been an increased change in traffic complexity, conflict detection and situational awareness for the tested ATCOs. Increase in change has been followed by the increase in workload for the same categories; traffic complexity, conflict detection and situational awareness. Some other similar papers showed that other ATCOs also had some problems with the implementation of the FRA [12]. At the end of the survey, controllers were asked to state any additional comments regarding their experience as a FRA controller in SEAFRA environment:

- "FRA was a major change in ATC because no one knew what impact there would be on the existing traffic patterns. As a result, we got more workload because ATCOs have to vector everything, and new conflict "hot spots" have arised. The flight level allocation scheme is almost nonexistent compared to before, and we still don't know if this is going to be a good or bad thing (controlling-wise), of course, the airlines are happy because of lesser fuel consumption. ATCs are now working more complex traffic for the same unit rate."
- "Much simpler and cheaper for airline carriers, a lot harder and more complex for the ATCs."
- "Flight plan management has gone to hell with complexity."

- "Strongly positive - better track correlation with FPL trajectory received by OLDI message enabling early conflict detection, reduced r/t transmissions and sector occupancy, reduction of bunching hot spots in one sector (ZAG, PUL, DBK) - traffic is better distributed through sector volumes, change of ATC paradigm - controllers control traffic in volumes by help of trajectory prediction tools and not by flows, routes or points, attracts more users, better service to operators, compliance to PCP implementing rule, has benefits on all SES main pillars - safety, cost efficiency, capacity and environment."
- "Negative aspect - complicated cross-border procedures - should be resolved in the next implementation."
- "ADDITIONAL REMARK - this is a cross-border FRA implementation, not just Croatia FRA (B&H, Serbia, Montenegro & Croatia). It is to be extended next year with two more countries, Slovenia and Austria (current SAXFRA) forming the SECSI FRA initiative."
- "Implementation of the FRA is one of the major technological mistakes in Zagreb ACC. It raised the level of complexity, reduced profits and capacity. Adversely affects the safety of air navigation as the final product of our company."
- "I think it's a positive change which will be highlighted with years and experience of working in it."
- "The biggest problem with the introduction of the FRA is that there are no more standard places where you can expect conflicts, but it can be literally anywhere in the airspace. It happens that, for example, two different companies have the same take-off and landing aerodrome but completely different routes. Regardless of the FRA, some air carriers still plan their flights so that the routes are not direct, so you wonder then whether the "direct" route is really the cheapest, ecological, etc. Generally speaking, I think it was to be expected that the concept of direct routes would become a reality, however, the traffic complexity increases and by increasing its complexity, the capacity of air traffic controllers in the sector is decreasing."
- "Much more complex. Sector capacity remained the same or they are increased. Impossibility of conflict resolution by direct routes, because the aircraft are already heading directly and it requires a large number of aircraft to be resolved by turning the heading. Increased coordination with neighboring units."
- "Too big of a change in a short time that, with the increased air traffic, in some cases complicates things, and I do not see big benefits for us or for companies."
- "It became harder to detect traffic flows, i.e. traffic flows are now dispersed throughout the map. That resulted in the loss of the familiar hotspots and the creation of the new ones. Also, now it's more difficult to incorporate an aircraft into a new flow because there's more converging traffic instead of a "single line" flow. Converging conflicts take more time and workload to resolve than other kinds."
- "I am convinced that, in the case of the FRA, it goes hand in hand to the carriers (economically) under the pretence of ecology (emission of harmful gases and oxygen burning by shortening the flight duration), while at the same time ATC's job is becoming more complicated. There are no established conflict points but are all around the AOR depending on the flight plan, too many routes are on the same FL, head on etc. All this adds to the workload and the low awareness, which simultaneously reduces the capacity of the sector. More and more in aviation it is about money and profits, and unfortunately in this and in a number of other changes, the safety of air navigation is undermined."

From the ATCOs discussion, we can see that there are diverse comments. Some believe that FRA is good and that ATCOs only need time to adapt, while others believe it is a safety issue and that traffic complexity has increased alongside with harder conflict detection and undermined situational awareness.

4. CONCLUSION

In this paper, we have presented the opinions of 34 ATCOs from Zagreb ACC that are actively working on free route airspace and since the finish of this paper now on the new SECSI FRA airspace. It can be concluded from their answers that traffic complexity, situational awareness and conflict detection has increased and that the workload for those categories has also increased. But although there has been an increase in conflict detection, ATCOs also stated they had no problem whatsoever in conflict resolution. In fact, precisely 50% of them stated that conflict resolution is at a moderate level. Also, they stated they can handle the same or even more traffic than before, although more than 70% of them told that traffic routes are more complex than before. So, it is safe to say that they can still manage new traffic situation that has arisen from the implementation of FRA.

Finally, for future work, it would be good to see how ATCOs would evaluate work in the new SECSI FRA environment and to compare the results from two surveys. Such a new research could give us information if ATCOs only needed time to adapt to FRA environment or the situation has worsened. Since the main problems were conflict detection and the need for more advanced ATC tools, we believe that with the applicable forecast traffic complexity model, these negative comments would vanish.

ACKNOWLEDGMENTS

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APPLICATION OF SIMULATION TOOLS FOR ANALYSIS AND OPTIMAL CHOICE OF INTERSECTION CONTROL TYPE

ABSTRACT

Simulation tools have become an invaluable help in evaluating and choosing the optimal solution for different traffic situations. Real-time interventions require significant financial resources and are often misleading. The simulation model represents of the real system using computer technologies. By using a calibrated and validated simulation, it is possible to achieve very high accuracy in describing the observed traffic process. Nowadays, there is a whole range of simulation tools available to traffic experts to help them analyze individual traffic situations and problems. One of the most widely used microscopic tools is PTV Vissim. Using the micro-simulation tool PTV Vissim on selected intersection, importance of simulation tools in selection of optimal variant solution was shown.

KEY WORDS

simulation tools; model evaluation; intersection; traffic flow, PTV Vissim;

1. INTRODUCTION

Intersections represent points in the road network where two or more roads are merged, the traffic flows weave, cross, merge or unmerge and there are noticeable changes in the moving directions of the vehicle, which causes problems with capacity and traffic safety. Unsatisfactory intersection design lead to reduced and decreased traffic safety, increased travel time, increased queue lengths and significant external effects. Solving such problems requires significant financial resources. Implementation of simulation tools simplifies the ability to analyze and optimize the management of traffic flows at intersections. Traffic experts today have a wide range of simulation tools available with their special features and some of them are presented in this paper.

In this paper, using the micro-simulation tool PTV Vissim, a model of the existing state at one intersection was analyzed and several variant solutions of the reconstruction were proposed. The main goal of the paper is to emphasize the importance of simulation tools and their irreplaceability in the process of selection of optimal variant of new or reconstructed intersection.

2. OVERVIEW OF SIMULATION TOOLS FOR MODELING INTERSECTION CONTROL TYPE

Nowadays, there is a whole range of simulation tools for modeling traffic flows that are available to traffic experts. The tools differ in a variety of possibilities for modeling different traffic situations and behaviour of traffic participants. The best-known simulation tools for designing and optimizing intersections are: PTV Vissim, Synchro Studio, LinSig, OSCADY PRO, TRANSYT, Paramics, PICADY, ARCADY, AIMSUN and Sidra Intersection. Simulation tools can be divided into several groups such as

deterministic tools and micro-simulation tools. Deterministic models utilise empirical algorithms to calculate optimum settings based on fixed inputs. Model inputs vary by software type but serve to abstractly represent the traffic network and its underlying condition. Stochastic micro-simulation softwares can represent and analyze complex traffic problems because they are based on driver behaviour. They can provide a detailed overview of complex processes affecting driver behaviour [1].

2.1 Deterministic Simulation Models

Deterministic simulation models use the methodology of the "Highway Capacity Manual" (HCM). These tools are often used for the analysis of isolated intersections. The following simulation tools belong to this tool group:

- Sidra Intersection,
- ARCADY,
- PICADY,
- Synchro Studio.

Sidra Intersection is a simulation tool used to design and evaluate isolated intersections and road corridors. It can be used to analyse signalised intersections (pretimed and actuated), signalised and unsignalised pedestrian crossings, roundabouts (unsignalised), roundabouts with metering signals, fully-signalised roundabouts, two-way stop sign and give-way / yield sign control, all-way stop sign control, single point interchanges (signalised), freeway diamond interchanges (signalised, roundabout, sign control), diverging diamond interchanges. This simulation tool was developed by Sidra Solutions from Australia. Sidra Intersection allows modelling of separate vehicle types (Light Vehicles, Heavy Vehicles, Buses, Bicycles, Large Trucks, Light Rail / Trams and two User Classes) with different vehicle characteristics [2]. It is used to evaluate capacity of intersection, vehicle delay, queue length, fuel consumption and emissions of harmful gases. In Figure 1, is shown graphic user interface of Sidra Intersection simulation tool.

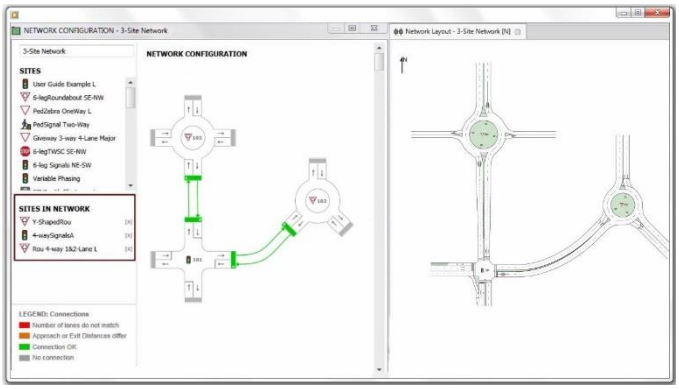


Figure 1 – Graphic user interface of Sidra simulation tool
Source: [2]

ARCADY (engl. Assessment of Roundabout Capacity and Delay) is a simulation tool developed by the Transport Research Laboratory from United Kingdom, which is used for modeling roundabout intersections. It is most often used for predicting capacity, waiting times, delay times and traffic accidents, traffic congestion and evaluation of proposed solutions. An empirical model was used to estimate the traffic parameters, which is related to intersection geometry and driver behaviour. Contains "what if" scenarios, and direct comparison of results provides a clear comparison of the design elements, selected models, profiles, or characteristics of individual intersections [3]. In Figure 2 it is shown a graphic user interface of ARCADY simulation tool.



Figure 2 – Graphic user interface of ARCADY simulation tool
Source: [3]

PICADY (engl. Priority Intersection Capacity and Delay) is a simulation tool used to analyze traffic parameters of a unsignalized intersection, also developed in the TRL laboratory in the UK. This simulation tool considers key design elements such as lane widths, curve radius, triangular islands, intersection visibility, and driving behaviour [4]. In Figure 3, a graphic user interface of PICADY simulation tool is shown.

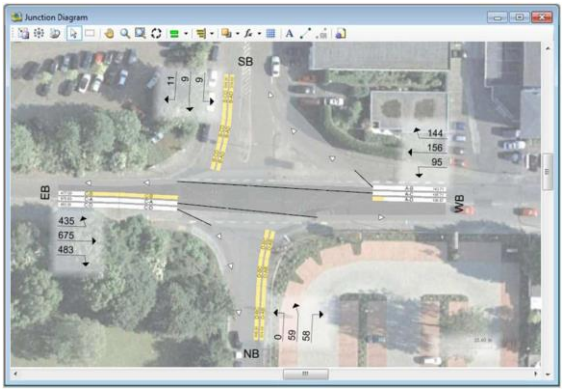


Figure 3 – Graphic user interface of PICADY simulation tool
Source: [4]

Synchro Studio is a simulation tool, developed by Trafficware based in the United States. Synchro is used to model all types of intersections. This tool uses the HCM (Highway Capacity Manual) methodology for capacity calculations. User friendly graphic interface allows to analyze data in a short time. The evaluation of data is done using guidelines and "Manual on Uniform Traffic Control Devices" (MUTCD). [5] In figure 4, a graphic user interface of Synchro Studio simulation tool is shown.

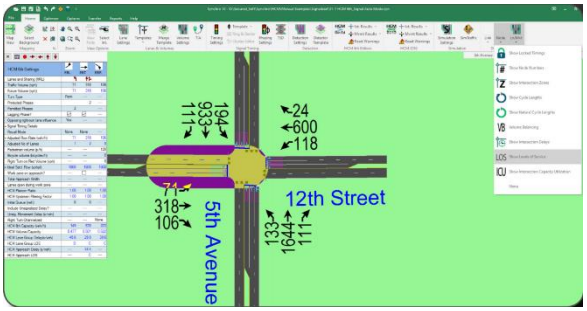


Figure 4 – User friendly graphic interface of Synchro simulation tools
Source: [5]

2.2 Microsimulation Models

Microsimulation tools can model the movement of a single vehicle in the road network. They enable realistic behaviour of vehicles, such as lane changing and overtaking. In that view, they differ from the above mentioned deterministic simulation tools in which all vehicles have a consistent behaviour. Compared to deterministic models, better presentation and stochastic approach to micro - simulation tools provide a more realistic view of driver behaviour, as well as the entire transport network [1]. The most commonly used microsimulation tools are:

- PTV VISSIM,
- AIMSUN,
- Paramics.

PTV VISSIM (njem. Planung Transport Verkehr Verkehr In Städten – SIMulationsmodell) is a microscopic simulation tool for modeling urban traffic network and public transport operations and pedestrian flows. The accuracy and credibility of the simulation model depends mostly on the modeling quality of the vehicle's behaviour in the simulated transport network. Unlike other simulation tools that use constant vehicle speeds and deterministic logic of car following, PTV VISSIM uses the psychophysical model (Figure 5) of driving behavior developed by Rainer Wiedemann in 1974 at the University of Karlsruhe in Germany [6].

The basic concept of the Wiedemann model is that a driver of a faster vehicle (in single traffic lane, without the possibility of leaving the traffic network), starts slowing down when he perceives a slower vehicle in the same traffic lane. Since a driver in a faster vehicle can not accurately determine the speed of a slower vehicle, he slows below the speed of the slower vehicle and gradually starts to accelerate to the speed of the slower vehicle.

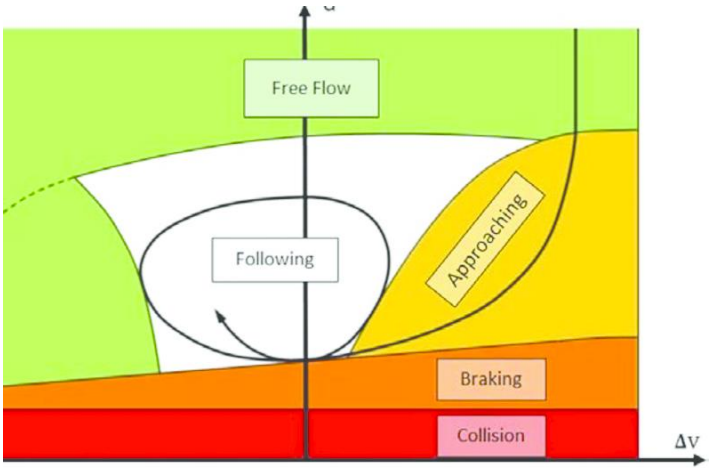


Figure 5 – Car – following model according to Wiedemann
Source: [13]

PTV VISSIM performs simulation of the traffic flow by moving "driver-vehicle-units" through the defined traffic network. Each driver in the network with their specific behavioral characteristics is assigned to a vehicle and the previously defined technical capabilities of a vehicle (eg. maximum vehicle speed, maximum acceleration and deceleration, etc.) are respected. Attributes describing each "human-vehicle" unit can be categorized into three basic groups:

1. technical specifications of vehicles - vehicles length, maximum speed, potential acceleration and deceleration, current position of the vehicles in the network, current speed and acceleration of the vehicle etc.;
2. behavior of "human-vehicle" units - psychophysical driver sensitivity thresholds (ability to estimate specific traffic situation, aggressiveness of driver, etc.);

3. the relationship between the vehicle in queue in the same and adjacent traffic lanes, the relationship between the current roadway and the next intersection, the relation to the next signalized intersection etc. [6].

The attributes that need to be entered PTV VISSIM are vehicle volumes, road geometry, traffic flow distribution, vehicle classification, desired speed distirbution and peak hour volumes. In figure 6, a graphic user interface of PTV Vissim microsimulation tool is shown.

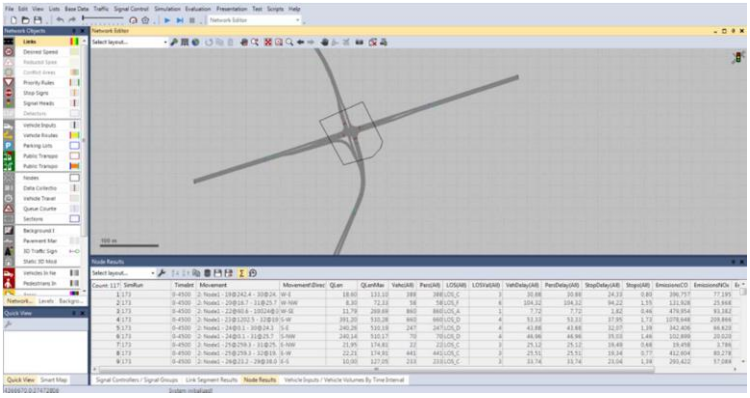


Figure 6 – Graphic user interface of PTV Vissim microsimulation tool

AIMSUN (Advanced Interactive Microscopic Simulator for Urban and Non-Urban Networks) is a microscopic simulation tool that has the ability to display actual traffic data on different transport networks. AIMSUN uses Gipps lane changing model which is a function of:

- type of driver,
- geometry of the section,
- feasibilitiy of lane change,
- desirability of lane change.

Algorithm “asks” each vehicle at every “time step”: Is it necessary, desirable, feasible to change lane? [7]. In Figure 7, it is shown a graphic user interface of AIMSUN microsimulation tool.

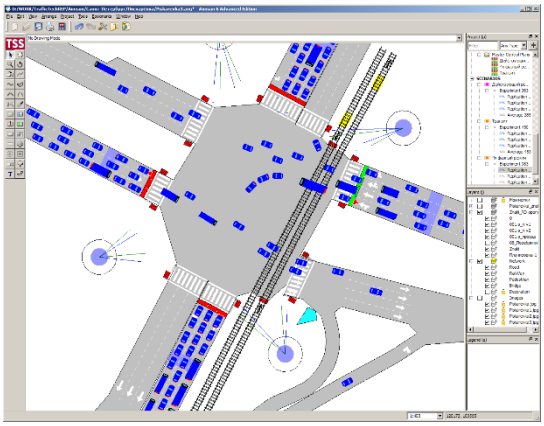


Figure 7 – Graphic user interface of AIMSUN microsimulation tool
Source: [8]

The model provides very detailed information on the transport network such as vehicle classification, vehicle speed, road capacity, traffic flow density, road slope, modeling traffic demand based on origin - destination matrices (OD matrix), modeling traffic demand based on traffic counting, modeling different intersection control type, from fixed to actuated control type, roundabouts, modeling network incidents, and using Variable Speed Limits signs (VMS) [7].

Paramics is traffic microsimulation software developed by University of Edinburgh which is based on car following and lane change model. This model was created by Hans-Thomas Fritzsche. Paramics is used for modeling different types of intersections such as signalized intersections, unsignalized intersection, roundabouts, junctions, toll stations, parking spaces, public transport, etc. In figure 8, a graphic user interface of Paramics microsimulation tool is shown

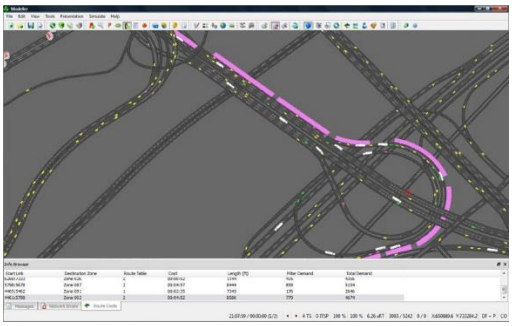


Figure 8 – Graphic user interface of Paramics microsimulation tool
Source: [14]

3. OVERVIEW OF TRAFFIC PARAMETERS FOR EVALUATION OF DIFFERENT INTERSECTION CONTROL TYPE

The traffic flow represents moving of several vehicles at the same time in a certain time sequence. It is necessary to define the basic parameters for describing traffic flows on roadways. The basic difference in the movement of vehicles in traffic flows in relation to movement of a single vehicle is that it is affected by the mutual interaction of the vehicles [9].

The basic traffic flow parameters are:

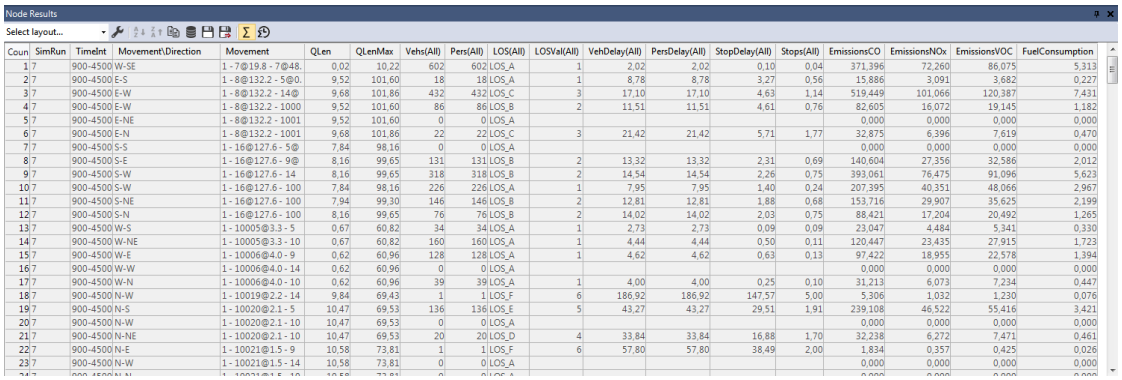
- traffic volume,
- traffic flow density,
- traffic flow speed,
- vehicle travel time,
- gap time,
- vehicle headway [9].

Modern microsimulation tools have option of selecting many data for evaluation of intersections. Depending on the network objects used, various data is produced during simulations, e.g. information on vehicles, links, areas, nodes, traffic jams, green time distribution or PT waiting times [10].

Evaluation is performed using the following elements:

- vehicle travel times,
- queue lengths,
- vehicle delay,
- level of service (LoS),
- information about each individual vehicle,
- link evaluation,
- node evaluation,
- public transport delay,
- emissions of harmful gases,
- signal controllers [11].

The most widely used evaluation menu for evaluating intersections in the microsimulation program PTV VISSIM is „node evaluation“ (Figure 9). "Node" represents a defined area around the observed intersection [10].



Node Results

Select layout...

Coun	SimRun	TimeInt	Movement\Direction	Movement	QLen	QLenMax	Vehs(All)	Pers(All)	LOS(All)	LOSVal(All)	VehDelay(All)	PersDelay(All)	StopDelay(All)	Stops(All)	EmissionsCO	EmissionsNOx	EmissionsVOC	FuelConsumption
1	7	900-4500	W-SE	1 - 7@19.8 - 7@48.	0,02	10,22	602	602	LOS_A	1	2,02	2,02	0,10	0,04	371,396	72,260	86,075	5,313
2	7	900-4500	E-S	1 - 8@132.2 - 5@0.	9,52	101,60	18	18	LOS_A	1	8,78	8,78	3,27	0,56	15,886	3,091	3,682	0,227
3	7	900-4500	E-W	1 - 8@132.2 - 14@	9,68	101,86	432	432	LOS_C	3	17,10	17,10	4,63	1,14	519,449	101,066	120,387	7,431
4	7	900-4500	E-W	1 - 8@132.2 - 1000	9,52	101,60	86	86	LOS_B	2	11,51	11,51	4,61	0,76	82,605	16,072	19,145	1,182
5	7	900-4500	E-NE	1 - 8@132.2 - 1001	9,52	101,60	0	0	LOS_A						0,000	0,000	0,000	0,000
6	7	900-4500	E-N	1 - 8@132.2 - 1001	9,68	101,86	22	22	LOS_C	3	21,42	21,42	5,71	1,77	32,875	6,396	7,619	0,470
7	7	900-4500	S-S	1 - 16@127.6 - 5@	7,84	98,16	0	0	LOS_A						0,000	0,000	0,000	0,000
8	7	900-4500	S-E	1 - 16@127.6 - 9@	8,16	99,65	131	131	LOS_B	2	13,32	13,32	2,31	0,69	140,604	27,356	32,586	2,012
9	7	900-4500	S-W	1 - 16@127.6 - 14	8,16	99,65	318	318	LOS_B	2	14,54	14,54	2,26	0,75	393,061	76,475	91,096	5,623
10	7	900-4500	S-W	1 - 16@127.6 - 100	7,84	98,16	226	226	LOS_A	1	7,95	7,95	1,40	0,24	207,395	40,351	48,066	2,967
11	7	900-4500	S-NE	1 - 16@127.6 - 100	7,94	99,30	146	146	LOS_B	2	12,81	12,81	1,88	0,68	153,716	29,907	35,625	2,199
12	7	900-4500	S-N	1 - 16@127.6 - 100	8,16	99,65	76	76	LOS_B	2	14,02	14,02	2,03	0,75	88,421	17,204	20,492	1,265
13	7	900-4500	W-S	1 - 10005@3.3 - 5	0,67	60,82	34	34	LOS_A	1	2,73	2,73	0,09	0,09	23,047	4,484	5,341	0,330
14	7	900-4500	W-NE	1 - 10005@3.3 - 10	0,67	60,82	160	160	LOS_A	1	4,44	4,44	0,50	0,11	120,447	23,435	27,915	1,723
15	7	900-4500	W-E	1 - 10006@4.0 - 9	0,62	60,96	128	128	LOS_A	1	4,62	4,62	0,63	0,13	97,422	18,955	22,578	1,394
16	7	900-4500	W-W	1 - 10006@4.0 - 14	0,62	60,96	0	0	LOS_A						0,000	0,000	0,000	0,000
17	7	900-4500	W-N	1 - 10006@4.0 - 10	0,62	60,96	39	39	LOS_A	1	4,00	4,00	0,25	0,10	31,213	6,073	7,234	0,447
18	7	900-4500	N-W	1 - 10019@2.2 - 14	9,84	69,43	1	1	LOS_F	6	186,92	186,92	147,57	5,00	5,306	1,032	1,230	0,076
19	7	900-4500	N-S	1 - 10020@2.1 - 5	10,47	69,53	136	136	LOS_E	5	43,27	43,27	29,51	1,91	239,108	46,522	55,416	3,421
20	7	900-4500	N-W	1 - 10020@2.1 - 10	10,47	69,53	0	0	LOS_A						0,000	0,000	0,000	0,000
21	7	900-4500	N-NE	1 - 10020@2.1 - 10	10,47	69,53	20	20	LOS_D	4	33,84	33,84	16,88	1,70	32,238	6,272	7,471	0,461
22	7	900-4500	N-E	1 - 10021@1.5 - 9	10,58	73,81	1	1	LOS_F	6	57,80	57,80	38,49	2,00	1,834	0,357	0,425	0,026
23	7	900-4500	N-W	1 - 10021@1.5 - 14	10,58	73,81	0	0	LOS_A						0,000	0,000	0,000	0,000

Figure 9 – Node results menu in microsimulation tool PTV VISSIM

For each node in Chapter 5, this parameters will be shown:

- average queue length,
- level of service for every movement (LoS),
- average vehicle delay,
- emissions of CO.

4. DEVELOPMENT OF MICROSIMULATION MODELS

As an example of using a microsimulation tool in analysis of the existing state and selecting the optimum variant solution the microsimulation tool PTV VISSIM was used. For developing simulation models and the evaluation of the proposed solutions, the intersection in Sveta Nedelja was chosen, in the western part of the Zagreb County. The intersection is close to the residential zone, the industrial zone and the logistics park and represents a significant attraction of this area. Macrolocation is shown in Figure 10.

Using simulation tool, significant difference will be shown in output results by comparing two different subtypes of the same intersection control type (Variant 1 and Variant 2).

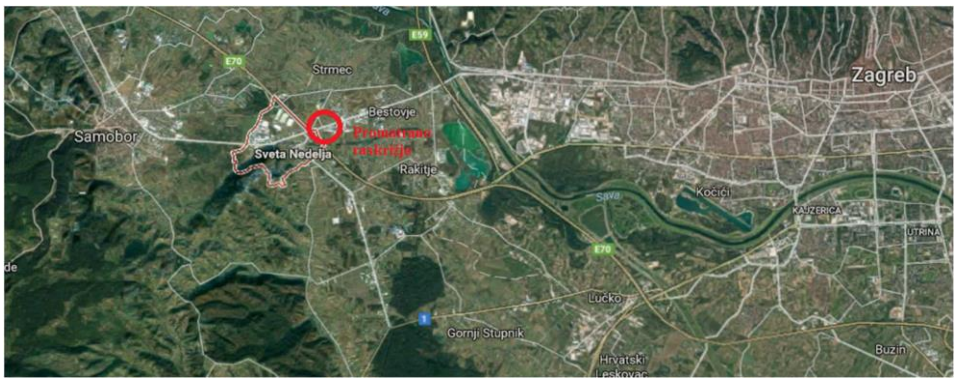


Figure 10 – Macrolocation of selected intersection
Source: [15, modified by authors]

Traffic was counted in the morning peak period from 6:30 AM to 8:30 AM. In the period from 6:30 AM to 7:30 AM 2262 vehicles were recorded and in the period from 7:30 AM to 8:30 AM 2635 vehicles were recorded. With traffic counting, the necessary data for the model of the existing state, as well as the proposed variant solutions, were collected. During model developing, it is necessary to define a simulation parameters so the results, which were obtained from traffic counting, represent the state that was achieved on the field.

4.1 Analysis of the Existing State

The analyzed intersection has four approaches, and the most saturated direction is from West to South. The intersection is located outside the central part of the City, so the concentration of non-motorized traffic is neglected. The process of developing a model begins with intersection design and determining the number of lanes and width and length of the lanes at each approach. After defining the intersection geometry, it is necessary to enter the traffic volumes at each approach, the traffic flow classification, and the distribution of the traffic flows. The analyzed intersection is controlled by traffic lights, fully actuated. All movements at the intersection are detected, and all signal groups have a minimum and maximum duration of green time. There are five phases in signal program and the cycle duration is 98 s. In the western approach (appraoch 1), the right turns are separated by a triangular island and must give priority to all vehicles in the main direction to safely merge in the traffic flow. In PTV Vissim [10] mentioned way of managing traffic flow is determined by using "priority rules" or "conflict areas". In this model, the "conflict areas" menu functions were used, where minimum critical time gap values can be entered. The "desired speed distributions" have been modeled to show the credibility of traffic flow. Simulation model of existing state was shown in Figure 11.

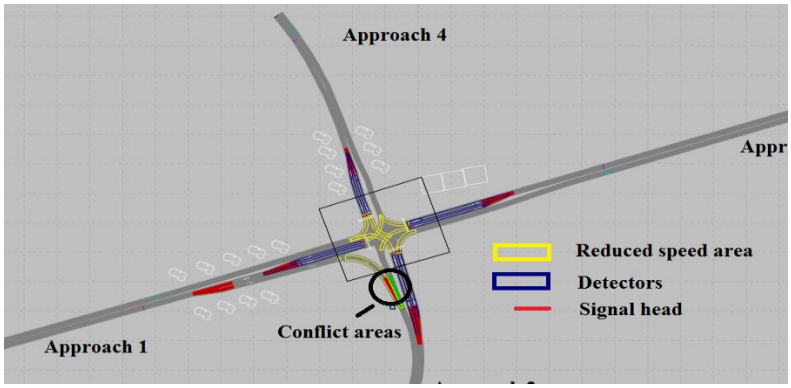


Figure 11 – Simulation model of existing state
Source: [by authors]

4.2 Analysis of a Roundabout Intersection

Variant 1 proposes the construction of roundabout intersection. The intersection is defined with four approaches, one entry and one exit lane. Inscribed circle radius is 27.0 meters, center island radius is 20.4 meters, entry radius is 24.6 meters and exit radius is 24.3 meters. Circulatory roadway width is 6.6 meters, approach entry width is 5.4 meters and approach exit width is 5.7 meters. Representative vehicle for trajectory check is trailer truck. In Figure 12, the model in PTV Vissim microsimulation tool is shown. As in the model of the existing state, priority is modeled using the "conflict areas" [10].

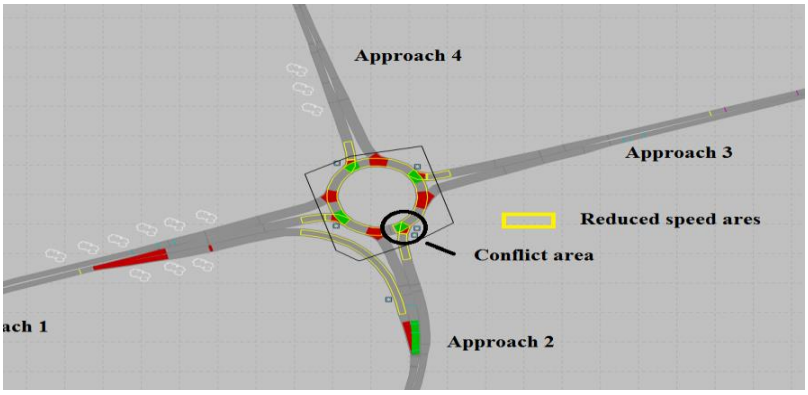


Figure 12 – Simulation model of a roundabout

4.3 Analysis of a Turbo Roundabout Intersection

Variant 2 proposes the construction of a turbo roundabout intersection (Figure 13). Turbo roundabout is an intersection with mountable raised lane dividers that connect several approaches. It can be a two-lane or three-lane circular intersection. The specificity of this roundabout is that the lanes are mutually separated with lifted dividing elements (delineators) that prevent the lane change (weaving of traffic flows) on the circular roadway [12].

Traffic flows at turbo roundabouts have already been defined prior to the entry into the intersection, separated during driving in the intersection, and at the exit from the turbo roundabout intersection[12].

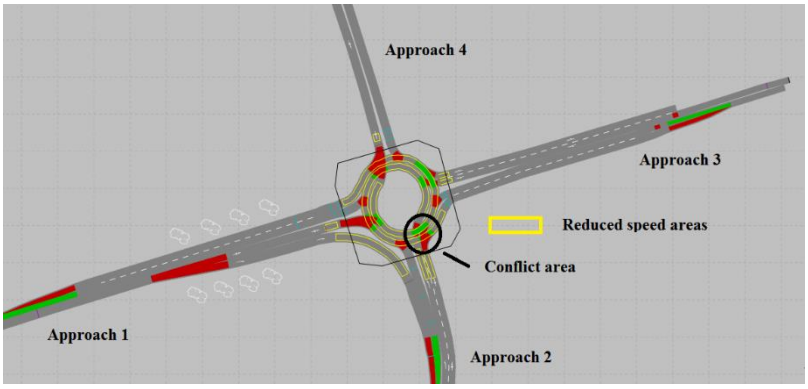


Figure 13 – Simulation model of a turboroundabout intersection

5. EVALUATION OF SIMULATION MODELS

After the development and validation of the microscopic models, detailed traffic flow data were obtained of the existing state and of proposed variant solutions. In Figure 14, the average queue length is shown on each of the approaches of the existing state and proposed variant solutions. It is obvious that the average queue length at the approach 2 of roundabout is 741.6 meters, and on the current state is 376.0 meters, which is 97.2% higher than the existing state. These significant queue lenghts represent a safety problem because vehicles use shoulder lane of motorway A3 Bregana - Zagreb - Lipovac. The average queue length of turbo roundabout is 12.3 meters, which is by 96.7% less than the existing state.

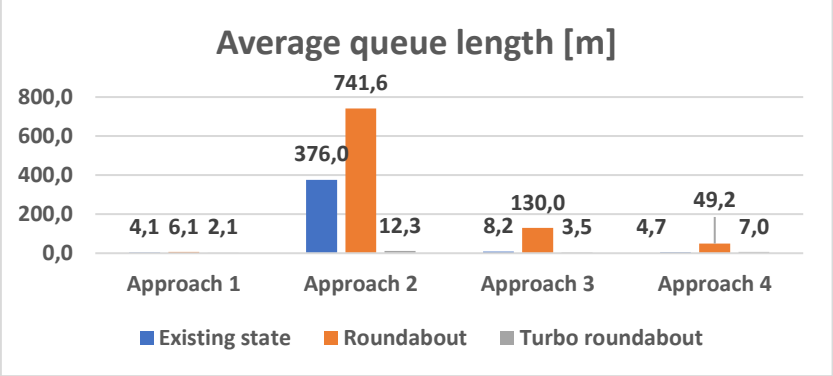


Figure 14 – Comparison of average queue length

The vehicle delay of existing state and proposed variant solutions is shown in Figure 15. It is obvious that the vehicle delay at the approach 2 of roundabout intersection is 249.1 seconds, and vehicle delay on approach 2 of existing state is 141.8 seconds, which is 75.7% higher. The vehicle delay at the

approach 2 of turbo roundabout is 22.4 seconds, which corresponds to service level C and it is less for 84.2% compared to the existing state.

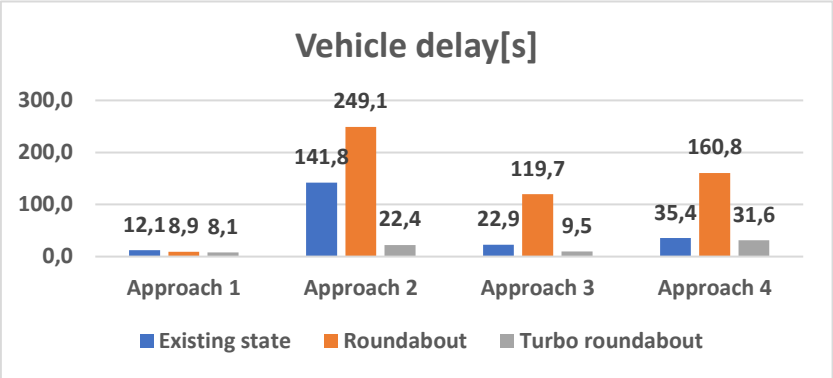


Figure 15 – Comparison of vehicle delay

Figure 16 shows the average travel time of vehicles on all approaches. The average travel time of vehicles at the approach 2 of roundabout intersection is 391.5 seconds, and on the existing state is 257.2 seconds, which is 52.2% higher. The average travel time on approach 2 of turbo roundabout is 97.9 seconds, which is 61.9% less than the existing state.

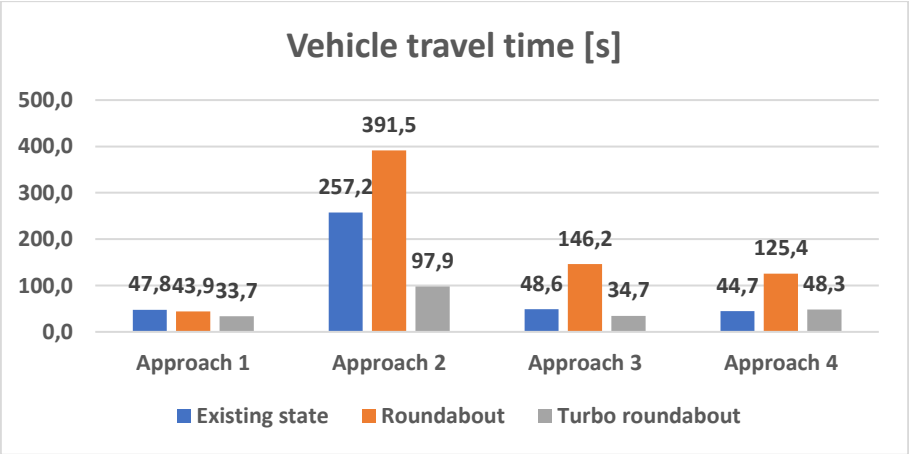


Figure 16 – Comparison of vehicle travel time

Carbon monoxide emissions are shown in Figure 17. It is evident that the emission of harmful gases at the approach 2 of roundabout (13337.3 g) is 44.0% higher than the emission of the harmful gases on the existing state, which is 9262.2 grams. Emissions of turbo roundabout intersection (4238.4 grams) are less by 54.2% than the emissions of the existing state.

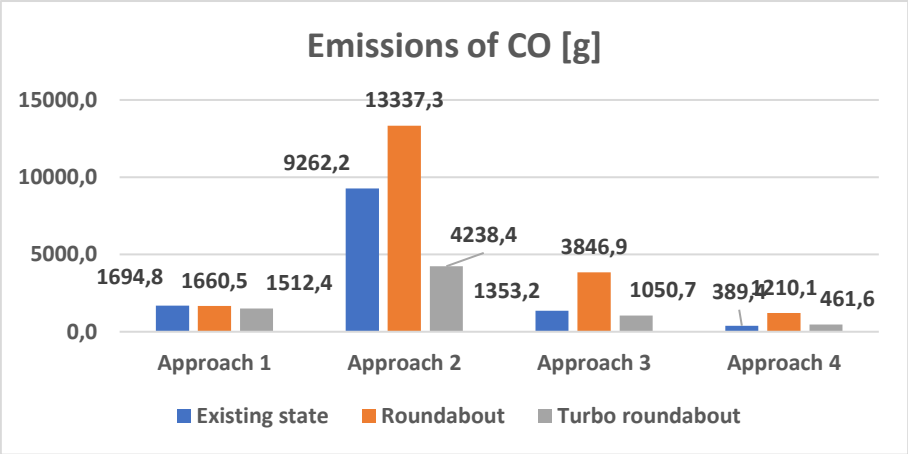


Figure 17 – Comparison of emissions of CO

6. CONCLUSION

This paper analyzes implementation of simulation tools for analysis and optimal choice of intersection control type. Simulation tool can be divided into deterministic and microsimulation tools. Deterministic tools use empirical algorithms for calculating traffic parameters based on fixed input data while microsimulation tools use the driver behaviour model. Micro-simulation tools can select many data for analysis and evaluation of traffic solutions, and the most commonly used evaluation menu is a "node evaluation" showing the vehicle data recorded, the average queue length, the maximum queue length, the vehicle delay, the emissions of harmful gases etc.

To show the importance of micro-simulation tools an example was developed. In this example it was clearly shown that two different subtypes of the same intersection control type can have significant difference in output results. The simulation models were developed using the PTV Vissim micro-simulation tool and existing state was analyzed of the selected intersection and two variant solutions were proposed.

It was concluded that the existing condition is unsustainable due to the significant queue length at approach 2 which reaches 741.6 meters. The vehicle delay time on approach 2 of existing state is 141.8 seconds corresponding to the level of service F according to the HCM methodology. By evaluating the traffic parameters of the roundabout intersection, it is concluded that this solution does not contribute to solving traffic and safety problems. The optimal traffic solution is the intersection with a spiral flow or turbo roundabout that has improved the quality of traffic flow. The average queue length on approach 2 of turbo roundabout is lower by 96.7% compared to the existing state, the vehicle delay is less than 84.2% for the same appraoch, the vehicle travel time is less than 61.9% and the emissions of harmful gases 54.2% compared to the existing state.

By developing this example and by comparing output results it was clearly shown that simulation tools are irreplaceable part of traffic profession.

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PERFORMANCE OF PUBLIC TRANSPORT BUSES REGARDING TO ELEVATION CHARACTERISTICS

ABSTRACT

Vehicles that are used for Public transport system have many various technological problems. One of technological problems is to determine optimal vehicle or vehicles for different line and line routes. Every line and line routes have specific infrastructure and natural characteristics. Infrastructure and natural characteristics have key influence on choosing right vehicle or vehicles. Beside infrastructure and natural characteristics, there is elevation and parameters of traffic flow that also have influence. Elevation play key role in line and line routes in hilly areas. Choosing right type of vehicle is not enough sufficient for optimizing that part of public transport technology. Optimal engine, gearbox and transmission is also important part. Determine optimal vehicle with sufficient capacity for passengers with engine, gearbox and transmission with best performance is goal of this paper.

KEY WORDS

public transport vehicles; elevation; engine; gearbox; transmission;

1. INTRODUCTION

This paper will consider parameters of three different public transport lines, and due to that parameters analyse optimal City bus engine, constructional elements of buses and best gear and transmission ratios. Public transport lines are settled in the urban area, and bus type which will be analysed is MAN. Also, this paper will study and compare the performance of buses, considering the altitude of every line included. The goal of this paper is to determine optimal transmission elements of the buses, taking into account the altitude and travel speed on selected lines.

2. BASIC DATA ABOUT BUSES AND PUBLIC TRANSPORT LINES

Traffic of ZET buses currently consists of 34 bus lines; 78 of them are city and 56 suburban lines. Currently vehicle fleet consists of more than 430 buses [1]. Most frequent brands are:

- MAN - 191 buses;
- Mercedes - Benz - 136 buses;
- Iveco/ Irisbus - 99 buses.

Mostly used are low floor buses, while high floor buses mostly ply on lines of suburban traffic. Since July 2007 ZET started using biodiesel as fuel in 10 buses, gas in 2 buses. With time that way increased so ZET showed intention for increasing consumption of biodiesel and gas in all their vehicles in ration 50:50. In this work there will be described 3 different bus lines, also buses in which transport of passengers is being carried out on watched lines [7].

Table 1 – Technical data of the MAN buses

Buses MAN	LIONS CITY (GL)	LIONS CITY (M)
Max, total technical weight (t)	28	18
Wheelbase between 2nd and 3rd axle (mm)	5875	4395
Wheelbase (mm)	24446	18058
Passenger capacity (sitting/total)	57/106	30/61
Max engine power (kW)	235/265	184/213
Max engine Torque (Nm/o/min)	1600/1800	1000/1100
Min specific consumption	199 g/ kW/h (1400 min^{-1})	196 g/ kW/h (1400 min^{-1})
EURO category of engine	EURO 6	EURO 6
Gearbox	ZF-Ecolife	DIWA 6
Number of gear ratios	6	4
Gear ratios	i_1= 3,364 i_2= 1,909 i_3= 1,421 i_4= 1,000 i_5= 0,720 i_6= 0,615	i_1= 5,20 i_2= 1,43 i_3= 1,00 i_4= 0,70
Transmission ratios	5,1; 5,7; 6,2	5,1; 5,7; 6,2

Source: [2]

Studied bus lines are:

1. Line 330 (Zagreb Glavni kolodvor - Velika Gorica)

This bus line has been selected because it has no big changes of elevation. There are also relatively little number of bus stations, while travel speed is relatively big. Traffic on that line acts on relation Zagreb (Glavni kolodvor) - Velika Gorica. From the direction of Zagreb - Glavni kolodvor, working time on the line 330 starts from 04:35:00 and finishes at 16:40:00. In the opposite direction, starting from Velika Gorica, working time starts at 04:40:00 and finishes at 16:00:00. On the line 330 there are 6 bus stations.

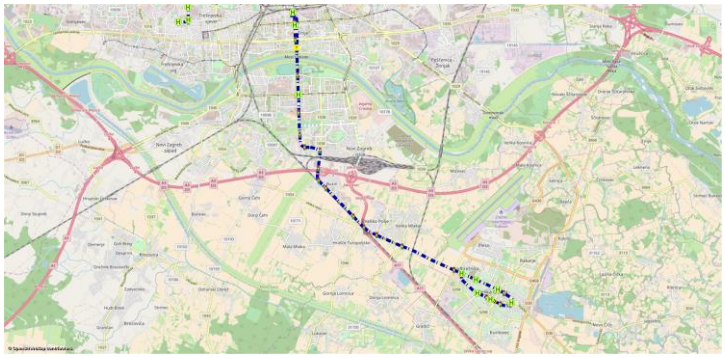


Figure 1 – Line route of the line 330
Source: [1]

2. Line 128 (Črnomerec - Lukšići)

This bus line has been selected because it has a huge change of elevation. Main characteristics are many bus stations, relatively low speed of traveling and principle of traveling is mostly ˝go-stop˝. Traffic on that line acts on relation Črnomerec - Lukšići. It is mountain - type line. From the direction of Črnomerec, working time starts at from 04:30:00 and finishes at 23:55:00. In the opposite direction, starting from Lukšići, working time is at 04:45:00 and finishes at 00:10:00. On the line 128 there are 13 bus stations.

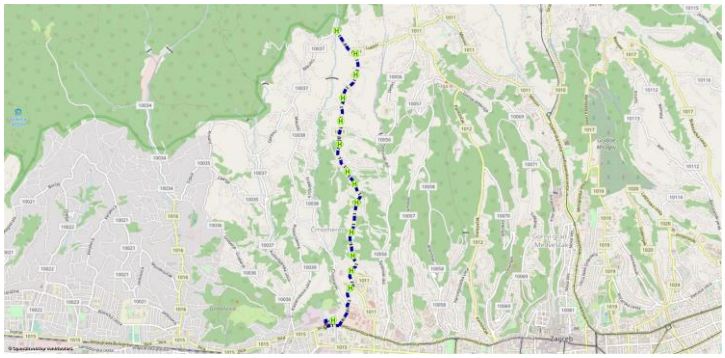


Figure 2 – Line route of the line 128
Source: [1]

3. Line 118 (Trg Mažuranića - Voltino)

This bus line has been selected because it has no big changes of elevation. Number of bus stations, traffic density, many crossroads with traffic lights require many ˝go-stop˝ actions. Spped of traveling is relatively low. Traffic on that line acts on relation Trg Mažuranića - Voltino. From the direction of Trg Mažuranića, working time starts at 04:55:00 and finishes at 00:50:00. In the opposite direction, starting from Voltino, working time is at 04:35:00 and finishes at 00:30:00. On the line 118 there are 11 bus stations.

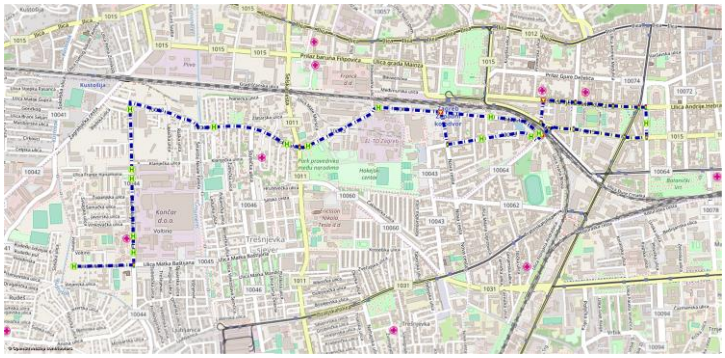


Figure 3 – Line route of the line 118
Source: [1]

3. ANALYSES OF TRANSPORT AND TECHNICAL CHARACTERISTIC OF THE PUBLIC TRNASPORT LINES

For analysis there have been used real data, collected using GPS trails in rush hour with resolution of 1 second. It refers to 330, 128 and 118 bus lines [6]. There will be observed 3 components on following graphical presentation:

1. Elevation - marked with blue colour;

2. Travel speed – marked with orange colour;
3. Average travel speed – marked with dotted orange colour.

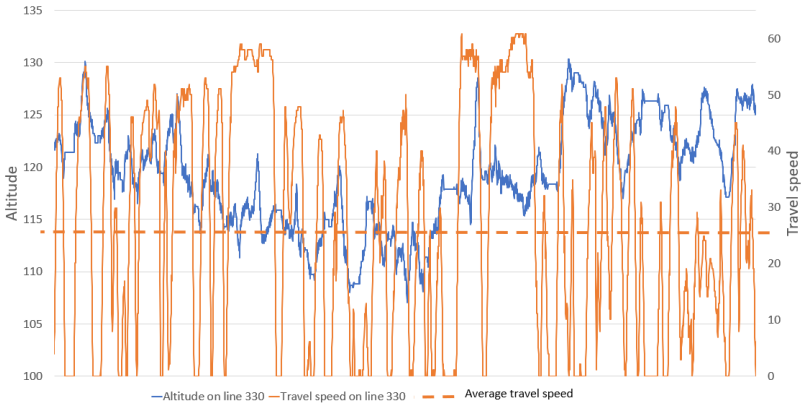


Figure 4 – Comparation of the altitude, travel speed and average travel speed of the line 330
Source: by authors

Table 2 – Line 330 parameters

Max recorded travel speed	62 km/h
Average travel speed	27 km/h
Length of line route (A-B)	7850 m
Total length of line	15700 m
The highest altitude	133,30 m
The lowest altitude	107 m
Travel time	52 min
Waiting time	12,15 min

Source: by authors

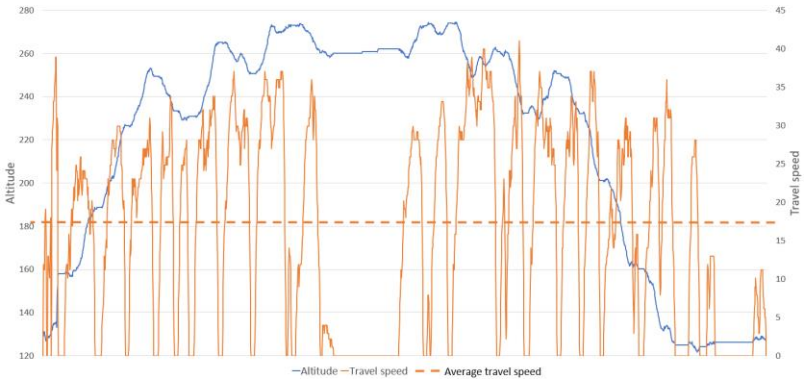


Figure 5 – Comparation of the altitude, travel speed and average travel speed of the line 128
Source: by authors

Table 3 – Line 128 parameters

Max recorded travel speed	42 km/h
Average travel speed	16 km/h
Length of line route (A-B)	2400 m
Total length of line	4800 m
The highest altitude	137,80 m
The lowest altitude	109,90 m
Travel time	24,27 min
Waiting time	9,6 min

Source: by authors

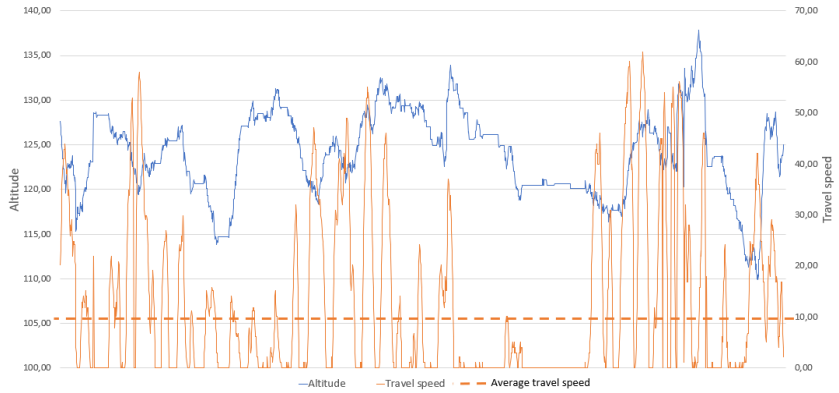


Figure 6 – Comparation of the altitude, travel speed and average travel speed of the line 118
Source: by authors

Table 4 – Line 118 parameters

Max recorded travel speed	61 km/h
Average travel speed	12,45 km/h
Length of line route (A-B)	2450 m
Total length of line	4900 m
The highest altitude	137,80 m
The lowest altitude	109,90 m
Travel time	20 min
Waiting time	13,7 min

Source: by authors

4. OVERVIEW AND COMPARASION OF OBTAINED RESULTS

In this chapter there will be processed overview and comparation of obtained results of buses. Following alterant will be compared:

- ZF – Ecolife
- DIWA 6

with different differential ratio: 5,1-5,7-6,2. Two following graphical presentations show evaluation of bus engines, considering fuel consumption. First, we give short description of terms differential and gearbox [3].

4.1 Differential

Function of differential is to stop turn-over of vehicle in situations in which wheels, because of driving in turning on the road, do not rotate with same speed on both sides. That mainly refers to driving wheels. Thanks to differential transfer, danger of turning-over or vehicle slipping-out while turning is minimal, except the situations made by people. There are three main differential tasks:

1. Transmission of power from engine to wheels

2. Portable ratio reduces speed of rotation of driving axle (engine) and speed of rotation of half-axle that transmits power on wheels. Reduction of rotating speed is achieved with different size of gears and number of gear teeth.

3. Transmission of power on wheels allowing different turning speed [4].

4.2 Gearbox

Gearbox is device or mechanical transmitter that serves for changing speed of rotation or direction of turning of driving shaft and working spindle, while speed of rotation of driving machine or engine stays unchanged. In this work automatic gearbox of bus brand MAN are being observed. They are:

- ZF-Ecolife

Advanced version of ZF-Ecolife automatic gearbox with system of governing with gearbox. Step 3 improves driving comfort both for driver and passengers. Quiet and soft changing of levels of transmission without interruption of tractive force and constant quality of changing with little possibility of error enhance ride comfort. Besides that, new software package Step 3 guarantees shorter periods of resting thanks to its optimized diagnostic function with UDS (Unified Diagnostics Service).

- Voith DIWA

Gearbox has been embedded in series in all models of MAN Lion´s city buses. It is characterized by electronic integration in driving group, effective mechanic - hydraulic branching of power, also powerfull secondary retarder. Besides that, it has program of changing degrees of transmission - SensoTop that depends on topography. Also, at heavier vehicle class guarantees optimized number of turning while changing and considerably lower fuel consumption. Separated altimeter recognizes climbs and downgrades and calculates for that optimal points of changing levels of transmission; it hasn´t been automatically sustained. Both types of gearbox are used at all types of buses (city, suburban, intercity and tourist)[5].

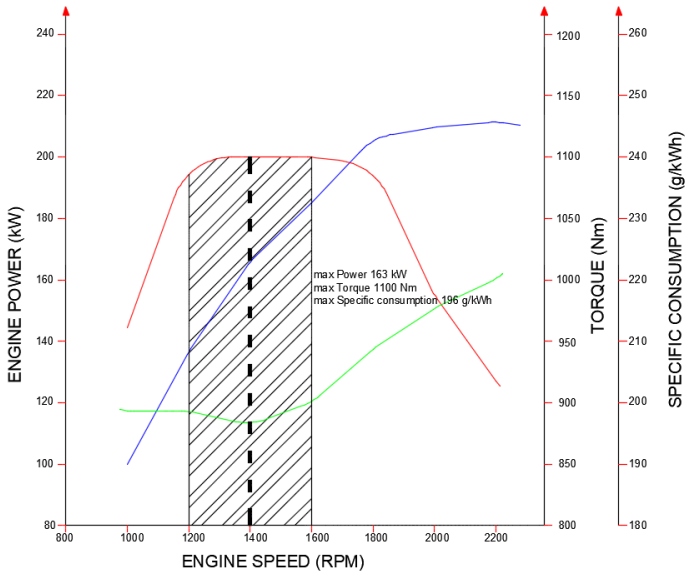


Figure 7 – Comparison between engine power, torque and specific consumption for the diesel engine D0836LOH66
Source: by authors

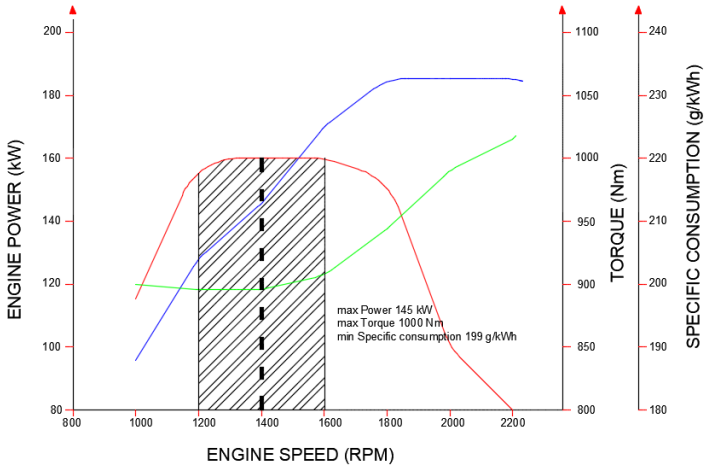


Figure 8 – Comparison between engine power, torque and specific consumption for the diesel engine D0836LOH67
Source: by authors

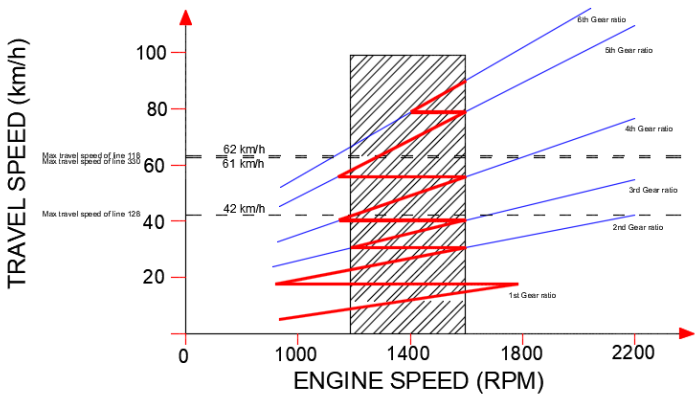


Figure 9 – Shift ratios of the gearbox ZF – EcoLife depending on engine speed and 5,1 transmission ratio
Source: by authors

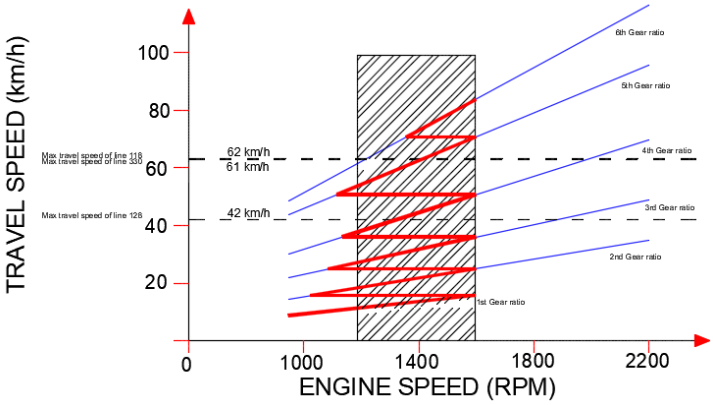


Figure 10 – Shift ratios of the gearbox ZF – EcoLife depending on engine speed and 5,7 transmission ratio
Source: by authors

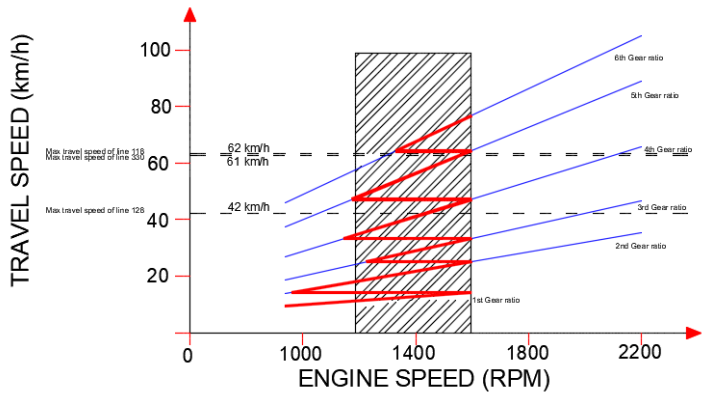


Figure 11 – Shift ratios of the gearbox ZF – EcoLife depending on engine speed and 6,2 transmission ratio
Source: by authors

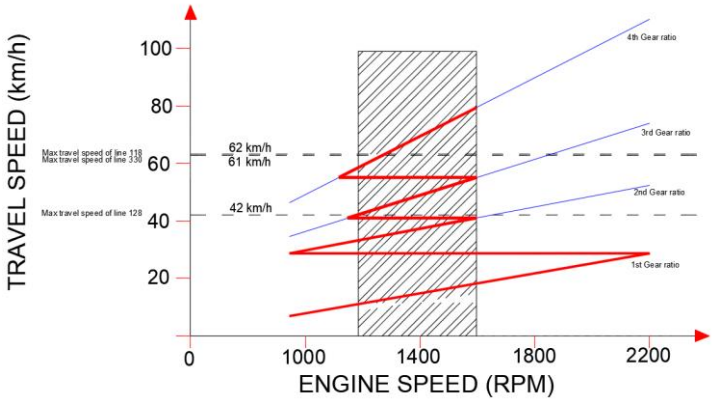


Figure 12 – Shift ratios of the gearbox DIWA 6 depending on engine speed and 5,1 transmission ratio
Source: by authors

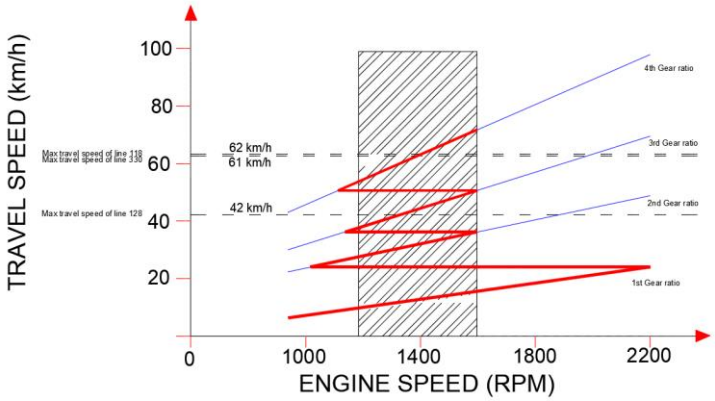


Figure 13 – Shift ratios of the gearbox DIWA 6 depending on engine speed and 5,7 transmission ratio
Source: by authors

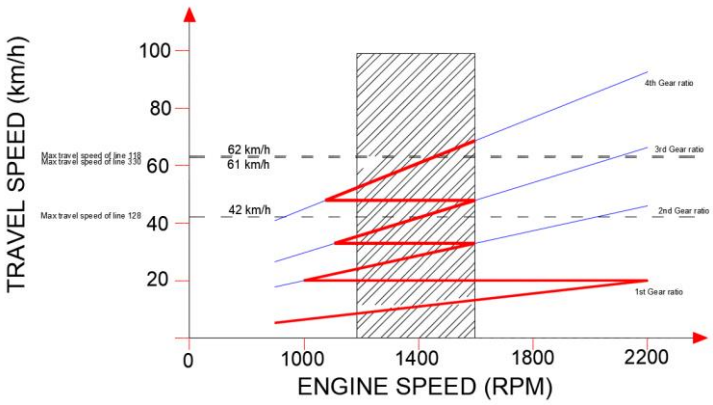


Figure 14 – Shift ratios of the gearbox DIWA 6 depending on engine speed and 6,2 transmission ratio

Source: by authors

Zone of optimal working space of engine operation (in which fuel consumption is lowest) is determined as 1400 +/- 200 min^{-1} for both engines from 1200 to 1600 min^{-1}. In serrated diagrams there are also zones of optimal working spaces of engine operation drawn and they are base on which is determined how often and how long will each alterant allow engine to work in optimal working space, also lowest fuel consumption considering line on which vehicle moves.

5. CONCLUSION

This paper presents the characteristics of two engines, two transmissions and three differentials on three different public transport lines, attempting to calculate the choice of optimum combination of gearbox and differential, due to the public tranpsort line line at which the vehicle would drive. According to the characteristics of both engines, they are very similar, their fuel consumption range is approximately 1400 min^{-1}. A comparison of the vehicle motion characteristics was done according to the pile diagrams of each gearbox and differential in a way to observe how often each gearbox would allow the engine to operate in the optimum operating range around the engine's lowest engine fuel economy. From the diagram it is apparent that on each line - whether it is mountainous or flat, it is desirable to use a combination of engines and transmissions with the lowest transmission differential in differential (5,1) of all offered differential. This is because such a differential makes it possible to keep the vehicle longer in the optimum engine belt. With all other combinations of gearboxes and differential, a more frequent engine operation is achieved outside the optimum engine range. Also, regardless of the choice of transmission and differential, it is easy to notice that when switching from the first to the second gear, the greatest deviation from the work in the area of the optimum working area is achieved, that is, the difference between first and second gear yields is too high to keep the engine working area in the optimum operating belt. Unfortunately, this can not be avoided in any case.

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APPLICATION OF NLP ALGORITHMS IN ITS MARKET ANALYSIS

ABSTRACT

Artificial intelligence (AI) is the branch of computer science which aims to incorporate human intelligence into computer programs. Natural language processing (NLP) is a branch of AI regarding to morphological, syntactic, semantic analysis and discourse processing of language. This paper presents technique of using NLP algorithm in marketing of Intelligent Transport System (ITS) services. Marketing is an extremely important process involved in selling and presenting products. Paper deals with applying AI in a specific market, such as ITS. ITS refers as upgrade of the existing traffic system using information communication technologies (ICT). In this paper authors propose the framework for classification of commercial content published by companies that are developing ITS services as defined in well-known ITS architectures. That kind of information could provide market and marketing analysis assistance.

KEY WORDS

Intelligent Transport Systems; Market analysis; Artificial intelligence;

1. INTRODUCTION

Intelligent Transport Systems (ITS) stands out as advanced solutions in field of traffic and transport. ITS can be defined as information-communication upgrade to classical traffic system with positive effect on increasing traffic flow and performance and reducing negative effects of traffic such as pollution, waiting time, etc. ITS is recognized as effective system and market size is expected to reach USD 47.5 billion by 2022 [1]. One of the largest areas of market growth is expected in traffic management, automotive telematic and public transport.

A fast-paced technological development and progress and the appearance of innovative technological products\services create a state of uncertainty on the market, manifested through technological alterations of prices, production, design, distribution, organization, etc. Such uncertain environment demands dynamism, high level of innovation, flexibility and continuous adaptation. Considering the development of new high-tech products\services, it's necessary to have a reorganization in the terms of quality, design, service\product, organizational-technological flexibility with the purpose of meeting the end-user's high demands. Because the technology in question is new, it's very important for end users to understand how to use this new service\product, what are the advantages and the purpose of application. Without the mentioned information, it's certain that the advanced technological solution would be unusable or out of function. Such a new environment requires an adaptation of a marketing conception. For that reason, there is a need for an upgrade of the traditional "technological-economic" approach [2]. The conception of the High-Tech Marketing lies on the determinants of the general marketing theory and on specific characteristics such as; product

or service should solve the user's real problems, the transparency of the market and of technology, technological innovation of products\services, etc.

In paper [3] authors analyze the market by application and region. They analyze market competitiveness and concluded that notable participants include Kapsch TrafficCom, Siemens AG, Hitachi Ltd., Q-Free ASA, SWARCO AG, TomTom NV, Garmin International, Denso, IBM Corp, and Xerox Corp. In [1] authors analyze the market size according to cooperative vehicle systems, traffic management solutions that enable improvement in road safety, roadway hazards, detecting accidents during dangerous weather conditions. In [3] technique for clustering the IT maintenance tickets with the NLP algorithm is demonstrated. Main goal was to create machine learning system for clustering maintenance tickets in order to automate the process of resolving problems. Input to algorithm was short texts from testers written in natural language. Natural language processing was used in order to derive keywords from texts. In [4] authors propose an approach to cluster social media posts.

In this paper NLP algorithms will be used as a tool for processing collected relevant commercial content in order to extract useful information used for analyzing market of ITS services.

2. MARKETING OF ITS SERVICES

Lately High-tech marketing has really been connecting with technological disciplines, especially important being the connection with transportation technology disciplines. In that sense, ITS have been imposing themselves as significantly innovative concepts for solving transportation problems for the past 20 years. "Intelligent" is the attribute characterizing the application of high technologies. In the context of ITS, it's referring to the ability of gathering data, processing and delivering different services to end users. In that way a better and a more adaptable traffic\transport system behavior can be achieved. The application of advanced ITS solutions has been confirming the improvement of the transportation system performance and of the quality of service for end-users. Derived from the general conceptual metamodel of high-tech marketing, the marketing of ITS services will be designed after the conception of the tech marketing of services, while the ITS hardware will be designed after the "industrial" marketing models [5]. Technological novelties often create uncertainties on the market. In the context of marketing, there are two kinds of uncertainties - technological and market uncertainty. In such a dynamic, unpredictable and uncertain environment competitive volatility can occur.

The traditional marketing mix is based on the classic "4P" conception, but due to the complexity of high-tech solutions it has expanded to 3 more variable instrumentations - people, physical evidence and process [2]. The "7P" conception helps high-tech companies to analyze and define key problems that could affect the marketing of their products or services. In the last few years, the "7P" conception is stated as a frame for a digital marketing mix.

On the ITS market the offer is divided in two categories - hardware and services which unite software and communication services. The demand could be classified based on customers or interested groups (stakeholders), which could be: end-users (drivers and passengers), network operators, shareholders, service providers, tourist companies, local community, city administration, etc.

The global ITS market (Figure 1) can be segmented according to the types, components and applications [6]:

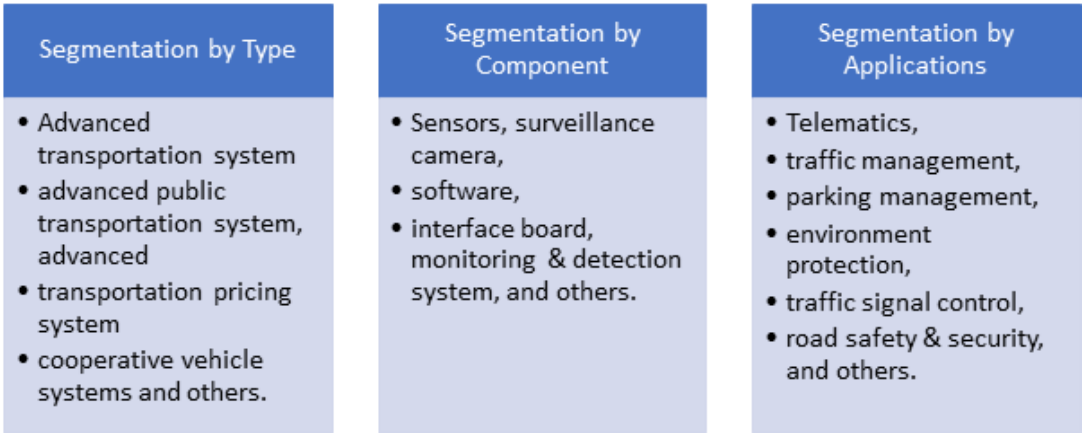


Figure 1 – The global ITS market segmentation
Source: [6]

The demand for digital services is fast growing. A big flow of real-time data will significantly contribute to the development of new ITS services. Communication and information technologies are becoming more and more present, which gradually leads to the personalization of information services. The most recent and up to date services on the ITS market are the ones from the field of end-user's informing. The Traveler Information Service is the key component in the European Commission's strategy for the future of transportation. Getting the right information, at the right time and at the right place is of great importance for a successful urban public transport, especially for the multimodal transport system. Such a dynamic system allows making a correct timely decision about the choice and mode of transportation. An advanced information service combines a set of different data gathered from external environment. The data in question is about user's points of interest, information about user's objects of interest, habits in the sense of choosing the route and mode of transportation. Further application development goes in the direction of absolute personalization [5].

Besides the advanced services of passenger and driver information, traffic and transportation cooperative systems are becoming more and more popular on the ITS market. Cooperative systems in traffic and transportation are systems in which vehicles can wirelessly communicate with other vehicles, infrastructure (roads and accompanying equipment) and with other users (pedestrians, VRU, etc.). In relation to other existing systems, the technology of cooperative systems allows a two-way communication: V2V - vehicle to vehicle, V2I - vehicle to infrastructure, V2U - vehicle with other users (ie VRU), I2U - infrastructure with other users (i.e. VRU) [7]. In other words, C-ITS are systems allowing effective data exchange using wireless technology, so that vehicles can connect with each other, with road infrastructure and other traffic participants.

To place the ITS service/product on the market and make it attractive to end-users, it is necessary to define the needs and demands of the targeted group of users. This takes into consideration the market analysis [5]. In order to get useful insights about customers' needs, demand and to create lifecycle relationship with customers, AI with its technologies (Machine Learning, Natural Language Processing, etc.) is now being used in market analysis.

3. ARTIFICIAL INTELLIGENCE APPLICATION IN MARKETING

Practical goals of AI are to accomplish human intelligence in computer programs. There are many cognitive tasks that are simple for people but extremely difficult for computers. AI develops systems which solve such type of tasks. AI is based on the idea of symbolic representation of knowledge. It is based on the emulation of the model we find in nature. Every aspect of learning or any other property

of intelligence can be described so that a machine can successfully imitate human behavior. This approach is known as the Turing test. The basic areas of AI are expert systems, machine learning, neural networks, fuzzy logic and robotics [8].

In marketing AI is used for wide range of application such as generating content [9]. Smart content allows better engagement of visitors on web site by showing customer content relevant to them. The big data of customer behavior can use probability models generated by machine learning algorithms for more effectively targeting ads at the most relevant customers [10]. Marketing automation techniques generally involve a series of rules, which when triggered initiative interactions with the customer. Machine learning can run through billions of points of customer data and establish when are the most effective times to make contact, what words in subject lines are most effective and much more. These insights can then be applied to boost the effectiveness of your marketing automation efforts.

4. DEFINING CLASSES FOR ITS APPLICATIONS

Practical goal of this paper is appliance of NLP algorithms in market analysis of ITS applications. ITS is one system made of many functional areas and functional areas are made of many applications, classification process of NLP algorithm will be done regarding to national ITS architectures. Applications are based on a shared platform. For market analysis of ITS applications, ITS applications must be divided into groups or classes. At the World Congress in Yokohama 1995. ITS functional areas are divided into nine different groups [11]: Sophisticated navigation system, automatic toll collection system, safe driving support, traffic management optimization, road management efficient, public transport support, commercial vehicle efficiency, pedestrian support, emergency vehicle operations support. European Intelligent Transport Systems Framework Architecture divided ITS functional areas into eleven groups [12] such as electronic fee collection, emergency services, traffic management, etc. (Figure 2)

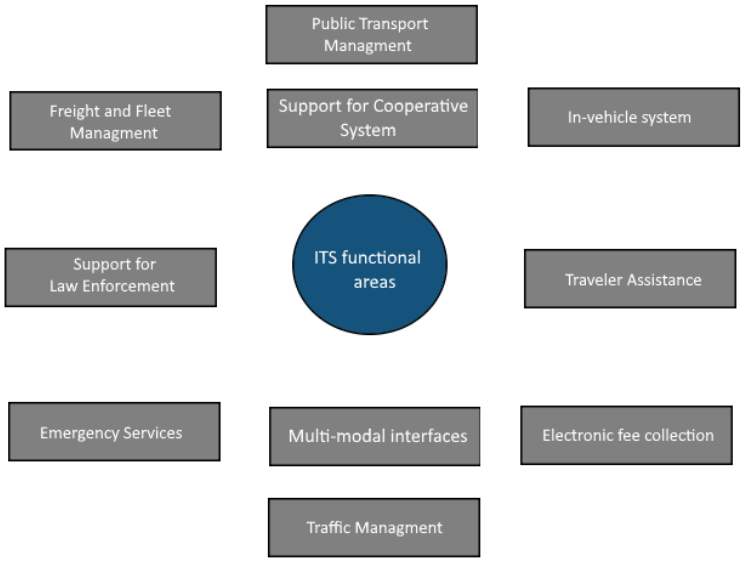


Figure 2 – ITS functional areas by FRAME project
Source: [12]

Electronic Fee Collection aims to eliminate the time delay on toll roads, bridges, and tunnels by collecting tolls without cash and without requiring cars to stop using electronic tool transponders [13]. Emergency Notification and Response associated services aid a specific individual or driver to request help from, and provide information to, authorities about a distress situation. Emergency notification and response systems are intended to provide appropriate assistance to distressed vehicles in timelier manner by providing accurate information to emergency response operators [14][15]. Public Transport

Management applies transportation management and information technologies to public transport systems to inform passengers, increase operational efficiency and improve the safety of passengers [16]. In-Vehicle Systems includes many technologies such as anti-lock braking system (ABS), electronic stability program (ESP), emergency call system (E-call), blind spot monitoring system, monitoring the state of vigilance of the driver, adaptive head light, Obstacle and collision warning, real time traffic and travel information, speed alert, lane departure warning system. Traveler Assistance is based on static and dynamic information about the transport network and services for users prior to and during the trip, and provide tools for transport professionals to collect, archive, and manage information for future trip planning activities. Support for Law Enforcement define standards and applications for coordination with emergency agencies, disaster response management, disaster data management. Freight and Fleet Management include logistics, freight management systems and multimodal transport. Example services include vehicle fleet tracking, vehicle fleet dispatching, freight container tracking [17].

Classification process of NLP algorithm will be done regarding to described development areas of ITS. When the process of creating classes is complete it is possible to append social media posts of a company to the ITS class that is most appropriate.

5. NATURAL LANGUAGE PROCESSING

Expression “Natural language” is commonly referenced as language that is used by humans for spoken or written communication. Such as Croatian, English, German or others. Natural languages have been developing for many years and passed from generation to generation and are very hard to define explicit rules for communication in comparison to programming languages of mathematical formulas. Good example is popular saying “Break a leg!”, humans knows that meaning is to wish someone a good fortune, but computer could understand it as serious injury.

Natural Language Processing (NLP) is process of extracting important information from natural human languages. To do that natural language should be converted to artificial language, mathematical notations. NLP is used in widespread of different technologies that uses natural language such as: handwriting recognition, web search engines, chat bots, machine translations and many others. Some authors [8] noticed that NLP has come to play central role in globalized multilingual society. NLP can also be used as marketing tool. Social networks, open research articles pages, technical forums and many similar sources contains millions of pages useful for market research or for extracting trending topics.

In this paper NLP is used for determining market state of the art regarding to ITS services. Main objective is to find content that are mentioning ITS services. In order to accomplish that goal classification technique will be used. Authors [8] and [18] mention two approaches for classification techniques: language-modelling approach and machine learning approach.

5.1 Language Modelling Approach

In language modelling approach modelling component is n-gram. N-gram is one word or set of words with the length of n. Main goal is to define n-gram language model for $P(x|G_1)$ where P is probability that some text x belongs to group G_1. Or $P(x|G_2)$ where P is probability that some text x belongs to group G_2. Simple Bayes’ rule for two groups can be applied for classification of new text [8] [19] with:

$$P(x|G_1) = \frac{P(G_1|x)\,P(x)}{P(G_1)} \tag{1}$$

And for G_2:

$$P(x|G_2) = 1 - P(x|G_1) \tag{2}$$

5.2 Machine Learning Approach

In machine learning approach main goal is to represent text as feature vector and apply classification algorithm to determine affiliation to some class. Feature vector is a set of feature-value pairs on which classification algorithm is applied. For comparison to language modelling approach features can be the n-grams and values represent a relevance of the feature. Relevance of a feature can be calculated with many methods. One method is to count feature occurrence in text.

6. NLP FOR MARKETING OF ITS SERVICES

Goal of this paper is to develop framework for gathering useful insights from content in order to provide market insights for marketing analysis. NLP algorithms will be used to extract vectors of words for creating classes for every ITS service. After creating classes every new content can be classified and appended to ITS service. Figure 3 describes a framework.

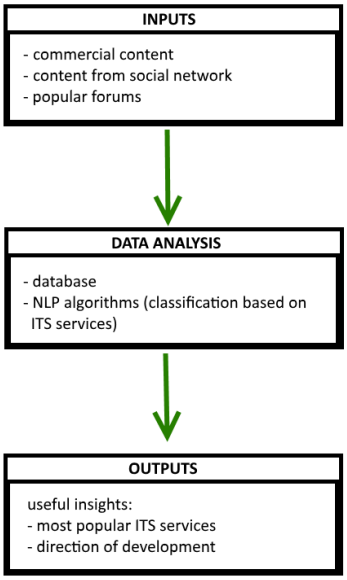


Figure 3 – Framework overview
Source: Created by Authors

6.1 Defining Classes of the ITS Services (Training Phase)

First step of the method is to define classes that will represent ITS services. Classes are presented as feature vectors that describes given ITS service. That feature vector contains of features (words) that describe ITS service and value of relevance for that feature. To create such classes first step is to gather large amount of data that describes ITS services. For that purpose, relevant commercial content has been gathered from following sources: social networks (profiles of companies that are developing ITS services), web-sites of companies that provide ITS services, professional magazines/papers, public forums (Stack Overflow).

Every gathered content $c_i \in C$ where C is a collection of all content, is represented as vector of words where $c_i = [w_1, w_2, \dots]$ and w_i is every word from content c_i. Vectors of words must be processed in order to filter out as many words not useful for classification. First step of filtering is lemmatization. Lemmatization is process of reducing words to their base or root [20]. For example, words “marketing” and “markets” are based on word “market”. Method uses more sophisticated approach for filtering words because it uses vocabulary and morphological analysis of words, removing endings and returning base of a word, which is referenced as lemma [21]. From words “am”, “are” and

"is" lemmatization process would return word "be". Next step is defining rules for removing stop-words and to eliminate words with low frequency.

Authors in [21] describe stop-words as semantically non-selective words which are very common in natural languages and that kind of words are generally not useful in classification process [22]. Then $TFIDF$ metric is calculated. $TFIDF$ is combination of word frequency tf and and inverse document frequency idf, in order to produce weight for each word in given content:

$$TFIDF_{w,c} = tf_{w,c} \times idf_w \tag{3}$$

where w is one word in a content and c is a content.

For every vector of words n keywords are extracted $K = [w_1, w_2, \dots, w_n]$ where K is vector of keywords. In that way keywords from every relevant content that describes ITS services are gathered and compared to each other in order to get keywords that describes given ITS service. Those keywords will represent a class $CL = [K_1, K_2, \dots]$ that will describe ITS service.

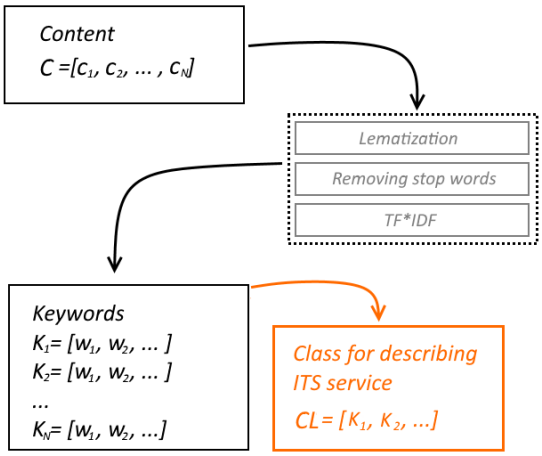


Figure 4 – Process of defining classes that are describing ITS services
Source: Created by Authors

6.2 Appending New Content to Predefined Classes (Testing Phase)

After defining classes for every ITS service next step is to process new relevant content and append it to ITS class. Every new content has to be represented with two vectors: vector of n words that contains all words from given content and vector that represents weight (importance) for each word. Those two vectors will be used in classification process. For defining weights for each word Document Frequency (DF) parameter is chosen. DF will have larger value for words that appears more frequently in given content [23].

For appending new content to ITS class Cosine Distance is used to measure distance between new content and class [3]. Cosine Distance is metric that describes similarity (distance) between two non-zero vectors and it is defined as:

$$dc(C, CL) = \frac{\sum_1^n cw_i clw_i}{(\sqrt{\sum_i^n cw_i^2})(\sqrt{\sum_i^n clw_i^2})} \tag{4}$$

Where C is a vector of words $C = [cw_1, cw_2, \dots, cw_n]$ that represents new content and CL is class defined as $CL = [clw_1, clw_2, \dots clw_n]$.

7. EXPECTED RESULTS

With defined classes for ITS services, next steps in a process of getting useful insights is to gather content published by companies that are developing ITS services. For a company COM_i in $COM_1, COM_2, \dots\ COM_n$ where n is a number of companies, a large number of relevant content must be gathered depending on a time span of an analysis. For every company COM_i content $c_1, c_2, \dots\ c_m$ must be gathered. Than company is defined as $COM_i = [c_1, c_2, \dots\ c_m]$. Every company belongs to an industry (automotive industry, electronic industry...). Industries should be represented as vectors of companies where every company can be part of more than one industry. Industry is then represented as $IND_i = [COM_1, COM_2, \dots\ COM_r]$ where r is a number of companies that belongs to given industry. In that way analysis can be done based on industries and companies. Collected content is representing new content that will be presented to algorithm for classification (mentioned in chapters above).

Classification process will determine the main subject of given content. With that information useful insights about ITS services market that can be gathered are given by Table 1.

Table 1 - Insights that could be gathered using proposed framework with indicators

Insight	Indicator
Popular ITS services	Number of content that are describing ITS services from companies or industry
Companies with largest investments in ITS services	Number of companies with a lot of content that are describing ITS services
Share of ITS services development in one company	Percentage of ITS related content in comparison to other subjects
Market share of ITS services	Based on share of ITS services development in one company

8. CONCLUSION

AI helps people in reducing the error and the chance of reaching accuracy with more precision. Computed methods for automated reasoning, learning and perception have become a common phenomenon in everyday lives. Repetitive jobs which are monotonous in nature can be carried out with the help of AI.

In this paper, we propose an enhanced approach that is based on NLP algorithm to support the extraction of classes of ITS services. It is necessary to collect a sufficient number of commercial content on which the algorithm will be trained. Also, a sufficient amount of posts from companies on social media that are leading in the production of ITS services. After gathering data first step of framework is to create classes that are describing ITS services. With defined classes the algorithm classifies new content related to ITS services. Expected results from this kind of classification are insights into ITS market like: the most popular ITS services, the market growth forecasts, most represented ITS services etc.

Future work will be based on the appliance of the methodology presented in this paper. The algorithm will learn to classify commercial content based on the ITS functional areas using big amount of data and each new content will be classified into one of ITS functional area. Classification process will help in determing the main subject of given content. That information is useful insight about ITS services market.

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USING OF DATABASES ON UNWANTED EVENTS TO INCREASE RELIABILITY AND SAFETY OF RAILWAY TRANSPORT PROCESSES

ABSTRACT

Each unwanted event has a reason that is often repeated. On the other hand, any event that results in delay, creates a hazardous situation. This follows directly from the functioning of system. The train traffic without delays is realized in accordance to the timetable, which is designed to allow collision free traffic of trains and other traffic participants. Therefore traffic in accordance to the timetable is a barrier preventing disasters. For this reason, it is important to learn from events causing in small consequences, but occur frequently. The article presents current experience in obtaining information from operating data on delays and accidents arising in the railway transportation system. There was shown possibility of using simulation models based on operating data to verify designed new timetables. In the paper were also described dependencies of infrastructure type, rolling stock and traffic relative to frequency and consequences of unwanted events.

KEY WORDS

railway system; operation data; reliability; safety;

1. INTRODUCTION

Transportation process duration is a random variable depending on many factors. Generally speaking punctuality is a function of:

- Train failures,
- Infrastructure failures (failures of rail, signalling etc.),
- Random accidents occurrence (associated with environment).

Train failures can be classified into events related to train or passenger interactions and system failures resulting from rolling stock failures. Vehicle reliability analysis has already been developed in researches for many decades. In 99.1% of all cases unwanted events occurring in railway transportation system has resulted maximum in delays. In 0.9% of cases an accident has occurred. Accidents include derailments, signals passed at danger, train collisions, suicides, collisions with road vehicles, etc. Only the most dangerous (with fatalities or major damage) are under investigation by committee of railway accidents - it is less than 0.1%. It follows that knowledge from 99.9% of all unwanted events is currently not used for improving reliability and safety of the railway system.

2. INFORMATION SOURCES

The railway transportation system is very complex. This applies to structure of the system and all processes taking place in it. Information on the operation of the system is stored in several places. The most important knowledge bases currently belongs to:

- national rail accident research commissions,
- infrastructure managers,
- railway carriers.

Each of these knowledge bases is characterized by a different profiles, in accordance with the main business. The main unwanted events investigated by the national authorities (national rail accident research commissions - NRARC) are [17]:

- serious accidents,
- accidents,
- incidents.

Serious accidents result from derailment of a rail vehicle, collision or similar events, which lead to at least one fatality, or five serious injuries, or damage to the system and the environment at a level of at least two million Euro. Accidents are events related to collision, derailment of rail vehicles, collisions at level crossings, or vehicle fire, resulting in no deaths (on board of a railway vehicle) or losses lower than two million Euro. Incidents are all other events (other than an accident or serious accident), which are related to safety of railway traffic [4, 17]. An accident commission can be established at one of three levels [23]:

- local commission,
- company commission,
- national rail accident research commissions.

Local commission investigates incidents occurred during shunting, rolling stock collisions, hit pedestrian, or people who jumps into a train. Company commission examines other events. Each event being incident, accident or serious incident is also reported to the national commission for research of railway accidents. NRARC supervises proceedings, takes part in the proceedings, or take control of the proceedings. Each event studied in this procedure results in:

- circumstances of the incident,
- causes of the event,
- prevention requests.

Research institutions for railway accidents have the best competence, so they may develop the most accurate and insightful reports. Research carried out by these institutions can bring a lot to the railway transportation system. In practice, these studies are restricted to a small fraction of all events in the system. For a required region in Poland less than 0.1% of all registered events have been notified by the national safety institutions [17, 22]. From all reported incidents, only 1.4% was investigated directly by NRARC. To the European Railway Agency (ERA) have been reported only 0.18% of the NRARC noticed events [17].

The national rail accident research commissions have the greatest potential to make changes which increase safety on the national railway as well as on railways in the world. Nevertheless, NRARC do not have the resources to be able to examine all existing events, so many phenomena posing a hazardous situation are not analysed. The next data sources are infrastructure managers. They supervise the operation and maintenance processes of the railway system. During traffic management process, operating data have to pass several instances of the infrastructure manager company. The general flow of information in case of an unwanted event is shown on figure 1.

Operating data (related to train traffic) is collected by traffic control points. Which can be located along a railway line or in form of a centralized control centre. Information on location of trains is obtained mostly from track-side devices. Random events which prevents or hinders system operation, are registered at a train control point via:

- trackside signalling equipment (interlocking),
- power equipment (traction network or auxiliary power system),

- train crew observations,
- traffic controller (when incident took place within the traffic control point).

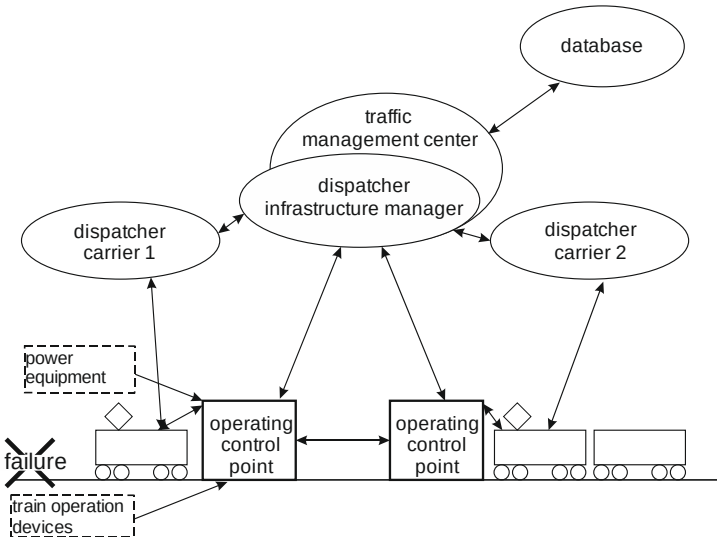


Figure 1 – Information flow in railway transportation system after an unwanted event

A traffic control point connects to the dispatcher and provides information about an event. The dispatching department is a part of infrastructure manager's traffic management centre. Parallel communication takes place between train crews and appropriate carrier dispatchers. As a result of the dynamic interaction between dispatchers of various companies it is possible to rise errors in the information that goes into the traffic database.

The main task of the dispatching department is a rapid reaction to an unwanted event. This process should allow to minimize secondary disruptions of failures for passengers, carriers, etc. In view of those obligations, carriers' dispatchers do not have complete data on total number of events that affects the reliability of railway system. Finally data are archived by infrastructure manager traffic management centre. Data are available as traffic books and failure books, usually contained in one IT system.

For a punctual trains or a small disrupted ones, data is collected only in relation to time when a control point is passed. However, after a disruption causes in delayed trains by more than five minutes (sometimes this limit has a different value), range of collected information will increase. Information collecting process after an unwanted event includes the following parameters [28]:

- type of failure,
- occurrence date,
- repair time,
- place of the event (route / station, kilometre of the line, number of occupied track),
- number of delayed passenger trains,
- summed delays of passenger trains,
- number of delayed freight trains,
- summed delays of freight trains,
- own delay of train (if cause of the event is that train).

The second infrastructure manager's activity area is infrastructure maintenance. Maintenance models (as well needed data) will depend on profile of the company's organizational unit. Examples of models have been collected and extensively described in many papers, e.g. [19, 20]. In case of infrastructure manager maintenance department the main task is to carry out diagnostic work to

monitor current technical condition. Depending on the results of standardized measurement procedures, the department may take the following steps, to ensure current safety level or increase it:

- no actions,
- implementation of speed limits,
- implementation of axle load restrictions,
- carrying out of repairs.

As a consequence, the maintenance department informs traffic department about current speed limits, axle loads and repair works, which may have negative influence on the line capacity. One possible way to describe From the system point of view the best measure is current speed limit related to nominal speed. The advantages of such measures are described in [30].

The main data source in the system are carriers, which have the most specialized databases. Their databases contain only information about carrier activities. Data on train traffic is secondary - originally derived from the infrastructure manager. The most important information at the disposal of a carrier is:

- type of train,
- number of seats required (depending on the number of passengers),
- energy consumption (depending on rolling stock type and railway line),
- timetable (transportation task starting time, transportation task ending time, starting place, ending place, number of trains, exchange time of passengers),
- operation work in train-kilometres,
- type of rolling stock,
- age of rolling stock,
- total mileage of vehicles,
- service intervals,
- capacity,
- stopping distance,
- installed power,
- acceleration,
- maximum speed,
- rolling stock reserves,
- gross train mass,
- axle loads,
- temporary location on the network.

Information derived from carriers are particularly important in case of vehicle reliability and safety analysis.

3. ANALYSIS OF UNWANTED EVENTS

Unwanted events occur continually within the railway transportation system. The events affect the system and processes inside it. These events can be classified in various ways. One possibility is to split events due to effects:

- no effect (misinformation),
- effects within the system,
- delay,
- incidents,
- accidents,
- serious accidents.

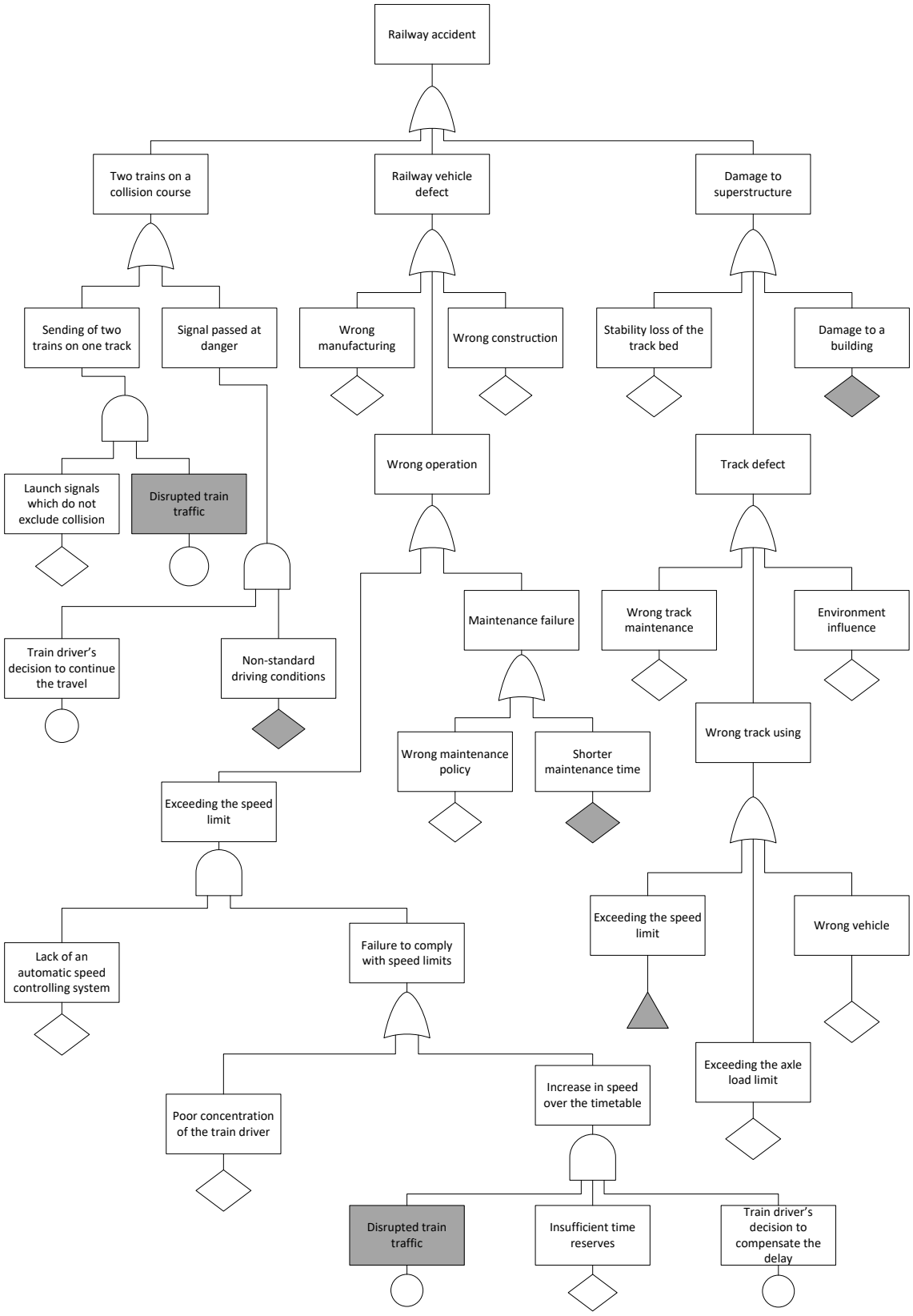


Figure 2 – Fault tree for the top event "railway accident"

Based on [21] it was found that the first two groups together represent about 20% of all events, railway accidents (serious, common and incidents) about 0.1% of all events. The remaining events lead to delays. More than 78% of the events fall into one group. Therefore, it is reasonable to create

a modified classification of events. With respect to [8, 21, 22, 28], events were divided due to the nature of the causes:

- environment – 17% (theft and destruction of infrastructure, rolling stock or cargo, atmospheric phenomena, foreign investment, incidents with people, incidents with road vehicles)
- failures of the infrastructure subsystem – 34% (level crossing devices, communication equipment, train control devices, track damage, damage to power equipment, unwanted events associated with train control, train accidents, infrastructure manager's investments),
- train – 49% (damage to rolling stock, events related to passengers, events related to train crew).

In [1, 24] it is written, that safety recommendations are primarily the result of proceedings after an accident. However, according to [25, 26] systemic investigation of safety take place for the case of serious accidents. It can take place only potentially for accidents and selected incidents.

Figure 2 shows a part of developed fault tree. The top event is a train accident. Train accident is understood here as a serious accident, as previously defined. For this reason, the fault tree does not include accidents with pedestrians, car accidents and other events that, in practice, do not contain risk of fatalities on the train, or damage to a total of over two million Euros.

As a result, main safety factors were identified. A very important conclusion rises, traffic disruptions are part of accident occurring process. Traffic disruptions change the operation conditions. This may lead also to human errors.

The planned schedule theoretically allows safe train traffic on the railway network without signalling equipment protection. Traffic control devices become a barrier to accidents. On the other hand traffic disruptions causes a hazardous situation.

A traffic control system on local control points (stations operated by staff) and supervisor system on the regional level was presented in [35]. The conclusion is that the human factor could be reduced by an overarching verification of operator actions. However, similarly to the case of standard traffic control devices may be situations where will be a need to bypass the system in order to allow further movement of trains. In [32] was drawn attention to the increasing number of tasks must be performed by traffic duty after an accident, or just delays. Then the convergence behavioural and cognitive stress growth affects traffic safety (over 90% of accidents in the rail transportation system occur after the takeover of responsibility by human [27], and disaster in transportation occur in about 80% of cases caused by humans [11]). The human factor is present in the whole system, not only in the direct management of trains by traffic control points [34]. It follows that the most dangerous is imposition of full human responsibility and changing process flows, contrary to planned timetables.

4. HANDLING OF OPERATION DATA – A METHOD CONCEPT

The paper [30] describes example results of research on reliability modelling of railway transportation system. It is focused on interactions of chosen parameters of the infrastructure system. Using operating data collected in the railway system, dependencies between frequency of unwanted events and operation work has been proven (superstructure, traffic control devices, electric devices, as well as rolling stock). Mention of taking into account operating work in reliability analysis has already appeared in [28].

It has been shown that at significance level of 0.05 the frequency of damage to rolling stock does not depend on the railway line, but on type of vehicle, operation work, and seasons. It was also shown that type of traffic control devices have an impact on frequency of unwanted events. Similarly, the type and age of superstructure. Also type and age, as well as type of trains on railway line have influence on failures of electric devices.

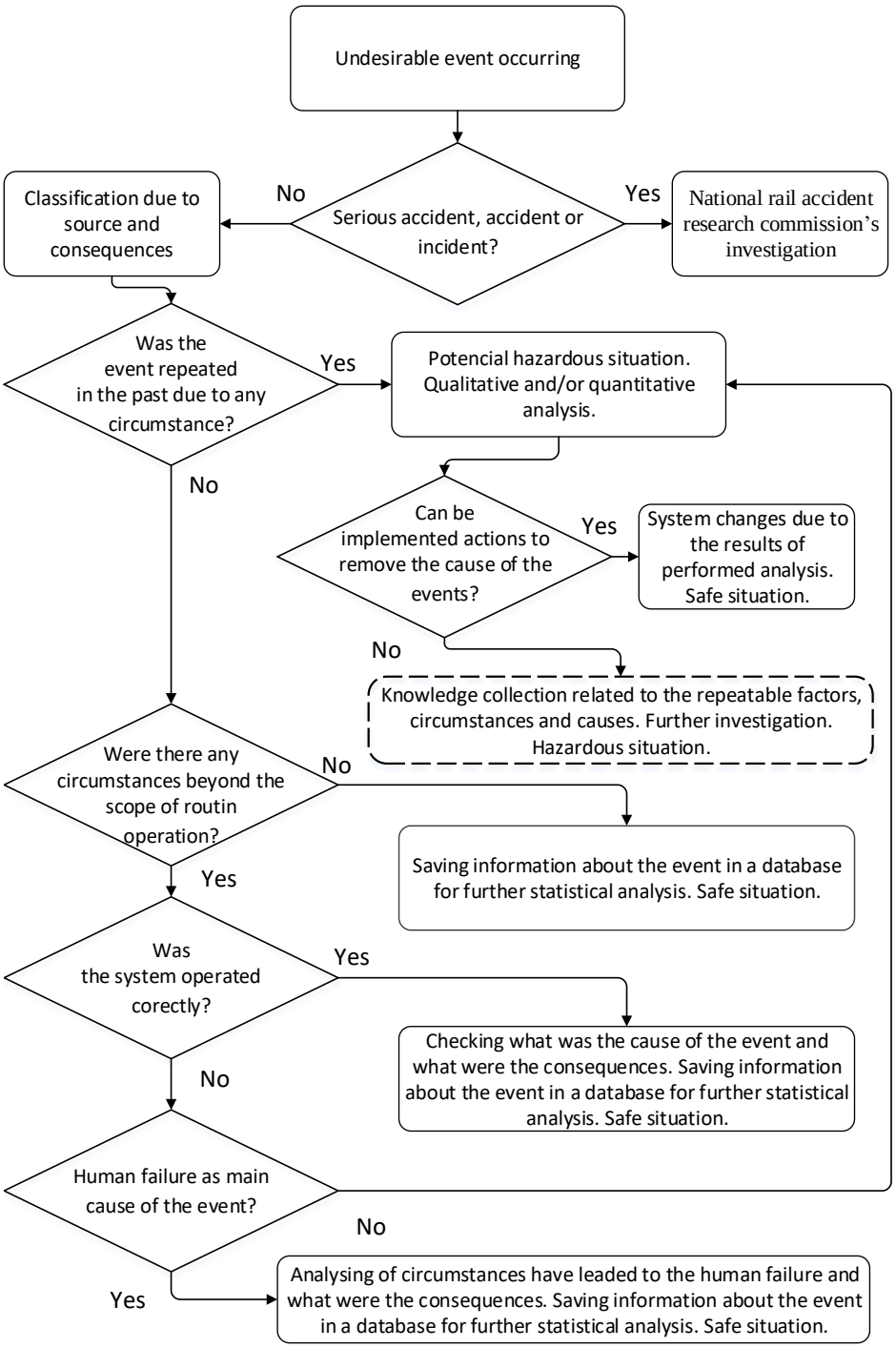


Figure 3 – Proposed method for handling undesirable events

Figure 3 shows an event handling approach concept for the railway transportations system. It classifies unwanted events that are normally not taken into account during safety analysing, because they are named as safe events. Nevertheless, many repeating safe events may give information about unwanted changes in the system, that can lead to accidents.

If the event not belongs to the NRARC group, than it is checked if the event was repeated in past operation. If yes, statistical analysis should be performed and the root of the whole set of events has to be found. For non-repeatable events the circumstances are compared within normal routine. If there is no deviation than the event should be saved for potential further investigation. The next question leads to find if the system was operated correctly. If it was operated correctly then the

cause and consequences have to be found, and information about the event has to be saved for further investigation. Finally the issue arises if a human failures have initiated the event. If yes then the circumstances of the event have to be found, and information about it has to be saved. If the answer to the last question will be negative then the decision model leads to hazardous situation. This is due to potential systematic failures in the system (wrong safety rules etc.).

Looking at real data from the railway transportation system, the events were analysed due to the proposed handling method. The results are shown in table 1.

Table 1 – Results for event grouping

	Analysing of circumstances of the human failure and the consequences. Saving information.	Checking what was the cause and the consequences. Saving information about the event in a database.	Saving information about the event in a database for further statistical analysis.	System changes due to the results of performed analysis.	Knowledge collection related to the repeatable factors, circumstances and causes.	lational rail accident research commission's investigation
Potential hazardous situation	No	No	No	No	Yes	Yes
Safety investigation required	No	No	No	Yes	Yes	Yes
Changes in the system required	No	No	No	Yes	Yes	Yes
Part of events from the sample	0.097	0.032	0.614	0.165	0.091	less 0.001

Only 0.001 of all events meet the requirements to be investigated by NRARC. The remaining events are not analysed systematically. Using the proposed method, 0.091 of all undesirable events can be classified as potential hazardous. The method allows to propose actions to investigate undesirable but safe events.

6. CONCLUSIONS

The paper shows main aspects of the collecting and using of operating data from complex transportation systems, on example of railway transportation system. It describes basic sources of knowledge, which are commissions investigating accidents, infrastructure managers and carriers. Description is completed by characteristics of available data and evaluation of data collecting process. The operating data structure was characterized in case of a real system. Events were divided in terms of consequences and in terms of causes. This knowledge will be useful for next researches.

Subsequently, attention was paid to a small piece of data that is used to improve safety of the system. A large flow of events with small consequences, but with influence on accidents, was indicated. The proof is based on a Fault Tree Analysis.

Events with small consequences were supplemented by examples of catastrophic events and causes of these events. Attention was paid to errors in design, materials, operation and human errors that led to disasters.

The final section describes the practical application of operating data in reliability researches. The overall conclusion is that in complex technical systems a large amount of data is collected. Unfortunately, these data are in many cases not used to improve safety and reliability. The proposed method must be developed in further studies.

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INTEGRATION OF LOGISTICS INFORMATION SYSTEMS WITH ELECTRONIC SALES CHANNELS

ABSTRACT

A contemporary communication model implies an electronic exchange of information among the participants in the process. With the development of technology, the level of automation and information exchange increases with the aim of enhancing the process and reducing the possibility of error, a more-efficient informing of stakeholders, decision-making, etc. In the sense of logistics, not a single logistics process may exist without the information necessary. This means that information plays an important role in every logistics process, regardless of type, product or service. Due to a mass usage of the internet, there are new sales opportunities, i.e. new sales channels. These channels are called electronic sales channels or e-commerce. This type of commerce is the most profitable especially due to its low cost and simplicity, which is why its importance has been growing. The trend of the sales development by means of electronic sales channels has had a direct effect on logistics and logistics processes of ordering, preparation, transport and delivery, as well as the flow of information in the channel and keeping all the participants in the process informed. The paper discusses the role and importance of e-commerce in logistics, logistics processes and the logistics information system. The paper offers the possibility to connect the electronic sales channels with the logistics information system and thus allow for the automation of information exchange between the logistics system and e-commerce.

KEY WORDS

logistics information system; integration; e-commerce; electronic channels; sales;

1. INTRODUCTION

In logistics, all active participants communicate and interact to exchange information. Contemporary integral logistics information systems have the possibility of both in-house communication, as well as external communication with external systems such as partners, institutions and other systems. The logistics information system is extremely important for a transparent, efficient and successful maintenance of the organization process. By means of introducing and applying contemporary technologies in logistics, one greatly contributes to the improvement and enhancement of logistics task performance. The connectedness and communication of participants in the logistics processes is ensured by means of using information-communication technologies that make the electronic exchange of information and data possible.

In March 2017, the European Union had 430.335.137 Internet users, and according to Eurostat data, 68% of them buy various goods by means of electronic sales channels.

The present day e-commerce is based on modern telecommunication, information-communication, computer and cryptographic technologies. By means of connecting the systems used in e-shops with logistics information systems, the interaction between the buyer, the seller and the logistics information system is guaranteed in real time. E-commerce allows for time-zone related, geographical and other barriers to be overcome. In such a market, the expenses and the prices of the goods have been made more accessible and more transparent.

The technical standards and the internet technologies on which e-commerce is founded are universal, which is why the integration of various systems is possible.

This type of commerce and using the information technologies has introduced great opportunities for the seller, such as the information about the buyer (name and surname, address, contact details, e-mail address, the most frequently ordered goods, the segmentation of the market in terms of various structures (e.g. sex, age, etc.) as well as the possibility to analyse and segment the market to the groups of buyers who can afford to pay a different price for the same product. On the other hand, logistics companies have in advance information on the type and size of goods, as well as the routes the goods would take to maximize the capacities in timely manner.

The most renowned e-shops are: Amazon.com with the revenue of 177,9 billion dollars in 2017 and eBay with the revenue of 8,97 billion dollars in 2016.

2. LOGISTICS INFORMATION SYSTEMS

One of the general definitions refers to the information system as to a set of methods, steps and resources designed in such a way as to ensure a certain goal is achieved. According to Steven Alter, "an information system is a software system to capture, transmit, store, retrieve, manipulate, or display information, thereby supporting people, organizations, or other software systems."[1]

Due to the development of computer science, there has been a more intensive usage of information and enhanced level of trust when it comes to making managerial decisions on the basis of information. As information has become accessible, it has been concluded that information is an important organizational factor, just like the workforce, tools and patents are. The information systems assist in managing knowledge and have been included as an inevitable part of numerous organizations and one of the key sub-systems in the business sector as a whole. The business information system may be understood as the integral system encompassing people and equipment for providing information that supports the organization's functioning.

The elements of each information system today are given as follows:

- technical equipment (*hardware*),
- computer programmes equipment (*software*),
- organizational support (*orgware*) and
- human resources support (*lifeware*).

All elements related to the physical realization of the process and the tools necessary (e.g. cables for connecting systems) are called 'technical equipment' and all the elements related to the non-material aspect of software support are called 'programme equipment'. The organizational support is made up of methods and processes that allow the information system to operate harmoniously. The human resources support comprises members of staff who make the functioning of the information system possible, whereas some authors include end users as well.

Logistics information systems (LIS) unite the needs of logistics with the possibilities of information systems and are designed in such as fashion as to provide the parties interested within the logistics processes and the operational management with skills necessary for managing the flow of materials and information among organizations and their business environment.

Logistics information systems co-ordinate information between various users, deliverers, and distributors in the delivery chain. [2]

The role of logistics information systems is maintained by means of ensuring assistance in the enhancement of business efficiency while understanding that the utilization of information technologies is a key factor when ordering, producing and delivering goods and services. In that manner, contemporary logistics information systems are developed in a completely automated and unique way thereby ensuring a complete administrative, functional and hierarchical integration of processes along individual functions of logistics support.

The logistics management in the system is usually based on the following information:

- the flow of information on materials and goods, including the stocks, the delivery deadlines, the needs of users, etc.
- the flow of information on commerce, including marketing, distribution channels, the process of transporting goods on the way from the manufacturer to the consumer,
- the flow of information on finances, including all the transactions (classic and e-payment),
- the flow of information (necessary, required and desired) obtained by means of communicating with all the members in the communication chain and the channels of the logistics information system. [3]

Appropriate collecting and processing of information, including the control necessary, allows for a rational utilization of limited resources within one business cycle, as well as achieving a certain level of economical solutions, productivity and profitability in the whole process.

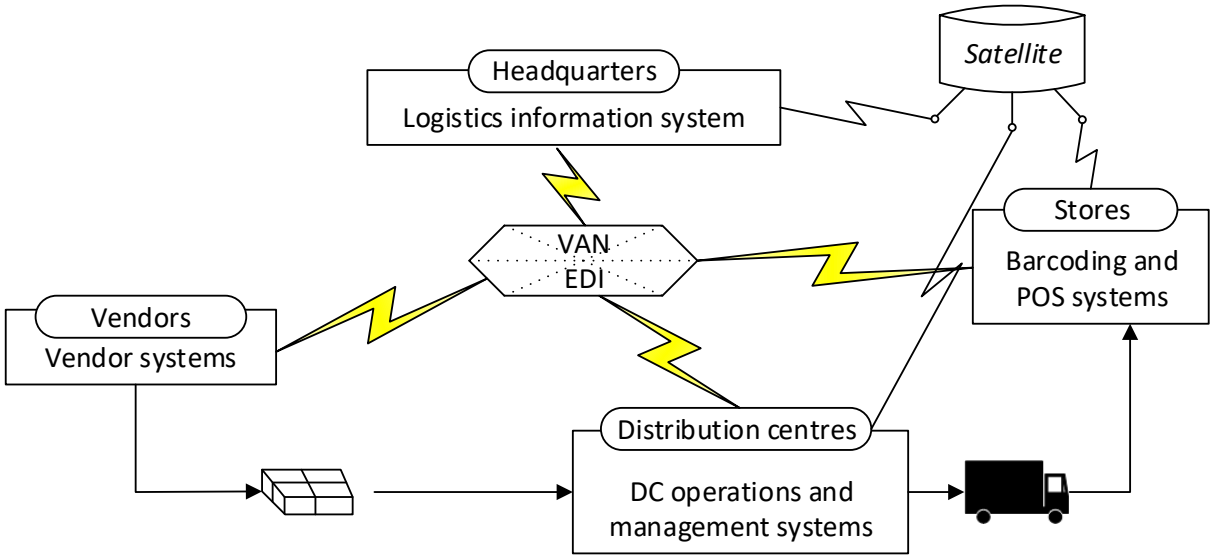


Figure 1 – A schema of a typical logistics system, the position and role of the logistics information system
Source: [3]

An appropriate regulation of the relations within operational and logistics management systems (see: Fig. 1) is the factor which confirms which links in the system are necessary to establish. Communication and electronic exchange of information among business partners—the sellers, the shops, the distribution centres—on the one hand, and the logistics information system of a business supported by contemporary information technologies, contributes to the savings, the speed of the delivery, lower costs for maintaining stocks, as well as to understanding minor errors in the communications system, etc. [4]

3. ELECTRONIC SALES CHANNELS— E-COMMERCE

The beginnings of e-commerce are mostly related to the emergence of the first e-commerce website—Amazon.com. Great changes that ensued, as well as the abrupt growth of e-commerce in the first twenty years of its development represent only a beginning of the expansion that is expected in the period to come, with the assumption that commerce on the global level in the following thirty years is going to be based on e-commerce exclusively. In order to understand all the benefits that e-commerce brings, it is necessary to define the key concepts.

There is not a single definition of e-commerce as several authors provide definitions that differ to a great extent. According to [5], e-commerce represents commercial transactions between organizations and individuals by means of using digital technology. However, perhaps the definition [6] that would describe e-commerce in the best possible way would be: "E-commerce is the process of buying, selling or exchanging goods, services and information by means of the publicly available networks, i.e. the Internet, in which the costs, as well as the time needed for the transaction, are reduced.''

When it comes to the classification of e-commerce, there are more categorizations provided. However, the basic ones are the ones that entail the very nature of commerce relations, i.e. commerce between business subjects—Business to Business Commerce or B2B. We may use eSteel.com as an example as this platform represents a platform for the steel industry which provides e-commerce for both manufacturers and buyers of steel. Another example is the end-user, market-oriented, daily and non-business commerce such as Business to Customer, or B2C. We may use Amazon.com as an example representing a general seller offering consumer goods to retail users. Third, Customer to Customer e-commerce (C2C) is maintained on the Internet among parties (consumers) interested which is best explained with the example of eBay.com which offers the commerce space where users may bid or directly sell their goods to other users.

The development of the Web has brought new methods of conducting business, such as P2P, or the Peer to Peer technology of sharing files and services using the Web without having a common server and M-commerce, which is based on the usage of wireless digital devices for the purpose of conducting transactions on the Web. [5]

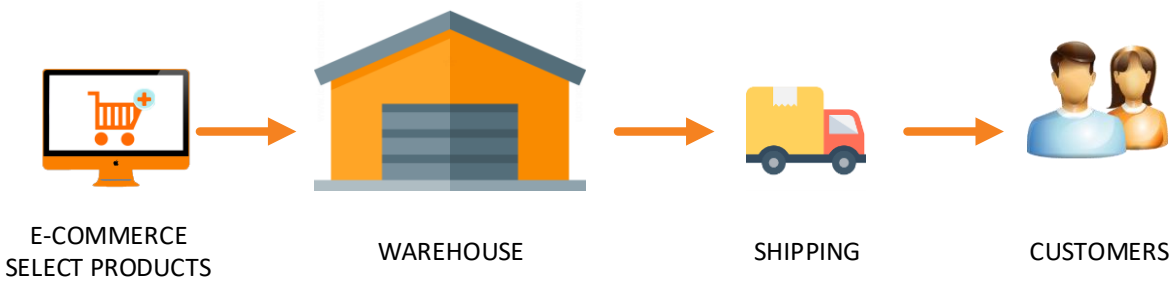


Figure 2 – E-commerce
Source: Authors

The technologies used by e-commerce allow users of social networks to create and exchange content with others across the globe. Two technological forces that drive e-commerce and that are constantly advancing are the Internet and one of its most widely used services —the World Wide Web (www). Without these two, e-commerce would not be possible. The Internet and the Web are technologies that have emerged in the recent past and are still rapidly developing with new devices, the technologies of connecting, software development, as well as other business or individual examples of development. The key technologies used in the M-commerce business models are 3G mobile phones, Wi-Fi wireless local computer networks, and Bluetooth. [5] New technologies represent and extremely important factor of industrial growth and investing into the Internet

technologies and new business models to allow for the development and growth of business outside of the physical market.

E-commerce has numerous advantages, but also disadvantages which are easily solved as a many institutions have given priority to solving problems in e-commerce recognizing it as one of the major driving forces of industry in the future. According to numerous authors, e-commerce owes its abrupt expansion and great popularity to its numerous advantages when compared to classic commerce. The benefits of e-commerce for buyers arise from interactive platforms and immediacy, as well as from a great degree of control. As for sellers, the benefits of e-commerce arise from a possibility to establish a better relation with clients, reduced costs of communication services, as well as from attaining a better degree of competitiveness among small businesses.

4. INTEGRATION OF LOGISTICS SYSTEMS WITH E-SHOPS

The term 'integration' implies joining and connecting parts into a whole, i.e. organizing parts that operate harmoniously towards the realization of common goals. By means of the e-commerce integration with a logistics system, an electronic information flow—that allows for the exchange of information between these two systems—is established. The e-commerce platforms are based on technologies using programming languages such as PHP, ASP.NET MVC, Java and MySQL or MSSQL databases. The architecture used in e-commerce is client-server architecture located on a public IP or URL address. The access to e-shops is done by means of web search engines once the shop address is entered. Today, there exist developed open source platforms for e-commerce which can be accessed by anyone, and some of the more well-known are X Cart, Magento Community Edition, PrestaShop, etc.

On the other hand, logistics systems are based on platforms and technologies used for the development of desktop applications such as C++, C#, VB, Java. These applications are of an internal use, i.e. an in-house use of a logistics firm using VPN tunnels for communication between distant points and forming a local network with distant computer units.

Due to a rapid expansion of e-commerce, there came a need to automate and integrate e-commerce (web shops) with logistics systems, i.e. exchange of information between these two systems. The need to connect these systems has led to the development of the Shipping API - Application Programming Interface (Shipping API), which is used as an integrator between technologies and languages used by e-shops and logistics systems.

In this way, the two information systems may communicate with each other and share data regardless of the operation system, the database or programming languages compatibility, using the SOAP (Simple Object Access Protocol) communication protocol. SOAP is platform-independent and based on XML. It is used for exchanging information and data between different systems by means of HTTP. HTTPS uses the following input for communication models [7]:

- C - Create – POST,
- R - Read – GET,
- U - Update – PUT,
- D - Delete – DELETE

Each SOAP message comprises several elements:

- the essential Envelope that identifies the XML document as a SOAP message,
- the header,
- the essential part of the message (the body),
- the part of the message on errors (fault).

Each message has to contain the Security Credentials (API KEY) if the communication is encrypted.

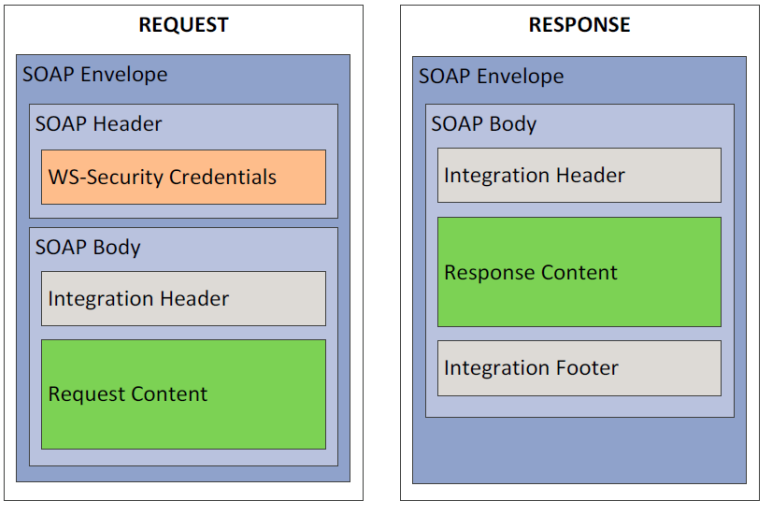


Figure 3 – Message structure in the SOAP protocol
Source: [8]

The security information and information exchange between E-commerce and WEB API, as well as between WEB API and the logistics system is ensured by means of the API KEY, which is a unique identifier and the secret token for authenticity verification. The API KEY is founded on the universally unique identifier (UUID - Universally Unique Identifier), which uses a 128-bit number marked by 32 hexadecimal signs represented in five groups of signs individually separated by hyphens.

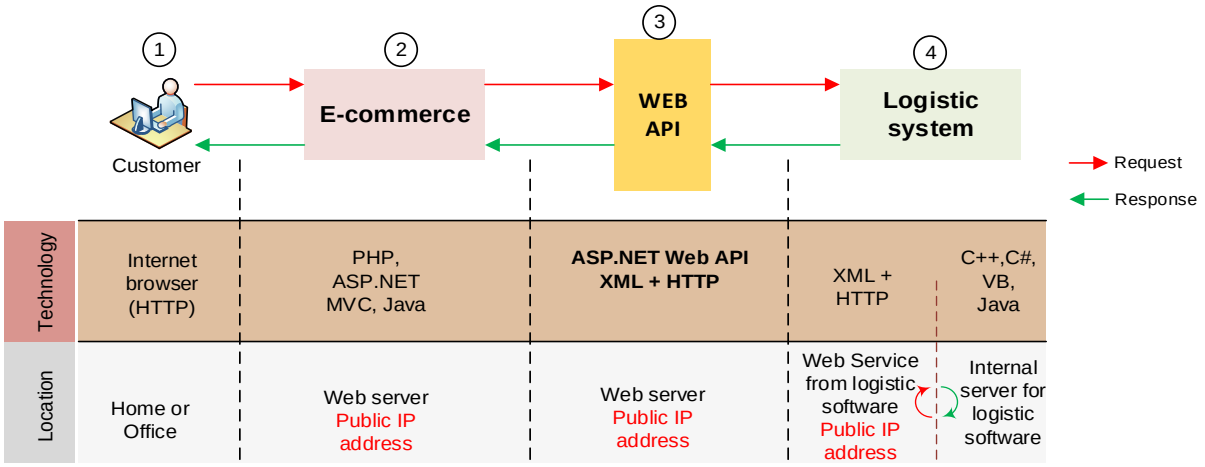


Figure 4 – Integration of e-commerce with logistics software
Source: Authors

The integration principle of work is as follows: Client (1) created on the E-commerc (2) platform a request for certain information available on the logistics system. E-commerc (2) by means of HTTP creates an XML document with a SOAP specification and the required method using encryption for communication and forwards the request towards WEB API (3) (SOAP server). WEB API processes if the request is valid and whether it contains the necessary key and forwards it towards the logistics system (4). The logistics system launches an appropriate application, downloads data and forwards them to WEB API. By means of SOAP protocol, WEB API returns information to the E-commerc system, i.e. the client. In this way a safe communication between these two information systems has been established.

Each individual service that is allowed on the e-commerce platform and which is related to the delivery of the package (the logistics information system), has to contain its own individual code that it communicates with API and which the API communicates with the logistics information system.

By integrating the E-commerc with the logistics information system, the buyer on the e-shop is provided with the following information:

- the day of the delivery,
- the time of the delivery,
- delivery up to a certain time (time define delivery),
- the possibility to move the day or time of the delivery,
- the price of transport services,
- the delivery to an alternative address,
- method of transport payment (Cash, credit card etc.),
- method of goods payment (Cash on delivery, credit card, etc).

After the buyer has selected goods on the e-shop platform and selected the services (the method of payment, the day of delivery…) which will be used to allow the delivery to be adjusted to his/her needs, all the information is digitalized and the preparation of the delivery thus simplified. After the physical preparation of the goods ordered, the administrator on the e-shop creates by means of API the form to be filled upon delivery which is automatically stored on the logistics information system at the logistics provider. After the physical preparation of the package, the administrator creates the package with the customs clearance invoice and creates a standardized label to accompany the order. After the package has been prepared for the delivery, the system sends data to the logistics information centre. In this way, the logistics provider is provided with the amount of goods that need to be taken from the e-shop stocks.

The benefits of e-commerce when the API system is applied are given as follows:

- automatic preparation of mail
- automatic preparation of standardized labels to accompany the package
- automatic preparation of the delivery invoice towards the logistics provider
- the possibility to offer all the services 24/7, offered by the logistics provider directly on the e-commerce platform.

5. THE INFLUENCE OF THE SYSTEMS INTEGRATION ON LOGISTICS PROCESSES

Logistics systems may be defined as systems of spatio-temporal transformation of goods, and the processes flowing in them as logistics processes.

Logistics, as a type of business process, implies[9] “the process of planning, implementation and the control of processes with the aim of efficient and successful transport and storage of goods, including the services and relevant information until the consumption point and in accordance with the requirements of the buyer’’.

The integration of e-commerce with logistics information system by means of the WEB API system has a multiple effect on logistics processes, especially on the processes required when preparing goods for the delivery. In the following text, we present the logistics processes with and without the systems integration.

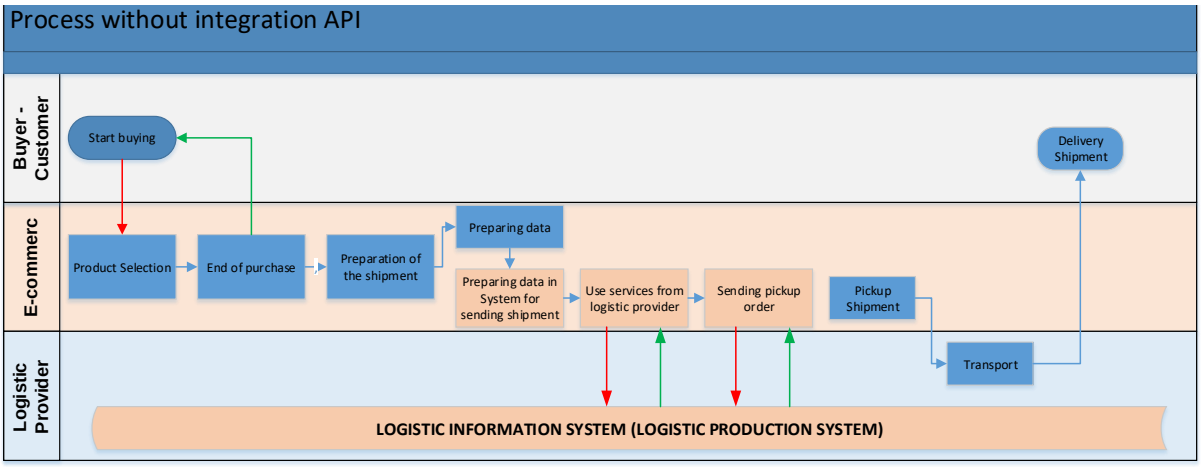


Figure 5 – Complete process without API integration
Source: Authors

In the systems without integration, the delivery services may be chosen exclusively by the operator that would be preparing the mail. What is more, all the information and details about the user who bought a certain product and to whom the delivery is to be made, is manually inserted into the mail delivery system which is usually installed by the logistics provider.

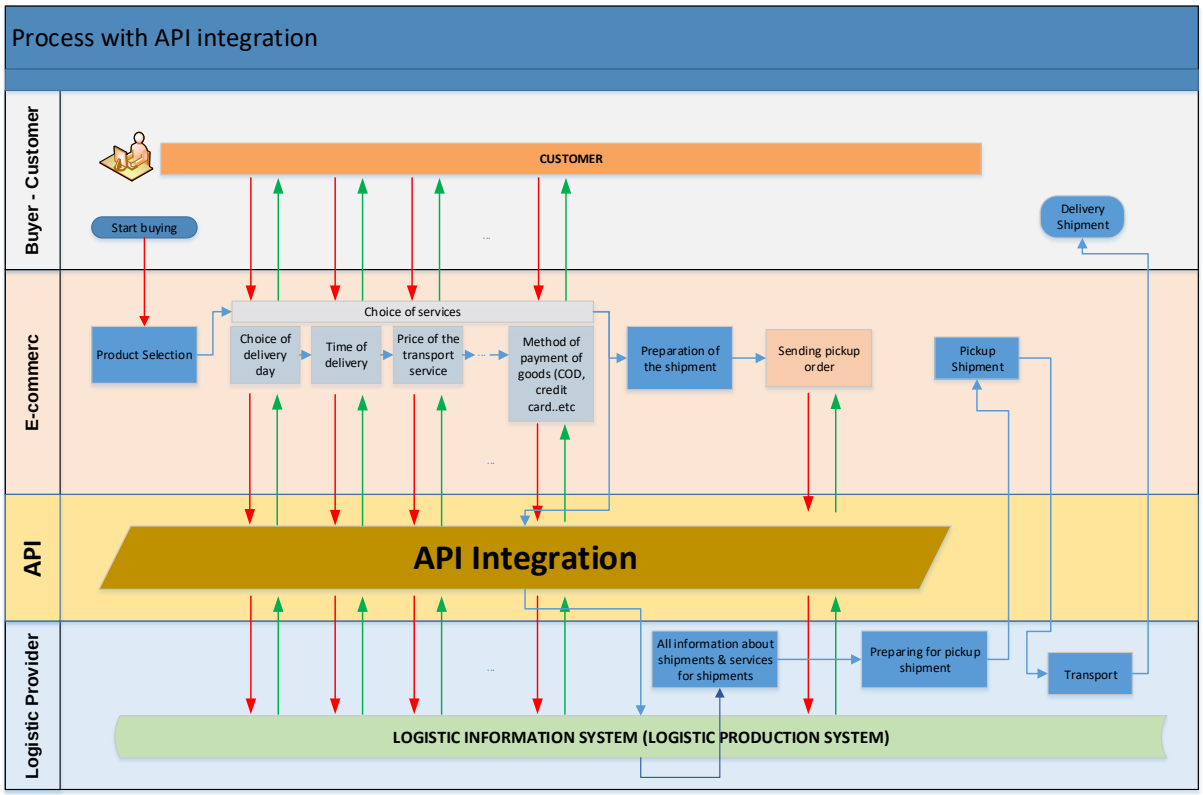


Figure 6 – Complete process with API integration
Source: Authors

Such a method of preparing the data and mail delivery is decentralized as the data about one user are found within one system, whereas the preparation and the information are stored on the other system, which leads to one manually inserting data, time consumption and certain additional costs when the preparation for the delivery ensues. In this case, the user does not have the choice to

select certain services that are related to mail delivery and the user is at a later point informed about the process once the logistics provider has obtained the information necessary (Figure 5).

In the systems with API integration, the processes become more complex, and it is in this way that the buyer is immediately informed about various services and expenses.

With the integration, it is easier for an e-shop to conduct the business as all the information on the delivery is available and integrated into the logistics information system and an additional preparation or application is not necessary. The information about the receiver, the services selected, the method of payment, etc. is readily available and no additional work is needed when working with data. From the e-shop system, labels are automatically printed for the identification of mail, and the package number is unique in the logistics information system and the e-shop system, which is why the buyer may follow his/her order and check in which phase of transport it is at any given moment.

Such an automated method of communication between the e-shop and the logistics information system allows buyers to use the services offered by logistics providers 24/7. Such a method of integration is especially relevant in the case that the logistics providers change certain criteria for the claim and delivery of goods (certain days for claiming or delivering goods, occasional lack of transport vehicles available, etc.). With the changes in the logistics information system, all the changes are automated and visible in the e-shop system, i.e. available to buyers. In addition, the integration gives buyers the possibility to follow their package in real time and by means of e-commerce.

5. CONCLUSION

The main goal of API is to create a bridge between different information systems in order to allow for a mutual and automatic exchange of information and data. As million of different applications are daily developed on different platforms, the importance of WEB API will be even more prominent. The biggest e-shop in the world, Amazon, which had the revenue of 177,9 billion dollars in 2017[10], has recognized the benefits of WEB API and had it integrated since 2006.

- By integration of logistics systems with e-shops it is possible to:
- allow for a better information flow between business subjects,
- realize transportation in a more reliable manner,
- reduce time for implementing activities necessary to meet the user needs,
- enhance the quality of services and reduce total costs arising due to a joint maintenance of the activities,
- carry out complex analyses (which users use which services and platforms most frequently).

Such a method of communication in real time gives a boost to logistics providers and allows them to plan their capacities in a timely manner, as well as to optimize their networks and adjust them to the needs and the requirements of the user.

Logistics providers which have the possibility to integrate the API systems with electronic sales channels are more competitive on the market primarily due to a rapid advancement of e-commerce and the B2C delivery.

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THE MODEL OF TRANSPORT MONITORING APPLICATION BASED ON INTERNET OF THINGS

ABSTRACT

Some unexpected events such as temperature fluctuations, humidity changes, and vibration may destroy the value of goods being transported. In order to prevent unwanted events and to overcome some shortcomings in process of delivering goods, an ICT (Information and Communication Technologies) need to be deployed. One of the major challenges is to enable the monitoring of the conditions in which goods are transported and stored. The IoT (Internet of Things) offer possibilities to locate and track goods from origin to destination and to monitor transportation conditions. IoT-based solutions enable to know when, where, and how some irregularities in the delivery process occurred. Moreover, these solutions provide possibilities of sending alerts to the client, transportation companies or other stakeholders to call for immediate assistance. Companies can improve service offerings and competitiveness of their operations as well as improve route travel patterns and transport conditions. Therefore, all stakeholders in the logistics chain can benefit from IoT technologies. In this paper, we present some possibilities of IoT application for logistics and supply chain management services including vehicle fleet tracking, goods monitoring and control, location-based services, etc.

KEY WORDS

Internet of Things; Smart Logistics; Fleet Tracking; Transport monitoring;

1. INTRODUCTION

IoT (Internet of Things) is the inter-networking paradigm based on identifying, sensing, networking and computation processes enabled by technology stack which provide a seamless connectivity between physical and virtual objects to facilitate the development of intelligent services and applications. IoT-based solutions can allow clients, logistics, and transportation companies to know where goods are located at all stages of the transportation process as well as to monitor transport conditions such as temperature, humidity, vibrations, etc. This information is critical in cases of sensitive goods transportation such as food, dangerous goods, pharmaceuticals, medical equipment, etc. Therefore, IoT can be used to control the transport conditions and make delivery more efficient. Logistic operators, transport companies, clients, and other stakeholders can achieve greater control over their freight by using these solutions.

IoT may help in resolving some transport problems because it can offer integration into traditional supply chains to track, trace, and monitor the movement of vehicles. There are many researches in this area where authors presented some aspects of IoT application in transport and logistic. For example, Liu Y et al. presented one of IoT-based solutions for food safety and quality control [1]. In this project authors described how the food supplies can become more transparent and safer by using IoT enabling technologies. In paper [2], authors highlighted the practical significance to

monitoring and managing the logistics processes and present a logistics monitoring technology based on WSN (Wireless Sensor Network). Paper [3] present application to tracking of pallets and containers while proposing the architecture of a collaborative platform based on IoT enabling technologies. Tadejko P. [4] studied some aspects of modern logistics related to the IoT technologies and described some shortcomings and challenges of logistics such as monitoring, intelligent information collection, efficiency of logistics operations, etc. In this research, future prospects of IoT in logistic are analysed. Therefore, IoT-based solutions can improve the efficiency of the whole logistic supply chain. Firstly, it can optimize the supply chain management; secondly it can make sources to be used effectively; thirdly it can make the whole supply chain to be visible so that it can improve the information of supply chain transparency; fourthly the supply chain can be managed in real time; the lastly it can make the supply chain high agility and complete integration [5].

In this paper, we describe IoT-based smart monitoring application for monitoring of the conditions in which goods are transported and stored. This application should include vehicle fleet tracking, goods monitoring and control, location-based services, and other services to improve the performance, safety, and reliability of the transport process [6]. IoT has made these processes easier and more cost-effective than traditional solutions. The solution proposed in this paper is applicable to any transport or logistics company that requires transport conditions monitoring in their vehicle fleet. Moreover, in cases of some unexpected events such as fires, exposure to floods or other risks, this solution enables sending alerts to the client, transportation company or law enforcement to call for immediate assistance. Logistics companies can turn to IoT-based solutions to minimize these risks and for enhancing the efficiency and safety of logistics operations.

Many IoT enabling technologies should be deployed for developing IoT-based smart monitoring application for transport. In this paper, we present some of these technologies and their possibilities. The main objectives of this paper are summarized as follows:

- To provide an overview of common IoT applications in transport and logistics;
- To propose a model of IoT-based smart monitoring application and to present its features;
- To present a common IoT enabling technologies.

The remaining of this paper is organized as follows. Section 2. provides an overview of possible IoT applications in transport and logistics. In this section, we propose IoT-based smart monitoring application and present its features. Section 3 introduces IoT enabling technologies and possible technological solutions for the proposed application. The final Section 4 contains concluding remarks.

2. INTERNET OF THINGS

IoT (Internet of Things) is the inter-networking paradigm based on identifying, sensing, networking and computation processes enabled by technology stack which provide a seamless connectivity between physical and virtual objects to facilitate the development of intelligent services and applications. Potentialities offered by the IoT make possible the development of a huge number of applications. IoT-based solutions are deployed in various vertical markets such as smart home, smart cities, smart healthcare, smart transport, and logistics, etc. These solutions provide a set of functionalities and capabilities which can be grouped according to a domain of utilization into four areas: monitoring, control, optimization, and autonomous operations. In this paper, we put in focus some IoT applications in logistics and transport and we present IoT-based smart monitoring application for monitoring of the conditions in which goods are transported.

2.1 IoT in Logistics

IoT contributes several key benefits for logistics operators which are present in the entire logistics value chain, including warehousing operations, freight transportation, last-mile delivery, etc. IoT enables logistics providers higher levels of operational efficiency through the development of

customized and automated services for their customers. Falling prices of device components (sensors, actuators, and semiconductors), faster wireless networks, and increasing data crunching capabilities only compound the business benefits, ensuring that IoT becomes a disruptive trend in the logistics industry over the next decade. Some of IoT benefits and impact areas such as operational efficiency, safety, and security are presented in Table 1.

Table 1 – Impact areas of IoT application

IoT aplication	Enable	Implementation
Traffic and Fleet Management	Efficient public transportation services through managing and gathering information data from streets, buses, taxis, and citizens using GPS devices, loop detectors, road sensors, video, and citizen reports	Automotive manufacturers, transportation operators and transportation information centers
Resource and Energy Monitoring	Tracking all kinds of resources, petroleum, natural gas, electricity and water. Waste reduction, disasters prevention. Strong potential to enable greater environmental sustainability	Utility organizations, municipalities, oil and gas companies, non-governmental organization, individuals
Connecting production environment	Closed form of operational technologies is migrating to open IP standards available information about machine performances, ambient conditions, energy consumption, status of inventory, increased scalability, interoperability, uptime, manageability, security	Factory environment of different purposes
Equipment and Employee Monitoring	Predict equipment failures and reduce risks, employee productivity improvements	Companies of different purposes
Logistics	Item condition and alert in case temperature or humidity of thresholds. Tracking shipments, damage detection, smart-inventory management. Monitor all assets in real time predictive maintenance of the machine systems. Higher level of worker health and safety. Optimization of energy consumption through smart warehouse energy management	Smart warehouse, freight transportation companies, all types of logistics providers

Source: Authors

Understanding of IoT application in logistic processes can be presented by decomposition of individual operations in following segments [7]:

- IoT in warehousing – a quality increase of warehousing operations is achieved by different sensors tags, a connection between machines and vehicles to a central system, different devices for monitoring and use of intelligent LED lights. Some instances of IoT application in a warehouse are: smart inventory management, optimal asset utilization, connected workforce, smart energy management, etc.
- IoT in transportation – IoT in freight transportation allows tracking and monitoring a container in a freighter in the middle of ocean, as well as shipments in a cargo plane mid-flight. Telematics sensors and multi-sensor tags on items transmit data about location, condition, asset utilization, spare capacity, material degradation and damages. These features create a good foundation for end-to-end supply chain risk management
- IoT in last-mile delivery - Sensors in official and private post boxes can notify the customer about package delivery status, the exact time of delivery, detect when supplies are running low to make automatic replenishment. IoT in last-mile delivery enables the flexible delivery process.

2.2 IoT-based smart monitoring application

IoT has a huge potential for developing intelligent applications in almost every vertical market including logistics and transport. For example, there are many IoT applications that have been already successfully implemented for smart traffic systems, fleet tracking solutions, control of logistics chain, collision avoidance systems in cars, etc. In this paper, we describe IoT-based smart

monitoring application for monitoring of the conditions in which goods are transported and stored (Figure 1). This solution allows clients, logistics and transportation companies to know where goods are located at all stages of the transportation process and to monitor transport conditions. This information is critical in cases of sensitive goods transportation such as food, dangerous goods, pharmaceuticals, medical equipment, etc.

There are three main advantages of using IoT solutions in logistics operations: tracking of transport means and goods throughout the logistic chain, detection of unexpected openings of transportation means (e.g. vehicle or container openings) and monitoring of transport conditions.

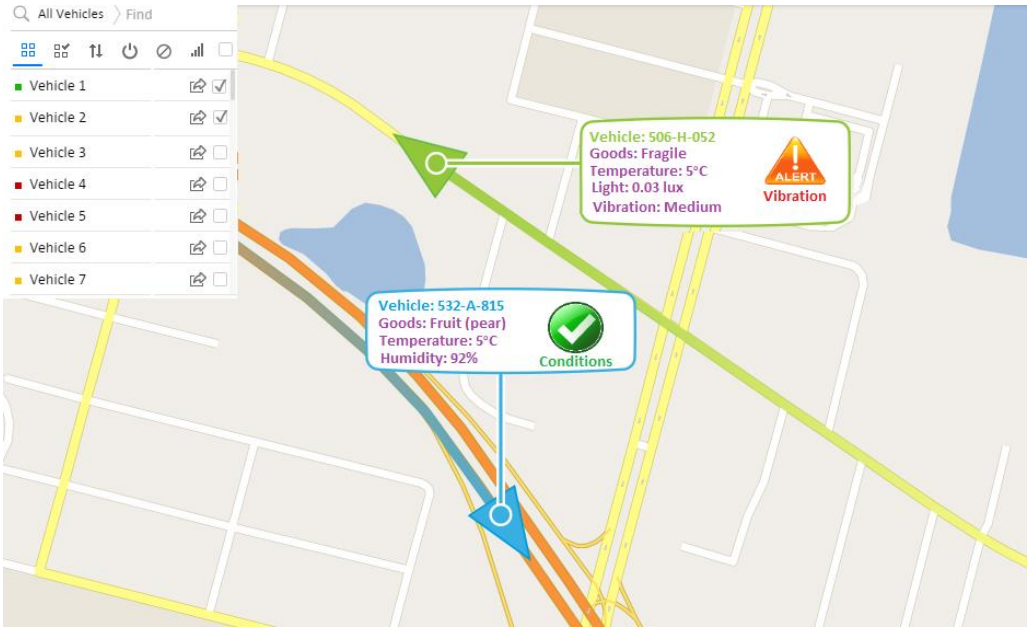


Figure 1 – IoT-based smart monitoring application
Source: Authors

For implementing this transport monitoring application based on IoT, delivery vehicles need to be equipped with environmental sensors to monitor temperature, humidity, light, and vibration in real time. Sensor data are gathered by a microcontroller and transmitted wirelessly to a user's device (e.g. smartphone) or to a cloud-based application that continuously analyses alarms and events. Also, IoT-based smart monitoring application requires position, sensing, transmission, and computation capabilities to enable real-time tracking and monitoring conditions of goods being transported. IoT devices can read geo-location coordinates, collect data such as temperature, humidity, or vibration, then send all the information to some computing systems such as user's devices, cloud servers, etc. This Smart Tracking solution can allow data exportation in different formats, such as CSV format for further analysis in the MS Excel or data may be inserted SQL system, etc. For advanced computing processes and storage of huge amount of historical data, this system needs to be able to integrate with Cloud platforms such as Axeda, ThingWorx, etc.

IoT based systems are usually complex due to a number of various technologies deployed for a specific solution. The main components of the IoT-based Smart monitoring system are the sensors, GPS, Communication technologies, an Internet gateway, a battery and charger, and application interface. This solution must meet requirements of computation and communication as well as autonomous power. For autonomous power, IoT devices can have an internal battery that allows them to run operations such as data collecting, computation and sending data to other infrastructure. Some computation processes may drain the available battery energy. Therefore, this resource needs to be used in an efficient way or IoT device charges its battery directly from the

vehicle battery. Key features and components of the IoT-based Smart Logistic application are summarized in Table 2.

Table 2 – Key features and components of IoT-based Smart Logistic application

Feature	Infrastructure	Description
Sensing data	Sensors	Sensing data from different kind of sensors (e.g. temperature, humidity, luminosity, CO, CO2, vibration, etc.)
Real-time tracking	GPS and Maps	Tracking geo-location coordinates (longitude/latitude) and transmitting information to the corresponding infrastructure.
Connectivity	Communication technologies	Sending data to storage and computing infrastructure such as Cloud computing or other devices (e.g. mobile phones).
Computing	IoT devices, Cloud technologies	Real-time monitoring, instantaneous control and optimization of transport processes.
Visualization and control	Web and Mobile application	A web interface and mobile application that displays condition information and vehicle locations as well as alerts.

Source: Authors

The application interface is used for data visualizations and remote control. It can be implemented as a web interface or mobile application. For example, a driver can receive alerts through Android or iOS application installed on his smartphone while company center and clients can overview the tracked vehicles and goods through the web interface. With the computing systems, WSN, GPS technology and Internet connectivity, the transport conditions (e.g. temperature and position) of each delivery vehicle can be monitored in real time remotely through wearable devices such as a smartphone, laptops, tablets, etc. or through web interfaces. The proposed architecture for IoT-based transport monitoring system is presented in Figure 2.

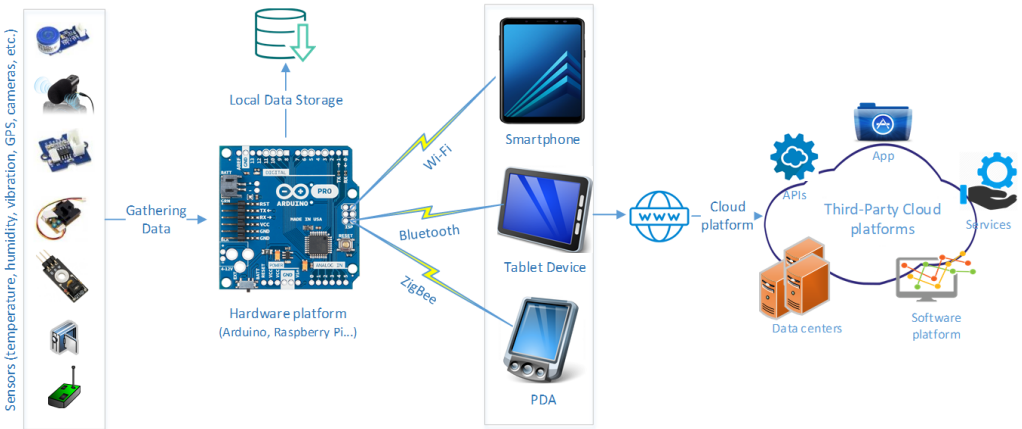


Figure 2 – The proposed architecture for IoT-based smart monitoring system
Source: Authors

To collect data about transport conditions, it is required to deploy various sensors. For example, if vehicles carry humidity and temperature sensitive-items adding various sensors to measure these environmental variables, there can be essential to ensuring that goods are managed during transportation and storage processes. If goods are fragile, registering vibration impacts by vibration sensors (e.g. accelerometer) can assist in identifying responsible authorities. A light sensor can be placed within a vehicle to determine when it has been opened. IoT application can be programmed to check if opening times correspond with scheduled times (estimated times). For this purpose, IoT devices need to incorporate a real-time clock, allowing accurate recording of the date and time of all events that occur. For embedding various sensors (e.g. temperature, luminosity, gas sensors, vibration sensors, etc.) it is required to use some sensor board such as IoT hardware platform (e.g. Arduino, Raspberry Pi, etc.).

Implementation of described smart monitoring application requires positioning technology such as GPS or other [8]. Position information is useful for real-time monitoring of shipping vehicles, vehicle fleet tracking, security purposes, etc. It is challenging issue to integrate information gathered from sensors with GIS (Geographic Information Systems) such as Google GIS, Axeda, ESRI or other. A map built with some API (e.g. the Google Maps JavaScript API) provides real-time visibility of vehicles and transport conditions. The combination of location data generated by GPS, time data, and other sensors gathered data, can register each event's location, date and time, and conditions during the transportation processes. If there is no need for real-time tracking, the time between samples can be set to some values, to provide energy efficiency and reduction of data transfer costs.

Cloud computing can be used for processing data and to distribute some resources, processes, and services to data centers which may be located anywhere in the world. Cloud computing provides computation and storage resources by deploying high-performance servers. This infrastructure provides storage for an enormous amount of data, extensive computing analysis, and other functionalities. However, the integration of IoT and Cloud computing is not efficient for many IoT applications due to inherent problems such as unacceptable network delay, lack of mobility support and location-awareness, etc. Therefore, a new computing paradigm is needed to support emerging IoT applications. There are several paradigms proposed to solve these problems such as mobile edge computing, cloudlet, fog computing, etc. The most of these computing systems can be used in cases where the Internet access is unavailable or high costs of data transmission over the network. The key idea of these paradigms is offloading tasks from a mobile device to local computing infrastructure and if there is a need to send data to traditional cloud servers. These computing systems include local storage and computing capabilities to store data (e.g. coordinates of the route, transport conditions, etc.) which can be used for further analysis.

Wireless communication technologies enable to send alerts and other data such as location and transport conditions to different infrastructure (e.g. smartphones, cloud data centers, etc.). By connecting different components, IoT-based smart monitoring application enables tracking vehicles as well as monitoring transport conditions during the entire transport process. This is one of the major advantages of IoT-based solution over the traditional types of vehicle tracking systems. The most common used in IoT environment are Wi-Fi, ZigBee, 802.15.4, Bluetooth, Bluetooth Smart Low Energy (BLE), GPRS, 3G, 4G, etc. However, it can be used and other communication technologies. Some of these technologies are used for WSN (Wireless Sensor Network) while others are used as RANs (Radio Access Networks) to the Internet.

3. IOT ENABLING TECHNOLOGIES

IoT (Internet of Things) is the inter-networking paradigm based on identifying, sensing, networking and computation processes enabled by technology stack which provide a seamless connectivity between physical and virtual objects to facilitate the development of intelligent services and applications. IoT is not an individual system but it integrates several subsystems and technologies to enable connectivity anytime, anywhere, by anyone and anything. For example, IoT includes sensors, network infrastructure, data analytic tools, etc. upon which various applications and services can be run [9]. Therefore, IoT solutions require a new “technology stack” that enable sensing and collecting data, seamless device connectivity, data analytics, autonomous actions, etc. IoT enabling technologies can be summarized into several categories such as sensing technologies, identification technologies, communication technologies, positioning technologies, etc. For the purpose of this paper, we present IoT enabling technologies which may be used for proposed IoT-based smart monitoring application. We grouped enabling technologies according to functional blocks composed of four main domains as shown in Table 3. These functional blocks are used to facilitate various utilities to the system such as sensing identification, actuation, communication, and management [10].

Table 3 – IoT enabling technologies

DOMAIN	Enabling technologies, samples and use cases		Functionalities
Application Domain	*IoT applications*	Smart home, Smart cities, Smart traffic, Smart healthcare, Industrial IoT, Smart agriculture, Smart farm, Smart meters, Environment monitoring, etc.	*Visualization, Application development environment, System and devices monitoring, control and management, Data and services management...*
	Architectures	Software architectures, SOA, RESTful, etc.	
	Software and APIs	OS (Contiki, FreeRTOS, LiteOS, Android, Riot OS, uClinux, Mbed...), APIs (JML, WebGL, RAML...), Embedded and custom apps built using «thing» data	
Middleware Domain	*Fog and Cloud Platforms*	OpenIoT, Amazon, Google Cloud, Libellium, IBM Watson, FIWARE, Arkessa, OnePlatform, SensorCloud, SmartThings, ThinkWorks, Oracle IoT, Plotly, Nimbits, ThinkSpeak, Xively, etc.	*Data storage, Data aggregation and processing, Big data analysis, Decision support (Expert and DSS systems), Machine Learning...*
	Data processing mechanisms	Data mining, Big Query, Cloud Datalab, Apache Hadoop, Kafka, Storm, RapidMQ, Scribe, SPARQL, SciDB, Semantic technologies (JSON, W3C, OWL, RDF, EXI, WSDL...), etc.	
	Data Storage	Storage infrastructure (public, private, hybrid), DB (MongoDB, Cassandra, Hadoop, HBase, CouchDB, Redis...), Storage architecture, etc.	
Networking Domain	*Communication Protocols*	Application (CoAP, MQTT, AMQP, XMPP, DDS, WebSocket...), Transport (TCP, UDP), Network (IPv4, IPv6), Routing (RPL), Service Discovery (mDNS, DNS-SD, SSDP, SLP...), etc.	*Seamless connectivity (anytime, anywhere by anyone and anything), Data transfer (device-to-device, device-to-application, application-to-device)...*
	Network interface	IEEE 802.11, 802.15.4, IEEE 802.15.1, IEEE 802.16, 3GPP, IEEE 802.15.6, WSN, Z-Wave, IEEE 802.3, RFID, NFC, UWB, IrDA, PLC, CAN, etc.	
	Adoption mechanisms	Adoption layer (6LoWPAN, 6TiSCH, 6Lo, IEEE 1095.1...), Connectivity interfaces (RJ45, ODB2, RS-232, RS-485, PLC, USB, Modus, SPI...), Gateways (Advantech, ADLINK, BRC...)	
Devices Domain	*Hardware platforms*	Arduino, Raspery Pi, Intel Galileo Gen, Intel Edison, Beaglebone Black, Broadcom, Netduino, Intel Edison, Flutter, Marvell, Tessel 2, Particle.io, Smart Things, etc.	*Identification, sensing, actuating, data processing and computation, power supply...*
	Embedded objects	Embedded sensors, Actuators, RFID/NFC tags, Identification (EPC, uCode, QR...), touch screen displays, firmware, onboard software, etc.	
	Mechanical & Electrical parts	Mechanical and electrical parts (e.g. batteries), Processing units (e.g. microcontrollers, microprocessors), Digital Signal Processors, Peripheral Controller Chips, etc.	

Source: Authors

Application domain manages application services that are usually provided through the IoT middleware layer. Therefore, software and APIs can be mapped to the application or middleware domain. There are some common embedded operating systems in use such as TinyOS, Contiki, LiteOS, Android, Riot OS, etc. These systems support low-power Internet communication which is required for energy efficiency. The SDKs (Software Development Kit) for these operating systems provides a software framework for various microcontroller firmware to be run on IoT devices. SDK framework supports application programming by using various programming languages. Another important building block of IoT systems are software platforms which provide an appropriate APIs and development of services independently of hardware. Some APIs enable to use other components such as GIS (Geographic Information Systems) such as different maps APIs. The most of software platforms for IoT are mostly based on Cloud Computing.

IoT middleware consists software and infrastructure which is designed to be the intermediary between IoT devices and application layer. IoT middleware technologies provide functionalities such as aggregating, filtering and processing received data from the IoT devices, information discovery, machine learning, predictive modeling and providing access control to the devices for applications. They enable IoT services development and data processing independently of the hardware platform. The most common solutions with these functionalities rely on Cloud technologies to provide storage for an enormous amount of data, extensive computing analysis, and other functionalities. There are three types of services provided by different cloud computing platforms: Infrastructure as a Service (IaaS), Software as a Service (SaaS), Platform as a Service (PaaS). There are many cloud platforms such as Microsoft Azure, Google Cloud Platform, IBM Bluemix, AWS, ThingWorx, Xively, ThingSpeak, Axeda, which enable a large-scale of deployment and IoT application developments.

The integration of IoT and Cloud computing is not efficient for many IoT applications due to inherent problems such as unacceptable network delay, lack of mobility support, location-awareness, security and privacy issues, etc. Therefore, some new computing paradigms are needed to support emerging IoT applications. These paradigms are known as fog computing, mobile edge computing, mobile cloud computing, cloudlet, etc. Summary of these paradigms is shown in Table 4. They help to overcome some of the issues mentioned before but provide only a basic computation function (e.g. filtering and simple data processing). Recent research shows that if there is a need for real-time computation than these technologies are a better solution than Cloud computing. However, if there

is a need for more advanced processing or to store huge amount of data, than summarized data can be transferred to Cloud infrastructure.

Table 4 - Summary of computing architectures

Computing platform	Features
Cloud computing	Distributes some resources, processes and services to large data centers which may be located anywhere in the world and accessed through WAN (Wide Area Networks). This infrastructure relies on resource sharing.
Fog computing	Heterogeneous nodes including high-end servers, routers, access points, set-top boxes, etc. These systems use multiple wireless access technologies: Wi-Fi, Bluetooth, ZigBee, 3G, LTE
Mobile edge computing	Compute or storage nodes deployed in the edge network and federated to cloud data centers. Small-scale data centers co-located with nodes or servers which are usually located with the RNC (Radio Network Controller) such as 3G / LTE base stations, Wi-Fi routers, etc.
Mobile cloud computing	Offloading tasks from a mobile device to traditional large-scale data centers installed at dedicated locations such as data centers. The most common network access technologies are 3G and LTE.
Cloudlet	Compact-size data centers (smaller clouds) deployed on Wi-Fi access points, femtocells or LTE base stations to provide virtual machine capabilities for IoT devices in real-time.

Source: Authors

Network domain includes hardware, software, technologies, and protocols that enable connectivity between IoT objects. IoT systems use an extreme diversity of communication technologies that often need to be interoperable in order to meet IoT requirements. The most of IoT services rely on wireless technologies to provide availability and mobility. The most common wireless communication technologies used for IoT are presented in Table 5.

Table 5 – The common wireless communication technologies for Internet of Things

Technology	Range (Coverage)	Data rate	Power
NFC	<10 cm	400 kbps	Very low
RFID	<3 m	400 kbps	Very low
Bluetooth	< 30 m	700 kbps	Low
BLE	5-10 m	1 Mbps	Very low
Wi-Fi	4-20 m	11-100 Mbps	Low-High
ZigBee	10-300 m	250 kbps	Very low
Wireless HART	200 m	250 kbps	Very low
6LoWPAN	800 m	250 kbps	Very low
WiMAX	50 km	11-100 Mbps	High
GPRS, EDGE	26 km	171-384 kbps	High
HSDPA/HSUPA	27 km	0.7 – 56 Mbps	High
LTE (4G)	28 km	0.1 – 1 Gbps	High
Cognitive radio	100 km	0.0001 – 10 Mbps	Low-High

Source: Authors

The existing network protocols used in traditional Internet services are not the corresponding option for IoT because of a variety of traffic models. Therefore, new protocols have been proposed according to a specific use case. For example, application layer protocols used in traditional Internet services are not the corresponding option for IoT due to constraints of LLNs (Low Power and Lossy Networks). Because of that, there have been created protocols utilized to connect to things as well as to end-user applications such as CoAP, MQTT, AMQP, XMPP, etc.

IoT devices domain presents endpoint layer that includes physical and virtual entities with various capabilities such as sensing, actuation, identifying, data storage and processing, connectivity, etc. IoT devices include embedded software (operating system, onboard application, etc.) and hardware (electrical and mechanical components with embedded sensors, processors, connectivity antennas, etc.). All devices should be identified by a unique ID and connected with other objects and/or with network domain by using various communication technologies. Sensors are objects that detect and measure some events or changes in its environment such as temperature, air pressure, acceleration,

light, movement, etc. There are many identification methods including EPC (Electronic Product Code), uCode (Ubiquitous codes), QR (Quick Response) or matrix barcodes, etc. Connectivity components enable wireless or wired connections by using different communication technologies which allow an exchange of information between different IoT objects. SN (Sensor Networks) is a collection of sensors which communicates between each other or/and transmits data to some other infrastructure (e.g. Fog or/and Cloud).

IoT constrained devices such as sensors have many challenges due to the requirements for identity management, processing, memory, connectivity, and energy capabilities. Also, sensors have limited processing abilities and because of that they usually do not process data and instead they forward data to another infrastructure (data storage) across the network. To expand computing and connectivity capabilities of sensors have been developed various hardware platforms. IoT hardware platforms extend processor and other possibilities of sensors and microcontrollers as well as facilitate interoperability and management of devices. An example of the IoT hardware platforms are Arduino, Raspberry Pi, Beagle Board, etc. Besides existing solutions, there are many emerging technologies [11-13] which empowers IoT systems. These new solutions can breakthrough future development and provide an even wider spectrum of capabilities and functionalities for usage of IoT in transport and logistics.

4. CONCLUSION

IoT technologies enable a seamless connectivity anytime, anywhere by anyone and anything to provide intelligent services including identifying, sensing, networking, processing and visualization capabilities. IoT-based solutions brought many new possibilities for large-scale services and products development which caused a massive wave of innovations in almost every vertical market including transport and logistics. This paper presented one of the ideas for IoT-based smart monitoring application and provided some ideas for future development. This application requires position, sensing, transmission, and computation capabilities to enable real-time tracking and monitoring conditions of goods being transported. For enabling these functionalities, it is required a set of different technologies such as sensing technologies, hardware, software and cloud platforms, communication technologies, positioning technologies, power, and energy storage, security mechanisms, etc. Considering that IoT solutions require a new “technology stack” we provided an insight into possible technologies which enable development of the presented solution. The main components of this system are the sensors, GPS, RANs, an Internet gateway, a power supply system, and application interface. IoT-based technologies can be used to monitor and control logistics operations such as transport of goods. The presented IoT-based Smart Logistic application is applicable to any transport or logistics company that requires transport conditions and position monitoring in their vehicles. Logistic operators, transport companies, clients, and other stakeholders can achieve greater control over their freight. This application can provide possibilities to companies to improve service offerings and competitiveness of their operations as well as to improve route travel patterns and transport conditions.

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DIGITAL TRANSFORMATION AND INNOVATION IN LOGISTIC - SITUATION AND PRIORITIES OF DEVELOPMENT IN THE AREA OF BOSNIA AND HERZEGOVINA

ABSTRACT

The paper deals with the problems and possibilities of digital transformation and innovations in logistics, with reference to the state and the necessary digital development priorities in the territory of Bosnia and Herzegovina. The aim of the paper is to explore the advantages, essential performance and barriers of digital transformation in logistics that has the potential to create a whole new working environment that undoubtedly increases the speed of processes and procedures in logistics. Digital solutions and innovations can play an important role in the development of environmentally sustainable and digitized logistics as well as greater interoperability and interconnection of IT systems and services. More and more digitization in the area of communications, information services, production and business processes also has a significant impact on the way of organizing and executing freight transport and logistics services. The methodology of work is based on analytical and comparative approach. The results of the analysis of the digital transformation indicator show lagging and slower progress on the territory of Bosnia and Herzegovina.

KEY WORDS

Logistic; Digital Transformatio; Innovation;

1. INTRODUCTION

Digitalization and digital technology could help the logistic industry to reduce its inefficiencies and negative environmental impact. Digital transformation and logistic innovation today are undoubtedly a key factor the success of every logistics company and very important factor. Characteristics that shape digital transformations include related factors of manufacturing elements in networked and synergic value chains, data gathering and analysis factors with the aim of improving the production process, optimizing costs, gaining competitive advantage, and meeting the expectations and wishes of the users of logistic services. Digital transformation has the exponential potential of creating an entirely innovative logistic environment where some jobs will disappear, the new being created, while most will experience a digital change. Digital business transformation is happening in supply chains, because digital business requires digital supply chains. New business models, enabled by digital technologies and focusing on the creation of solutions and value-added services, on top of cost reduction, are driving digital transformations. For the purposes of research, relevant interpretations describe digital transformation as the application of technology to radically improve the performance and the domination of the logistics sector. In addition, it is necessary to emphasize

ultimate goals of digital transformation, that are, processes in the business logistic environment especially when the use of digital technologies begins to enable logistic innovations and creativity and encourage significant changes in the domain of intellectual capital. To understand the phenomenon of digital transformation and innovation in information and communication technologies, it is important to look at dynamic changes in complex market conditions, the application of digital technologies in organizations, and the impact that these technologies have on logistics organizations, as well as the need to define new management approaches that will to provide timely business responses to the challenges of digital transformation in a continuous period of time.

Innovative technologies in the field of communication, information services, production and business processes have a strong impact on the organization and implementation of transport (goods) and logistics services. Today intelligent information and communication infrastructure and telematics services make cargo transport more efficient and safer. Co-operative transport systems and automated and autonomous transport solutions create additional potential for digital innovation in the logistics field, and smart multi-modal cargo and transhipment solutions become more and more important. Most of digital technology is related for location, connection of devices, big data analytics, cognitive computing and obviously the platforms where data are captured, processed and leveraged/accessed such as mobile platforms, information capture and processing platforms but also the networks and data environments such as the cloud.

2. PROCESSES OF DIGITAL TRANSFORMATION OF LOGISTIC SYSTEM

Logistic processes are an integral part of the added value chain. In transportation and logistics, processes are ubiquitous and hyper-connected. According to [16] hyper-connectivity processes inherently comes with a dimension of acceleration and speed and connectivity of processes, people and how it is used. Processes of logistics has one major task, making sure that any of the mentioned and other items arrive at the right time and place in the best possible condition. Logistical processes in the supply chain move at different speeds and changing expectations and evolutions in the digital transformation economy simply make digitalization a necessity across the logistics, transport and manufacturing industries where digital and always-on supply chains are becoming the new norm. Although transportation and logistics management is a really broad area, there are several evolutions which apply to the sector as a whole and de facto lead to digitation and digital transformation as key catalysts and consequences with several digital technologies to make it all possible. We can only speak of digitalization processes when digitalization as sumes a crucial role in the definition of processes that means that information technology assumes a leadership role and is no longer considered a single tool or an agent. Leadership role means that information technology significantly supports or even takes over processes and their related decisions, e.g. routine decisions while leadership role also means that information technology is used in a holistic, strategic, sustainable and consistent way.

Logistic customers want visibility and dashboards to be fast and timely as they know it is key in today's digital transformation economy. With each handling, shipping and any other treatment of goods comes processes, information flows and interactions. Digitalization requires the use of most recent digital technology that has reached a certain degree of maturity which is suitable for large-scale deployment. Efficiency, optimization, speed and timing have always been crucial in logistics and transportation. Logistics must communicate faster, safer, more reliably - be more interactive in order to be the driver of innovation and not its bottleneck. Industry 4.0 sets high standards of reliability and flexibility for the delivery of raw materials, intermediate products, finished parts and other goods. The industry 4.0 offers two sources of profitable opportunities for a logistics company, which has to determine five digital pillars with the aim of increasing revenue and lower costs *(Table 1)*. This pillars are key to capitalizing on the opportunities and the way in which a logistics company wanting to participate in a new industrialization must pass.

Table 1 – Digital pillars

1.	Build the appropriate digital logistic capabilities	4.	Facilitate cooperation in the industrial ecosystem
2.	Manage data as a precious assets	5.	Enable fast and customizable IT development through system and data architecture
3.	Provide cybernetic protection		

Source: [2]

In order to successfully build the appropriate digital capabilities, it is extremely important to combine logistical data, system integration and processes and make decisions based on functional information. Data becomes a valuable asset because data becomes the key to capturing control points along the industry value chain. It is extremely important to share data, because are data and analytics key to speed up processes, offer visibility to partners and customers, digitize value chains and, in a context of digital transformation, come up with new business models. Determining the balance between sharing and protecting data falls within the domain of strategic planning, and particular emphasis should be placed on the adequate implementation of the data architecture and security system. Digital transformation is a fast and adaptable IT system that allows data analysis and expected changes to adapt to the rest of the system very quickly, because the requirements of today's logistic users are extremely dynamic, so a complete system must be designed to respond quickly to changes.

Digitalization helps logistical manage the challenges what makes logistics professionals face new challenges every day. The supply chain is a fragile and complex structure and many things can happen on the way to the final customer. It is only a part of a global business network which consists of closely connected independent business processes. Supply chains have benefit from the positive effects of digitization processes *(Table 2)*.

Table 2 – Positive effects of digitalization processes

1.	Participants are flexibly integrated	4.	Decision processes are improved by providing crucial information
2.	Processes are networked	5.	Data is collected and enriched
3.	Data transmission is automated	6.	The information gained builds up know-how and it creates additional transparency

Source: [2]

Digitalization opens new dimensions in supply chain management for logistical companies and enables transport and supply chain optimisation. Six essential performance advantages are presented in Table 3.

Table 3 – Essential performance digitalization processes

1.	IT integration	4.	Standardization and automation of processesn
2.	Database of the highest quality	5.	Visibility & Collaboration
3.	Transparency	6.	Create new values due to systematic analysis

Source: [2]

Main advantages that digitalization creates for the supply chain in logistic are presented in Table 4.

Table 4 – Advantages of digitalization processes

1.	Reduced complexity	6.	Reduced errors
2.	Increased reliability	7.	Reduced transport cost
3.	Predictability and thus minimized risks	8.	Create new business areas and thus turnover potential and new jobs
4.	Increased innovation capability	9.	Increased agility and flexibility, e.g. in case of new market requirements
5.	Enable collaboration	10	Image of logistical company

Source: [2]

Market trends and processes are driving growth in logistics while technological advances are opening up new ways to meet that increased demand. The processes on logistical market and technology are numerous *(Table 5).*

Table 5 – Main market and technology processes

	Market processes		**Technology processes**
1.	A growing customer base	1.	The third age of the internet
2.	Rise of the digital consumer	2.	Rise of the platforms
3.	Political and economic developments	3.	3D printing
4.	Performance of the logistics industry since financial crisis	4.	Driverless vehicles

Source: [3]

2.1 Areas of Digital Transformation of the Logistic Industry

According to [3] five digital areas that are central to the digital transformation of the logistics industry are: information services, logistics services, delivery capabilities, circular economy and shared logistics.

First area is Information Services: the transportation and logistics industry is information-intensive and always has been data-driven. However, the big data and data-driven traditions are not a guarantee for a successful leverage of the new data realities. Data-driven logistics operator can optimize logistical operations, reduce emissions and cut costs. This point focuses on the flow of logistic data through the logistics value chain. Logistical data today is an untapped yet immensely valuable resource. Analysed properly, data can coalesce into a source of insights for further action. Logistical companies should understand data sources not as cost centres, but as future profit centres. Main digital areas of Information Services are presented in Table 6.

Table 6 – Digital areas of Information Services

Logistics control towers	**Analytics as a service**
- IoT (Internet of Things) enables continuous automated monitoring of shipments, infrastructure, transportation assets, workers and customer requirements. - The control tower has three levels: process execution, analytics, and visibility and data integration. Control towers can deliver unmatched levels of transparency throughout the value chain, helping to optimize logistics operations, reduce emissions and increase levels of customer satisfaction.	- Demand forecasting, maintenance analytics, inventory optimization, predictive asset management and network flow analysis. - Complex analytics will help logistics companies reduce operating costs, while having a major environmental impact. - Network optimization can reduce the number of trucks on the road and increase last mile delivery speeds - especially in cities - and thus lower emissions and waste production.

Source: [3]

Second area is Logistics Services: new logistics concepts can boost global trade and give smaller businesses the chance to compete. Three logistics services look set to have a lasting operational impact and demand as providers overhaul their infrastructure to stay competitive. Main digital areas of Logistics Services are presented in Table 7.

Table 7 – Digital areas of Logistics Services

Digitally enhanced cross-border platforms	City logistics	Same-day delivery
- SMEs (Small and medium enterprises) can use these to break down the end-to-end process into different steps and, together, offer a service to compete with the big players. - Digitally advanced logistics firms can cater better to emerging markets, where rising demand for their services could create new jobs.	- ITCS (Intelligent traffic control systems), noise insulation, air pollution monitoring and underground routes all improve the well-being of inhabitants. - CO_2 emissions are expected to decrease as freight consolidation efforts reduce vehicle miles driven in cities. - Better coordinated urban operations will reduce vehicle numbers, benefitting all city users.	- The fastest and most flexible solution for urgent and time-critical shipments. - Customers of an omni-channel retailer, such as a bricks-and mortar grocery store with an online home delivery service, tend to want their goods as soon as possible – especially if they are perishables. - Same-day deliveries could have a negative environmental impact due to increases in air freight instead of road freight.

Source: [3]

Third area is Delivery capabilities: different drones, driverless vehicles and 3D printing could revolutionize delivery methods. Crowdsourcing, innovations in manufacturing (3D printing) and technology (drones, autonomous trucks) have widened the range of options for deliveries and opened up logistics markets to new players. Main digital areas of Delivery capabilities are presented in Table 8.

Table 8 – Digital areas of Delivery capabilities

Drones	Autonomous trucks	3D printing	Crowdsourcing
- Able to deliver perishables on demand, drones could raise purchasing volumes for home deliverers, and thus revenues for logistics operators. - Shorter delivery times and increased purchasing flexibility would appeal to consumers, while the ditching of bigger vehicles would shrink operators' carbon footprint.	- Self-driving delivery vehicles can reduce accidents and emissions, while significantly boosting business bottom lines. - Moving in convoys, autonomous trucks avoid unnecessary overtaking and reduce fuel consumption by slipstreaming and optimizing speed changes.	- The ability to print objects on location might reduce demand for shipments, but there is an opportunity for logistics providers to refashion themselves as printers, shippers and installers of 3Dprinted objects.	- The fastest and most flexible solution for urgent and time-critical. - This can reduce environmental footprints by helping industry players make more efficient use of available capacity and thus reduce total driven miles. - By offering better rates, convenience and real-time tracking, crowdsourcing platforms could allow newer entities from outside the industry to grab a share of the market from existing players.

Source: [3]

Fourth area is Circular economy: there is great potential for logistics firms to develop plays in return services, enabling items to be reused or recycled. This idea underpinning the circular – or restorative – economy is that maximum value is extracted from resources while they are in use, then, at the end of a resource's service life, its constituent products and materials are recovered and regenerated. The practice could reap practical benefits in the logistics sector. Although the requirement for businesses to minimize the use of new materials reduces the number of potential new logistics commissions, it increases demand for complex return processes.

Fifth area is Shared logistics capabilities: these initiatives can reduce operating costs by boosting utilization rates of warehouses and vehicles. The sharing economy will benefit logistics as it allows all participants to share fixed costs, enabling companies to make several smaller investments rather than a single large investment. The main applications of shared logistics capabilities will be in sharing cost-intensive physical assets, notably warehouses and freight-transporting vehicles. Main digital areas of Delivery capabilities are presented in Table 9.

Table 9 – Digital areas of Shared logistics capabilities

Shared transport capacity	Shared warehouse capacity
- Strategy for reducing emissions and mitigating the transport sector's impact on climate change. Firms can split vehicle capacity simultaneously (for instance, by ride-sharing) or over time (for example, by truck-sharing). - Both ride-sharing and truck-sharing allow the cost of the journey to be divided. A part from improving last-mile delivery services - as shipments can be brought forward with shorter waiting times to fill up a vehicle shared by several companies - shared transport could also bring environmental benefits.	- Allows firms to benefit from cost synergies and greater flexibility. - Warehousing and IT costs can be shared across the customer base at a particular warehouse. This mitigates the risk of having a large fixed cost base, making cost per unit easier to control. - Sharing warehouse space could allow companies to carry out order and distribution consolidation in several locations, rather than just one, providing a better cost-to-serve ratio and reducing road miles due to improved drop densities.

Source: [3]

2.2 Identification of Success Factors in a Digital Logistics Industry

A series of short-term and long-term recommendations to help enterprises thrive in a digital logistics industry. We have drawn up a number of concrete investments in digital capabilities that will form the building blocks of a successful digital logistics business. We have divided these between shorter-term 'no-regret' capabilities, which a logistics firm needs to remain competitive, and bold plays, which are longer-term investments that may revolutionize a company's strategy. Success factors in a digital logistics industry are presented in Table 10.

Table 10 – Success factors in a digital logistics industry

No-regret capabilities		Bold plays	
Collect operational performance data along the entire value chain	Data needs to be consistent and holistic. Master data management is crucial as all data must be linked to the right source.	*Focus on new delivery concepts*	Autonomous trucks, drones and 3D printing have the potential to reduce operating costs - watch their development closely to spot the right time to invest and stay competitive.
Build or buy analytical capabilities to derive information from big data sources	This helps identify correlations between several data points, enabling operational efficiency gains to be pinpointed across the value chain. Identifying, recruiting and retaining analytics talent becomes an important part of HR strategy.	*Have a strategy in place for emerging logistics concepts*	As consumer demand changes, enterprises may need strategies for areas such as city logistics and same-day delivery.
Embrace shared transport	Shared transport platforms will allow logistics companies to improve margins by increasing utilization rates		

Source: [3]

3. LOGISTIC INNOVATIONS IN DIGITAL ENVIRONMENT

Digital transformation process of logistic system has the chance to be the driver of innovation. Innovative technologies are changing the global business relations. Digitalizationi in logistic include innovative uses of technologies in areas such as data analytics, the IoT and the cloud. It has become essential for the logistical service providers to use technological innovations to utilize maximum space, manpower, warehouses, vehicles etc. with control on wastage & fuel charges *(Figure 1)*. The innovative technology has allowed logistic companies to implement service strategies which could help us to get a faster service opportunity. Now the delivery boy will schedule deliveries keeping the total no of orders, vehicle capacity, availability and the delivery time slots given to the customers. Innovative digital solutions solve complex business problems. Innovations in logistics were more common among manufacturing enterprises than among service-producing enterprises. The existing studies offer a number of definitions concerning innovation.

According to [4], Innovation is an idea, practice, or object that is perceived as new by an individual or other unit of adoption. That is to say an innovation does not have to be new to the world. An innovation can be merely new in the eyes of the beholders. Therefore, a distinction can be made between inventions and innovations. According to [5], logistics innovation is defined as follows: By logistics innovation, we mean any logistics related service from the basic to the complex that is seen as new and helpful to a particular focal audience. This audience could be internal where innovations improve operational efficiency or external where innovations better serve customers. According to [5], logistics innovation includes new logistics related services and a new use of existing logistics related services. The robustness of the idea as new to a particular focal audience needs to be considered. Putting existing logistics related services to a new use raises the issue of imitation. According to [5], innovation is a subjective novelty which is the result of a conscious management process and which aims at economic exploitation. This definition also touches upon the idea of subjective novelty and imitation. However, the authors specifically claim that logistics service providers can and must regard imitation as innovation. The consequence to treat imitation as innovation is that an innovation in the logistics context might not be considered as an innovation in another context.

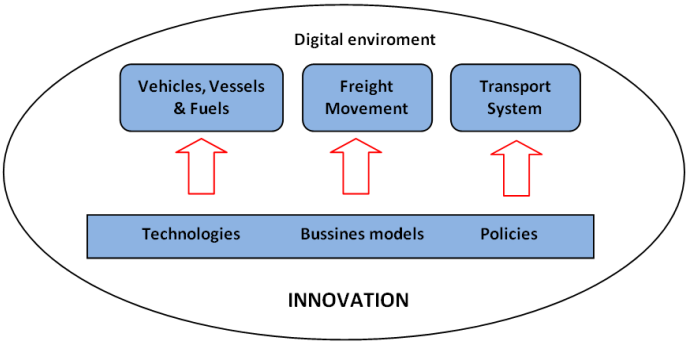


Figure 1 – Areas for innovation in logistic
Source: [1]

3.1 Influencing Factors on Logistics Innovation

Several researchers have shed light on the factors influencing logistics innovation. The existing studies can be categorized into two groups. One group of studies analyzes the driving forces, or drivers, for logistics innovation. Another group of studies depict the barriers to logistics innovation. Literature review findings are summarized in *Table 11.* and *Table 12.* claims that increasing competition as well as shortages of available capital are driving forces for logistics firms to innovate. In a conceptual paper, according to [7] propose that knowledge and technology play an important role in fostering logistics innovation. They also suggest that relationship networks can lead to logistics service innovation. Other autors out say that organizational learning mediates the relationship between relationship orientation and logistics innovation.

Table 11 – Literature review of driving forces for logistics innovation

Driving forces					
1.	Knowledge	10.	Relationship Orientation	19.	Competition
2.	Relationship Networks	11.	Customer Satisfaction	20.	Structural capital
3.	Financial reasons	12.	Training and Education	21.	Extent of supply chain learning management
4.	Technology	13.	Decentralization	22.	Supply Chain knowledge development
5.	Have a leading edge in Industry	14.	Extent of innovation management	23.	Operational Performance
6.	Employee Orientation	15.	Customer Orientation	24.	Formalization
7.	Shareholder Orientation	16.	Competitor Orientation	25.	Organizational Learning
8.	Combining of resources across supply chains	17.	Intended continuous Improvement	26.	Acquisition of knowledge
9.	Customer Orientation	18.	Relational capital		

Source: [11]

According to [8], compare factors driving innovation in distribution centres found that financial reasons, customer orientation, employee orientation to have a leading edge in industry, operational performance, competition and shareholder orientation as driving forces while they have classified these factors as external/internal and push/pull. Further, find that customer satisfaction and intended continuous improvement are the most important driving forces.

According to [5], direct antecedents to logistics innovation include the extent of supply chain learning management and the extent of innovation management and identifies acquisition of knowledge and training and education as key activities to spur logistics innovation. Similarly, propose that structural capital, relational capital and supply chain knowledge development are positively linked to logistics innovation. According to [8] show that customer orientation and competitor orientation positively affect service innovation capability. Last but not the least, find out that decentralization and formalization are structural antecedents of a firm's logistics service innovation capability.

Despite of the driving forces to innovate, multiple factors might impede management of innovation by logistics companies. However, as Table 12. shows, there are significantly fewer studies dealing with barriers compared to the number of articles analyzing the driving forces presented in Table 11. The reason for this gap is not self-evident. However, it does argue for more studies to investigate the barriers for logistics innovation.

Table 12 – Literature review of barriers for logistics innovation

Barriers			
1.	Regulation	8.	Lack of effective development processes
2.	Lack of clear definition	9.	Labor influence
3.	Lack of long-term relationships due to information sharing	10.	Lack of channel member innovation
4.	Technology as a major source of innovation	11.	Lack of openness
5.	Improper cooperation	12.	Reactive versus proactive innovations
6.	Inability to protect innovations with patents	13.	Ineffective transfer of knowledge
7.	Information abusing and resource-consuming	14.	Peculiar customers

Source: [12]

According to [10], claims that regulation, labor influence, and lack of channel member innovation are barriers to innovation in the railroad industry. According to [11], have identified several barriers including lack of clear definition of innovation, reactive versus proactive innovations, peculiar customers, ineffective transfer of knowledge, inability to protect innovations with patents, technology as a major source of innovation, lack of effective development processes and difficulty in concept testing. In addition, reveals four potential pitfalls including lack of long-term relationships, information sharing, improper cooperation and lack of cooperation openness.

3.2 Logistics Innovation Process

Model of logistics innovation process is provided on Figure 2. The model starts with setting the stage activities. These activities are devoted to encourage employees to understand customers requirements [5]. Setting the stage activities include educating employees to ask relevant questions, meeting the customers in an appropriate place and putting resources in place. Second, customer clue gathering activities concentrate on being closer to customers and developing in-depth insights about them [5]. These activities are aimed at collecting information about customers through interviews, meetings and company visits.

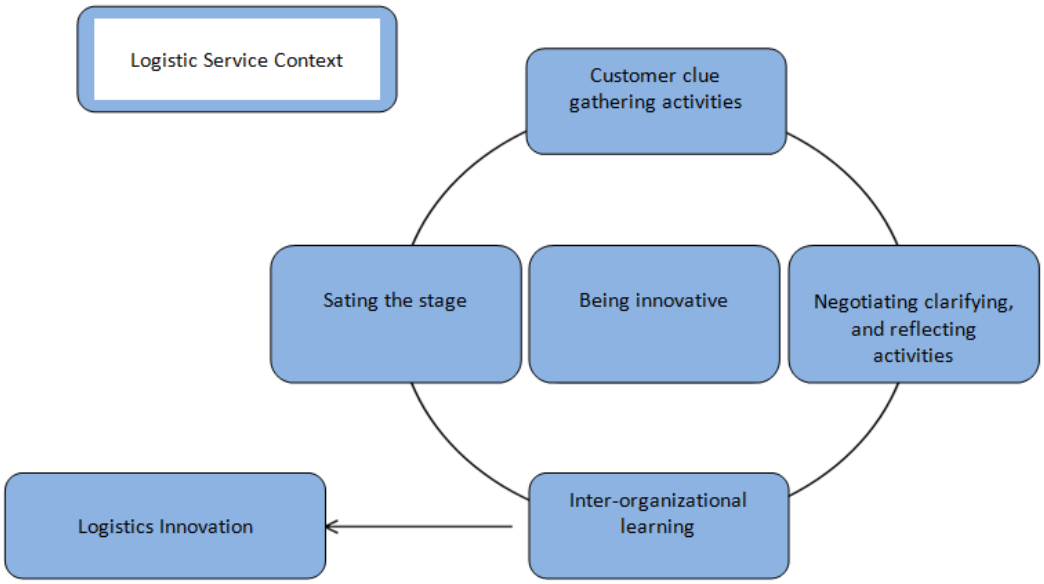


Figure 2 – Logistics innovation process
Source: [5]

Third, negotiating, clarifying and reflecting activities are conducted to reflect on the voice of the customer and to clearly comprehend customer's exact wishes [5]. Managers can then discuss internally and work together to identify an appropriate way to use the information. Last, inter-organizational learning refers to the new knowledge and insights that appear for managers from the logistics service provider and customer organizations [5]. The four sets of activities occur in a repeated loop and logistics innovations are generated as outcomes of this process.

According to [5], model offers a dynamic picture of the innovation process. However, the model is based on the voice of customer. The voice of supplier is neglected. Besides, the model does not say a lot concerning the internal focal organization and the importance of support from this side. In addition, the model describes the process in a general sense while it does not consider the differences of the focal organization's size and characteristics. Further, the model does not say much the daily activities conducted by the logistics managers. Since logistics is practice-oriented and logistics managers are tied up with daily operations, it is necessary to take a closer look at logistics manager's daily activities.

4 SITUATION AND PRIORITIES OF DEVELOPMENT OF DIGITAL LOGISTICAL ENVIRONMENT IN BOSNIA AND HERZEGOVINA

4.1 Situation of Digital Logistical Environment in Bosnia and Herzegovina

Although the information and communication sector has evolved over the past 20 years without system support and strategic guidance driven primarily by an entrepreneurial initiative, its structure, significance and size multiply over the Bosnia and Herzegovina (BiH) market. Up to the present time, there was no significant system support, and there was no significant progress in the implementation of strategic sector development plans at BiH level (Digital Infrastructure, Investments and access to finance, Supply and demand of digital skills, Integration of Digital Technology and e-Leadership). Regardless of such ratings, the information and communications sector in BiH is developing with different but continuous dynamics. Over the last four years, this development has been intensified in the context of steady growth in the number of employees, use of the Internet and the mobile tehnology *(Table 13).*

Table 13 – Key digital statistical indicator of Bosnia and Herzegovina - Januar 2018.

Parametar	Total population	Internet users	Active social media users	Mobile subscriptions	Active mobile social users
Number (million)	3.51	2.63	1.70	3.50	1.50
Penetration (%)	40% (urbanization)	75%	48%	100%	43%

Source: [15]

Apart from the degree of Internet usage, BiH has ranked lower in all other aspects than other countries in the region. The greatest backlog in ranking compared to the countries in the region of BiH is in the quality of education and support of the competent institutions. Despite this, the business performance analysis in 2018 shows a continuous trend of growth in total revenue generated by most ICT companies.

An additional complicating factor in the application of the innovation approach, with the anticipated potential of the company, the potential and ability of the company to root innovative innovations, the risk of endangering its own "traditional" products and services is also the regulatory framework for the introduction of digital products and services. The trend of a significant drop in technology prices, in a couple of years after their occurrence, greatly contributes to their popularization. Today, the Internet of Things technology in BiH is used for remote measurement of energy consumption and flow. Industries that are more engaged in digital transformation in BiH are banking and financial industry, telecommunications industry, media, retail and distribution and tourism. Recently, there have been changes in production, especially in the domain of IoT's production and predictive maintenance. Unfortunately, there are a great many examples of extremely low intuition for digital user interfaces, although there is a long-standing practice. Bosnia and Herzegovina at the bottom of the countries list of digital public services. Both the private and public sectors in BiH have been more intensively involved in digital transformation over the last couple of years, the pace is slow, there are positive examples, but there is still plenty of space and need for more ambitious changes, greater risk changes and more significant results.

Bosnia and Herzegovina is not lagging behind in the offer of innovation of digital services, but for the competitiveness of the logistics sector, it becomes crucial is to accelerate the digital transformation of both the corporate and the public sector. We neede us mobilization within the logistics industry, government and providers in education for action to address the lack of digital skills. As in most European countries, there is a lack of skills and knowledge. It is also necessary to provide concrete support to logistic companies in attracting and retaining digital talents. In order to strengthen the overall digital environment and the effectiveness of the economic system, it is crucial to harmonize and improve the existing logistics systems, using the modern concept of business logistics. In the context of the analysis of the situation of digital transformation of logistics in BiH, the problems identified in Table 14. are observed.

Table 14 – Key logistics problems at the system level

1.	at a relatively low level of the information technology development in the logistics	7.	an insufficiently developed and effective human resources management system
2.	insufficient investment in logistics properties due to various tax levies, land prices	8.	an insufficiently developed system for training the new logistics profile for the needs of modern logistic systems
3.	insufficiently developed infrastructure necessary for the establishment of logistics systems in full exploitation function	9.	inadequate knowledge and skills about all logistic systems and spatial-temporal dimensions of logistics systems
4.	insufficiently developed modern logistic systems in terms of organization and management system	10.	insufficiently developed customs control system in order to facilitate commodity flows, accelerate the time and volume of the trade of goods, with at the same time ensure the collection of fees
5.	insufficiently developed transport system that supports efficient customs control	11.	insufficient knowledge of important laws and activities on interconnections of distribution channels, physical distribution and logistic distribution
6.	undefined regulatory legislation and positioning of logistics centers	12.	low level of development of intellectual capital, logistics production and logistics networks

Source: [17]

4.2 Priorities of Development of Digital Logistical Environment in Bosnia and Herzegovina

Two fundamental and priority strategies in digital transformation are optimization - digitization of existing business (evolutionary innovation) and innovation - innovation at the business model level, creation of new products and services based on digital technology and so on (disruptive innovation). The recommendations for transformation on area of BiH draws upon three key digital actions: develop new business models and offerings, digitalize core operations, and build a robust internal digital foundation. The success model for logistics organizations requires a number of inputs. Some of these are presented in Table 15. and Table 16.

Table 15 – Develop new business models and offerings

New Digital Platforms	Advanced Analytics	Control Tower
Building robust innovation platforms will help remove supply chain inefficiencies, solve problems associated with asset underutilization, improve demand-supply matching, and increase visibility and connectivity across systems.	Putting powerful data-driven solutions to work can create new analytics tools that, in turn, can be sold to clients to help them optimize their own operations and efficiencies.	Providing solutions that boost operational visibility and connectivity between previously siloed systems allows stakeholders to more seamlessly connect to one another throughout the supply chain.

Source: [14]

Table 16 – Digitalize core operations

Advanced Analytics	Logistics organizations in BiH can use advanced analytics to optimize operations in pricing, routing, and partial load shipment consolidation.
Customer Experience	Putting in place a digital front end not only provides customers with a convenient one-stop shop experience, it also improves internal operational visibility and automates previously manual processes.
Process Automation	Increasing the automation of core internal business processes can help ease labor-intensive logistics operations (digitizing procurement with e-auctions).
Equipment Data	Use digitally tehnology for monitoring equipment health facilitates more effective predictive maintenance.
Next-Generation Solutions	Eyeing future operational improvements via robotics, artificial intelligence, and even augmented reality can help further elevate a logistical organization's operational efficiencies in distribution, warehousing, and picking and packing.

Source: [14]

Critical factors and challenges and digital logistics innovative solutions are presented in Table 17.

Table 17 – Overview of critical factors and innovative solutions

Critical Factors and challenges	Digital logistics innovative solutions
Continued Urbanization	Collaborative Supply Chain Logistics
Increased customer demand	Adaptive Logistics
Continued fragmentation across transport modes	Green & Sustainable Logistics
Limited energy resources	Intelligent Logistics
Environmental prioritization	Interoperable & Roaming Logistics
Europe's competitive and innovative edge	Transparent Logistics

Source: [13]

5. CONCLUSION

Logistic digital capabilities and information are key to close existing gaps and transform for better customer engagement, new business models and challenges facing the logistics industry. Digitization is still a major challenge in transport and logistics, but there is an area for optimizing processes and capturing information close to the source or point of action to speed up processes and enhance transparency while increasing agility. In logistics, many processes are already digitized or even automated in developed countries, but in Bosnia and Herzegovina that is not the case. If there are already systems, standards or processes in place that work, attempts should not be made to replace

them. It is need take concrete actions towards practical implementation of digital initiatives and innovations in logistics. Improving connectivity across the supply chain, the possibility to better predict, regulatory challenges, newer technologies such as drones and 3D printing, changes in logistics patterns and scenarios, challenges in resources, people, management, but also energy, integration of value chains and other are the reasons for the need for accelerated digital logistics transformation and on the area of Bosnia and Herzegovina.

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SUPPLY CHAIN IN THE CONTEXT OF CIRCULAR ECONOMY

ABSTRACT

Traditional approach to the supply chain is a reflection of the linear economy concept. One way movement is characteristic for both phenomena. The result of this approach is irrational use of resources and inappropriate management of waste, with all negative consequences, both for the economy and for the environment. The modern approach to the supply chain corresponds to the circular economy concept. The transformation of the traditional to the modern approach to the supply chain, as well as the transformation of the linear to the circular economy is characterized by feedback. Both phenomena involve considering the entire life cycle of a product. By applying general and special scientific cognition methods, the author researches the phenomenon of transformation of the traditional approach to the supply chain into the modern one, and the transformation of the linear economy concept to the circular economy and makes conclusions about presence of compatibility and conditionality of these phenomena.

KEY WORDS

supply chain; logistics; life cycle; circular economy;

1. INTRODUCTION

Supply Chain (SC) is a phenomenon with a complex definition. When defining the SC, the traditional approach puts emphasis on the flow of goods. However, besides being a flow of goods, the SC is also a flow of services and information. It is a phenomenon characterized by dynamics (flow) and information. While the traditional logistics is primarily based on activities of storage and transport, the SC also involves a flow of information among all participants in the SC. Therefore, when talking about the SC, one should talk about the flow of goods and information among participants in the SC, such as raw material suppliers, transport organizations, product manufacturers or service providers, product distributors, retail chains making it possible for a product to come to its end user and to be consumed. The SC is also present in the area of ensuring post sale services to the end users.

The Act on the prohibition of unfair trading practices in the business-to-business food supply chain (Official Gazette 117/17) states that the SC „ … encompasses all participants in production, processing and trade..., as follows: producers, ..., wholesalers and retailers." Further on, „ ... the SC can be defined as a type of a dynamic system in which information, money and products are constantly exchanged among the chain participants."[1]

„The supply chain can be considered a network of structures, distribution, transformation of procured materials into semi-products or final products for buyers."[2]

The SC can also be described as "... a series of activities and organizations through which materials pass during their journey from initial suppliers to end buyers."[3]

There are many more definitions of the SC, however it may be concluded that the SC is a flow of goods, services and information from suppliers, through transport, producers, distributors, and retailers to the end buyer. It can also be concluded that the SC is a complex system of integration of suppliers, producers, distributors and traders for the purpose of production and distribution of goods/services in the right quantities, in the right place and at the right time, all with the aim to balance supply and demand.

The SC is integral part of the economy and therefore its characteristics and its effects should be considered and investigated in the context of a country's economy. Interactions of the SC and the economy of a country are intensive and run continuously. Due to such relations and connections, the transition of understanding the SC from the traditional to the modern one should also be investigated, as well as the transition of the linear (LE) (traditional) to the circular (modern) economy (CE).

2. TRADITIONAL APPROACH

The planet Earth has all necessary resources which ensure quality of life of people in the modern times. However, a great deal of these resources is limited and should therefore be optimally managed. There is a series of factors representing the limit of growth, and three stand out: 1) Earth as a source of food and non-renewable material resources; 2) ability of the environment to accept waste and various emissions as negative environmental aspects of production processes and 3) the urban way of life characterized by consumerism.[4] Neglecting these limitations in the long run endangers the survival of people on Earth. In the short run it causes a series of problems of economic, ecological, sociological, political and ethical nature.

This means that unlimited growth is not possible and that it is necessary to speed up the transition from the traditional approach to the modern one, in numerous phenomena, primarily in economy through transition of its factors such as the SC, and others too.

Despite domination of the neoliberal concept prevailing in the world economy and „ ... the neoliberal economic doctrine appearing in the economic theory in the last thirty years of the 20th century, as an answer and a possible practical solution for the that time world economic stagnation occurring after over two decades of economic growth within the framework of the Keynesian and Neo-Keynesian state capitalism and in the theory of the dominating neoclassical synthesis, ..."[5] it can be noticed in the last years that awareness and understanding of the need to replace the liberal economy concept, respectively traditional approach of the SC.

2.1 Traditional approach to the Supply Chain

Traditional approach to the SC begins with procurement of raw materials needed for production of products or ensuring prerequisites for provision of services. Finished products are stored until the time of distribution, and then distributed, most often through a widespread retail network, to a big number of customers. Customers are usually end users or consumers of these products. Products are in most cases placed in packaging made of various materials: cardboard or paper, glass, plastics, metal and the like. This packaging has traditionally been transformed to waste and disposed of after consumption, most often in the environment.

It is obviously one-way movement (Fig. 1) of materials and goods, from raw materials required for production, through production of final products, storage, distribution, delivery to customers and consumption and disposal of waste in the environment.

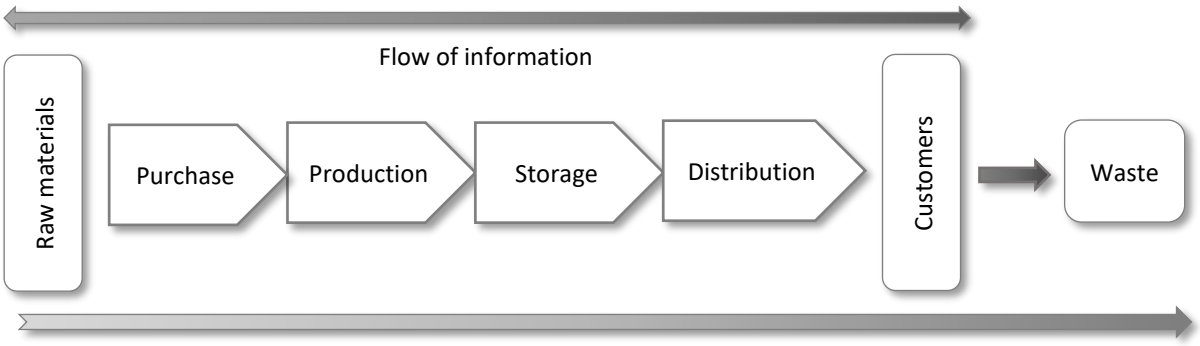


Figure 1 – Traditional approach to the Supply Chain
Source: Authors.

This concept has a serious shortcoming, and it is the fact that a product is not considered in its life cycle (Life Cycle – LC), from provision of raw materials for production from the nature, through production of a product, its use and treatment, and its final disposal in a safe way after the end of use, all in compliance with applicable regulations.

2.2 Linear Economy Concept

The LE concept (Fig. 2) also presents a linear one way movement, from exploitation of raw materials needed for production, through production, distribution to end users / consumers and consumption, and disposal of the remaining waste into the environment. At this, waste is generated in all phases of the LE: in the mining phase, i.e. the phase of providing raw materials by taking them from the nature, through the production process which also generates significant quantities of waste, then distribution and consumption. Waste generated in all LE phases is disposed of in the environment, with all consequences caused by such behaviour in the short and in the long run.

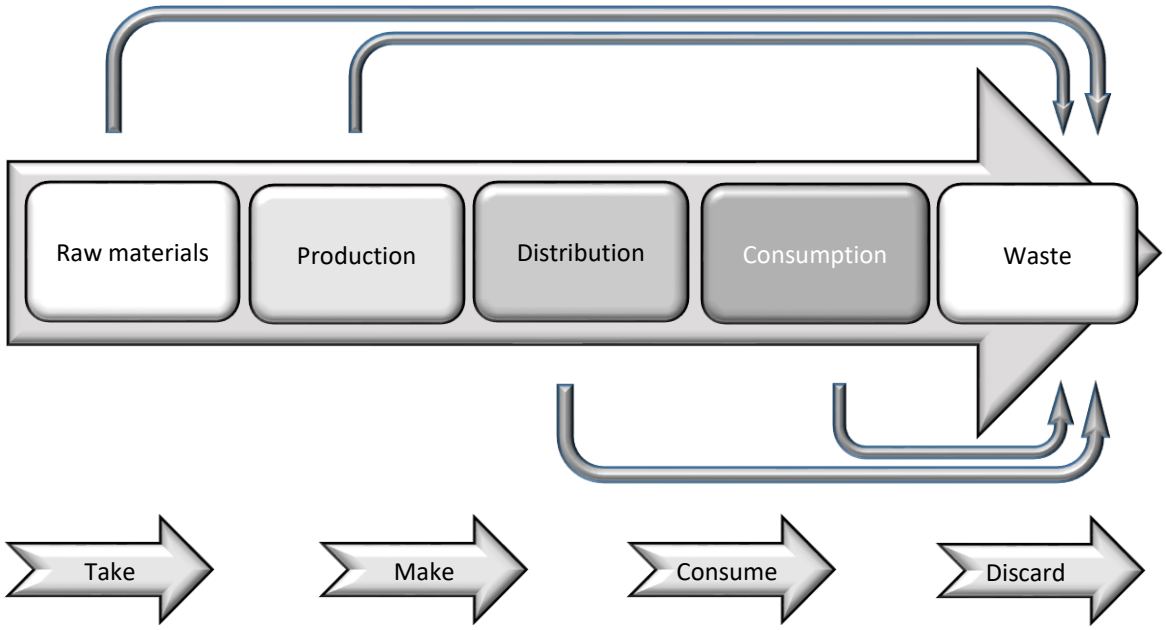


Figure 2 – Model of Linear Economy phases
Source: [6]

As shown (Formula 1), the total quantity of the SC waste in the LE concept (TwgL) equals the sum of waste quantities in all SC phases.[6]

$$TwqL = RMwq + Pwq + Dwq + Cwq \quad (1)$$

where the symbols have the following meaning:

TwqL – Total waste quantity – Linear economy concept

RMwq – Raw Materials waste quantity

Pwq – Production waste quantity

Dwq – Distribution waste quantity

Cwq – Consumption waste quantity.

This one way movement runs under the principle: 1) take; 2) make or produce; 3) consume and 4) discard. Can be said that such approach is traditional. In recent times numerous countries, regions and cities face consequences of such approach, both in the world and in Croatia. Due to absence of a waste management system mandates of many mayors are at risk (Napoli, Zagreb, Split, etc.), as are even mandates of ministers in some countries. Besides, significant financial means need to be ensured for solving waste management problem.

„Currently, world cities generate about 1.3 billion tonnes of solid waste per year. This volume is expected to increase to 2.2 billion tonnes by 2025. Waste generation rates will more than double over the next twenty years in lower income countries. Globally, solid waste management costs will increase from today's annual $205.4 billion to about $375.5 billion in 2025. Cost increases will be most severe in low income countries (more than 5-fold increases) and lower-middle income countries (more than 4-fold increases)."[7]

"As might be expected, the overall amount of waste generated is related to some extent to the population and economic size of a country. The smallest EU Member States generally reported the lowest levels of waste generation and the larger ones the highest. Nevertheless, relatively high quantities of waste were generated in Bulgaria and Romania and a relatively low quantity in Italy."[6]

Table 1 – Waste generation by economic activities and households, 2014 (thousand tons)

Total	Construction and demolition	Mining and quarrying	Manufacturing	Households	Energy	Other economic activities
2.319.500	804.866	654.099	236.589	192.518	85.823	345.605
100,00%	34,70%	28,20%	10,20%	8,30%	3,70%	14,90%

Source: [6]

The share of different economic activities and of households in total waste generation in 2014 is presented in Table 1. In the EU-28, construction contributed 34.70% (804.866 t) of the total in 2014 and was followed by mining and quarrying 28.20% (654.09 t), manufacturing 10.20% (236.589 t), households 8.30% (192.518 t); energy 3.70% (85.823 t) the remaining 14.90% (345.605 t) was waste generated from other economic activities.[8]

In 2010 the share of hazardous waste (97.490 t) in the total waste quantity (2.362.840 t) was 4.12%. Compared to 2010, in 2012 the EU-28 generated 2.20% more non-hazardous waste and 3.30% more hazardous waste, meaning that the quantity of the latter increased from 97.5 to 100.7 million tons. The share of hazardous waste in 2012 in the overall quantity of generated waste in the EU-28 was 4.19% on average and was below 10.00% in all member states except Estonia, where it amounted to 41.60% of the overall waste, and Ireland, where the share was 10.30%. The very high share of hazardous waste in Estonia was generated primarily by production of energy from oil shale. Among non-member countries, the biggest share of hazardous waste in the overall quantity of generated waste was recorded in Serbia (26.30%) due to intensive activities of mining industry and quarrying, followed by Bosnia and Herzegovina (21.20%) and Norway (12.70%).[8]

3. MODERN APPROACH

Considering limits in accessibility and availability of natural resources, the level of pollution of Earth and climate changes, sensibility of the widest layers of population in relation to the environment, rights guaranteed by constitutions of many countries, such as the right to clean air, drinking water, health protection, healthy environment and the like, conflicts, costs incurred due to nonexistence of a waste management system, etc., it can be stated that the traditional approach to economy is not sustainable. The SC as a significant structural element of every national economy should equally undergo a transition from the traditional to the modern approach.

„Transition in a broader sense of the word means processes through which states and nations try to achieve economic growth and development and reach in the sphere of social welfare the developed countries of the world, as a rule, North America and Western Europe. Although the term is usually linked to the developing countries, which try to accomplish the above mentioned goal, there is no reason why transition as a phenomenon would relate exclusively to the underdeveloped world. Namely, rich countries also try to continually achieve, to the greatest possible extent, optimal conditions for social development and new, higher economic growth, thereby also better quality and higher standard of life of its citizens. This is or it should be the fundamental goal of every transition process, and it was presented and promised as such to the countries, which started the transition process at the end of the last century, as a rule in a uniform pattern. Now, after some time has passed, it is clear that something and due to something, went fundamentally wrong in the relevant process. It is important to point out that some countries refused transition according to strict neoliberal rules, and it led to interesting results, at the same time offering an alternative as the basis for analysing and questioning the neoliberal economic concept.“[5]

3.1 Modern Approach to the Supply Chain

The modern approach to the SC is not one-way phenomenon. It does not end with disposing of waste in the environment after each SC cycle. What distinguishes it from the traditional approach (Fig. 3) is feedback.

Waste is no longer disposed of in the environment without any control, but is recycled. A part of waste that cannot be recycled is permanently disposed of in a safe way, in compliance with regulations.

Usually several SC members take part in the recycling system. The recycling-supply chain is a process with four stages:

- the first stage consists of collecting waste materials from recycling baskets and delivering that material to parties responsible for recycling;
- the second stage is processing of the recycling material into secondary raw material;
- the third stage is the use of secondary raw materials for making new products;
- the fourth stage is return of the product to the market.“[9]

„This process is repeated continuously, in cycles, based on the principles of the Shewhart cycle (P-Plan; D-Do; C-Check; A-Act). In this way waste is managed by applying the continual improvement methodology. Methodology of continual improvement based on Walter Andrew Shewhart’s (1891.-1967.) principle popularised by William Edwards Deming (1900.-1993.), and worldwide well known as the Deming cycle (PDCA cycle).”[6]

The modern approach takes the LC of a product into account. „The LC analysis measures economic and environmental consequences of a product during its production, use and disposal.“[10]

„The LC analysis evaluates the consequences caused by a product during the whole cycle of its generation, including the consequences of the product on the economy and the environment during its disposal in the form of waste.“[11]

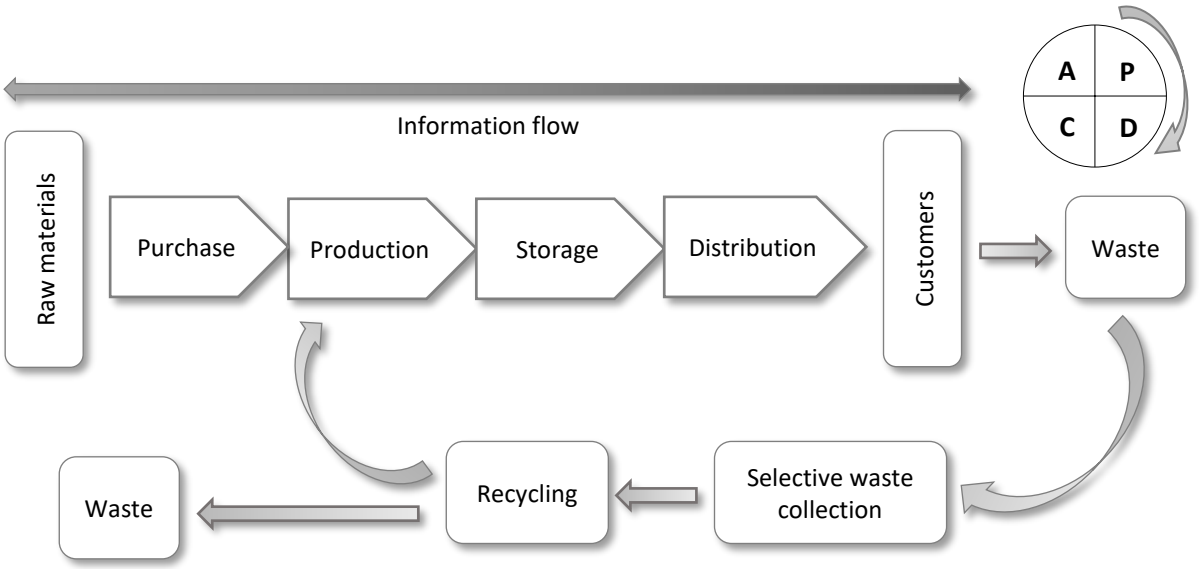


Figure 3 – Modern approach to the Supply Chain
Source:[6]

The waste recycling process is closely connected to the phenomenon of the "return logistics" or the "logistics of returns". Beside returns of new products by customers and consumers, used products and processed and exploited products by consumers, recycling is one of key areas of the return logistics.

Table 2 – Waste treatment, 2014 (thousand tons)

Total	Recycling	Energy recovery	Backfilling	Incineration	Landfill
2.319.500	839.659	109.017	236.589	34.792	1.099.443
100,00%	36,20%	4,70%	10,20%	1,50%	47,40%

Source: [6]

The data (Table 2) show that the EU-28 member states generated the total of 2.319.500 t waste in 2014, with the following use percentages: Recycling 36.20% (839.659 t), Energy recovery 4.70% (109.017 t), Backfilling 10.20% (236.589 t), Incineration 1.50% (34.792 t) and Landfill 47.40% (1.099.443 t).

3.2 Circular Economy Concept

According to the Circular Economy Concept – CEC, (Fig. 4) „ … waste generated during operation of processes within the SC is not discarded into the environment but is collected in the selective waste collection system, so that waste can be recycled, and a part of the recycled waste afterwards re-enters the production as raw material, reducing by this quantity the need for new ore extraction. The smaller part not suitable for recycling is safely disposed, in compliance with regulations."[12]

The total quantity of the SC waste in the CEC context (TwqC) as shown in Formula 2, equals the total quantity of waste generated in all phases of the SC, decreased for the quantity of recycled waste (RCwq).[6]

$$TwqC = (RMwq + Pwq + Dwq + Cwq) – RCwq \quad (2)$$

where the symbols have the following meaning:

TwqC – Total waste quantity – Circular economy concept

RCwq – Recycled waste quantity

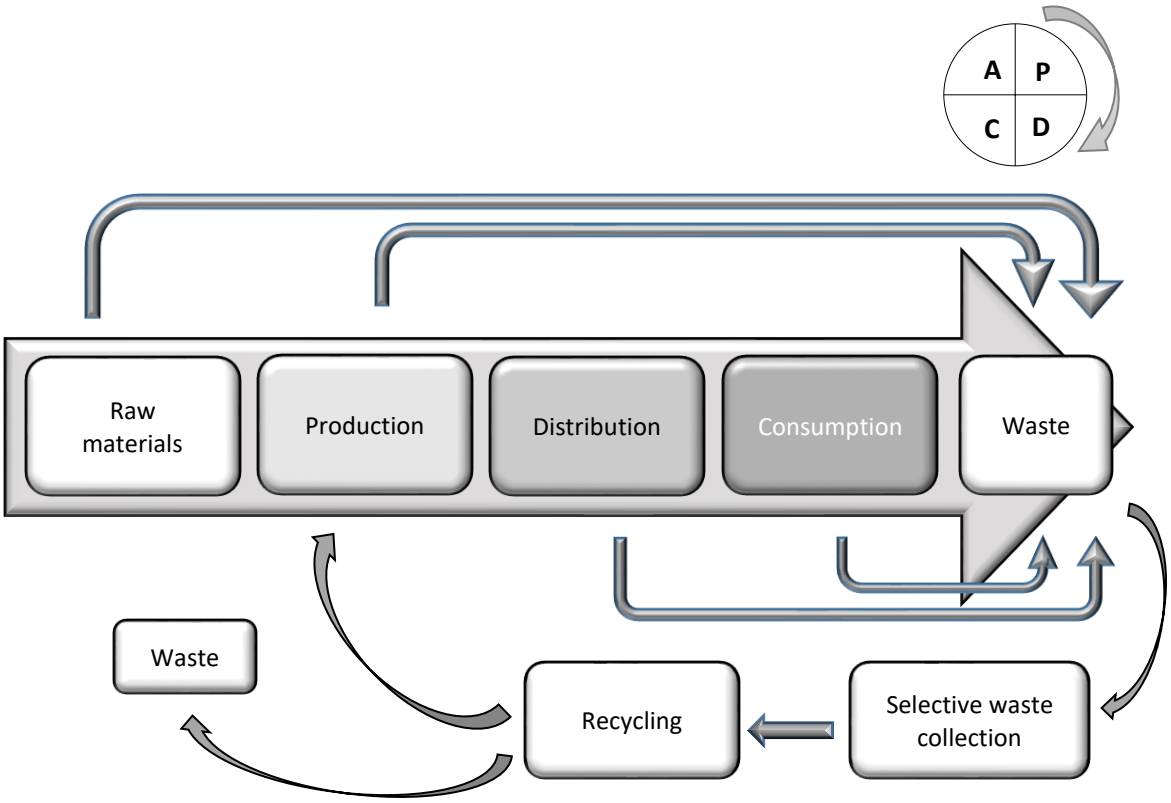


Figure 4 – Feedback as the assumption of transformation linear in the circular economy
Source:[6]

Since waste is generated in every SC phase, by optimization of waste management in each phase of the SC it is possible to further reduce the quantity of waste, or to optimize it, and this is relevant for at least two reasons: 1) reduction of the need to take resources from the nature and 2) reduction of total costs in the SC. Formula 3 shows effects of optimization of the waste management system within the SC, conducted in the context of the CEC as a modern approach.[6]

$$TwqO = (RMwq - Owq) + (Pwq - Owq) + (Dwq - Owq) + (Cwq - Owq)$$

$$TwqL > TwqC > TwqO$$

$$CECC = (TwqL - TwqC) - (TwqC - TwqO) \text{ or}$$

$$TwqL - TwqO \qquad (3)$$

where the symbols have the following meaning:

TwqO – Total optimized waste quantity

CECC – Circular Economy Concept Contribution.

4. CONCLUSION

Environmental pollution is a global phenomenon and therefore requires global solutions. However, every country should individually contribute to solving this problem, both by creating the adequate institutional framework and the environmental protection infrastructure and by practical acting. The SC is one of the foundations of any economy and its contribution to economy is crucial. Therefore it also has a significant impact on the environment, since numerous processes running within the supply chain necessarily contain negative environmental aspects. This is the reason why the traditional SC approach and the associated LE context are not acceptable in modern economies. They represent one way movement of goods, taking neither the LC of a product nor the waste management system into

consideration, and therefore they are unacceptable from the sustainable development perspective. Their transition to the modern SC approach and the associated circular economy context is necessary. The development of the waste management system and the analysis of the product LC characterize the modern approach. It is an economic, sociological, political and ethical question. It requires strategic considerations and making strategic decisions. The decision about transition from the traditional approach to the SC and economy, characterized by the LE, to the modern SC approach and the modern economy characterized by the CEC, is such a decision.

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DETERMINING THE “PEEK POINT” OF ROAD MARKINGS RETROREFLECTION

ABSTRACT

Road markings represent an important element of modern road surfaces. In order to ensure their satisfying quality, they need to be periodically tested. The quality of road markings is determined by measuring their visibility since this is their most important characteristic. During the application of road markings, a layer of “fog” is applied on the retroreflective material, i.e. glass beads. In the course of exploitation, this layer is slowly being removed, which causes the increase of retroreflection to a certain level. In that respect, the period after the application during which the tests are conducted differs in most EU countries, depending on the country’s technical guidelines. For this reason, the aim of this paper is to determine the “peek point” of road markings retroreflection in order to define a universal time interval in which the visibility of the markings should be tested after their application. The research included five single carriageway roads with thermoplastic markings and five roads with markings made of solvent-borne paint. The results indicate that the thermoplastic markings will reach maximum retroreflection after 13.20 days, while solvent-borne paint markings after 9.80 days.

KEY WORDS

road markings; retroreflection; visibility; quality measurements;

1. INTRODUCTION

Since the first use in 1911 on the Trenton River road in Wayne County in Michigan (SAD) until today, road markings represent indispensable element of contemporary roads [1]. They combine lines, signs and symbols to form traffic surfaces and help control and regulate traffic as well as guide, inform and warn traffic participants. It can be said that they communicate in a specific language by “telling” drivers what to do and how to behave in accordance with the upcoming traffic situation [2].

Since they are positioned in the drivers’ central field of vision, road markings affect the driver’s behaviour to a certain extent in terms of change in lateral vehicle position and driving speed which indicates that markings give drivers a sense of security and enable them to have a better visual guidance while driving [3, 4, 5].

Although previously conducted research on the effects of retroreflection on the occurrence of traffic accidents [6, 7, 8, 9, 10, 11, 12], due to their complexity, provided mixed and contradictory results, the prevailing opinion is that the retroreflection of markings has a positive effect on overall road safety.

Road markings are made of pigmented materials, most commonly paints, thermoplastic or cold plastic, and reflective elements which provide night-time visibility. Since their quality and durability mostly depends on their visibility, road markings need to be periodically tested in order to check their condition [13]. Their quality control implies conducting several different tests, of which the most significant are visibility tests, comprising daytime and night-time visibility measurements by means of static or dynamic measuring method. In the static method, road markings daytime and night-time visibility is measured using hand-held retroreflectometer, which is manually set on the marking. On the other hand, the dynamic method measures the markings night-time visibility during driving using a dynamic retroreflectometer mounted on the measuring vehicle [14].

Generally, markings are measured at least twice, after the application in order to check the quality of the contractor's work, and after the winter to determine whether the marking meets the minimum prescribed values of retroreflection, i.e. whether the marking needs to be renewed. Depending on the technical guidelines of a particular country, the period in which the markings retroreflection needs to be tested after the application differs. For example, in the Republic of Croatia, the visibility of markings must be measured in the period between 30 and 60 days after the application, while in other countries (such as Poland and Austria) they are measured in the period between 14 and 30 days or within a week after the application.

The reason for this lies in the fact that the markings retroreflection, after application, increases to some extent during a certain period of time [15]. Namely, during the application a layer of "fog" is applied on the retroreflecting material (glass beads) causing lower level of retroreflection. During exploitation, this layer is slowly removed, thus causing the increase in markings retroreflection.

The aim of this paper is to determine the time period in which retroreflection of solvent-borne paints and thermoplastic, as the most commonly used materials in the Republic of Croatia, reaches a "peek point" after the application. The obtained results may help the relevant road authorities in defining a standardized time interval in which the markings retroreflection should be measured after the application in order to check the quality of the contractor's work and ensure the adequate levels of visibility.

2. VISIBILITY OF ROAD MARKINGS

As mentioned in the introduction, the visibility of road markings is divided into daytime (Q_d) and night-time visibility (R_L). During daytime, drivers perceive markings mainly by the color contrast between the marking and the road surface. On the other hand, the night-time visibility is directly related to the retroreflection material and is a function of the luminous contrast between the road markings and the road surface, which is generally determined by the road marking retroreflectivity [16, 17]. According to European standard EN 1436, the coefficient of retroreflected luminance is defined as the ratio of the output surface luminance and the input surface illuminance measured in candelas per lux per square meter ($cd/lx/m^2$), or in a unit more suitable for markings which is milicandela per lux per square meter ($mcd/lx/m^2$) [18]. From this it can be concluded that the markings retroreflection is achieved as long as the reflective elements remain properly embedded in the markings - upon their loss or imperfect embedment, only daytime reflectivity is maintained [19].

Generally, the visibility of the road markings is influenced by several factors that can be categorized as shown in Figure 1. [20].

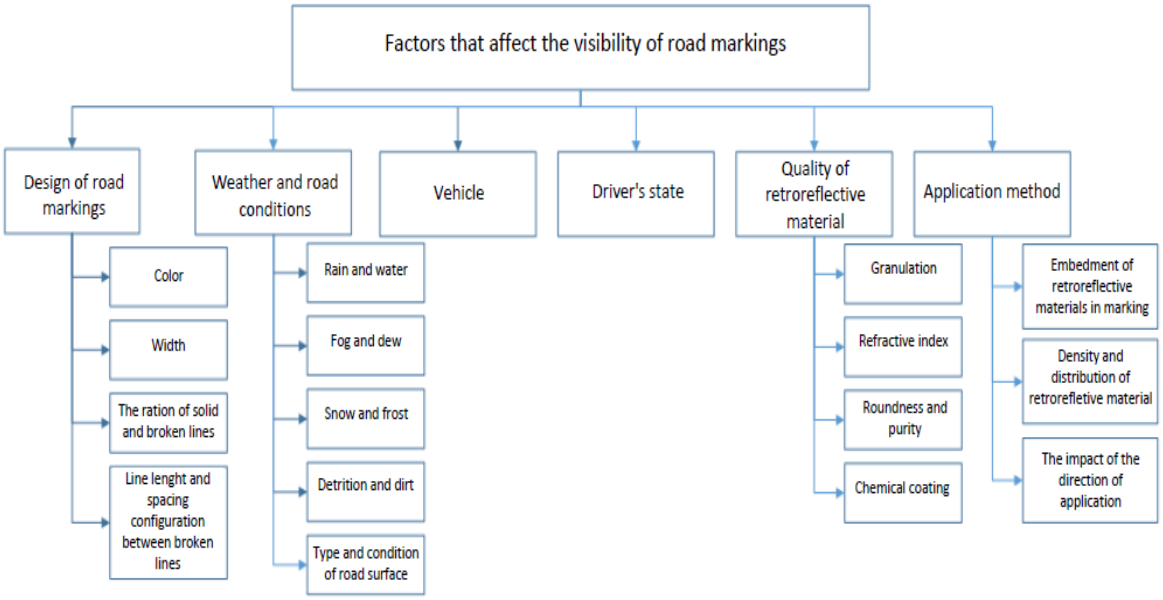


Figure 1 – Factors that affect road markings visibility
Source: Adapted from [19]

Furthermore, the visibility of the markings in wet and rainy conditions has a special importance for traffic safety. In these conditions their retroreflection is significantly reduced due to the layer of water that scatters the light from the headlights of vehicles and thus reduces the amount of light reflected from the glass beads. This deficiency may be alleviated using structured markings and glass beads with larger granulation, which are not submerged during normal rain conditions [19].

In addition, the driver’s perception of markings retroreflection changes with the type of vehicle and position of the driver. If the driver is sitting in a lower position (normal car), the light appears brighter than to a lorry driver who sits higher above the headlights, because the observation angle is smaller [18].

3. RESEARCH METHODOLOGY

The aim of this paper is to determine in which time period the retroreflection of road markings would reach its "peek point". For this purpose, from 2015 to 2017, the two most commonly used materials in the Republic of Croatia, solvent-borne paints and thermoplastics were analyzed. The research included five single carriageway roads with solvent-borne paint and five roads with thermoplastic road markings.

On every analyzed road, the retroreflection was measured using hand-held retroreflectometer (static method) which, manually set on the marking, measures daytime and night-time visibility. A Zehntner 6013 + static retroreflectometer was used for the purpose of this research. Considering the relatively small measuring range of static retroreflectometers, one of the main limitations of this method is that moving the device several centimeters may result in a significantly different measurement results. Also, due to the need for manual measurements, the static method may significantly depend on the controller [21]. To overcome these disadvantages, at each measuring location measuring point was marked as shown in Figure 2. In this way, measurements were conducted always at the same location, enabling accurate tracking of the markings retroreflection each day in order to determine the “peek point”.

Markings retroreflection for both analyzed materials was measured each day for a total of thirty days from the application day. On every analyzed road, five measuring locations were randomly selected on all three lines: center, right side and left side line, and retroreflection was measured in

the direction of the markings application. As a retroreflective material, standard 100-800 µm and 1.5 refraction index glass beads were used in both materials.



Figure 2 – Marked measuring point

4. RESULTS

As described in the previous chapter, road markings retroreflection was measured for 30 days after the application on five randomly selected measurement locations on every road.

Table 1 and 2 show the average values of initial retroreflection, i.e. retroreflection after the application, maximum value of retroreflection, retroreflection values thirty days after application, the number of days after which the marking reached the maximum value and the percentage increase of the retroreflection from the initial to the maximum value for both materials (solvent-borne paint and thermoplastic).

Table 1 – The retroreflection values of thermoplastic markings

Road No.	Line	Initial R_L (mcd/lx/m^2)	Maximal R_L (mcd/lx/m^2)	Increase of R_L (mcd/lx/m^2)	R_L after 30 days (mcd/lx/m^2)	Number of days until max R_L
1.	Center	320	360	12.50%	304	13
	Right side	261	320	22.61%	261	13
	Left side	258	321	24.42%	273	16
2.	Center	297	340	14.48%	321	12
	Right side	261	326	24.90%	246	14
	Left side	241	310	28.63%	265	14
3.	Center	328	354	7.93%	325	13
	Right side	249	334	34.14%	317	14
	Left side	238	300	26.05%	230	12
4.	Center	327	351	7.34%	294	10
	Right side	231	310	34.20%	259	16
	Left side	233	318	36.48%	265	15
5.	Center	306	344	12.42%	316	9
	Right side	241	320	32.78%	241	13
	Left side	229	317	38.43%	280	14
Average		268.00	328.33	23.82%	279.80	13.20
Std.		35.69	17.32	10.23%	30.13	1.87

As far as thermoplastic is concerned, the average initial retroreflection of the center lines is 315.6 mcd/lx/m^2, while the same value for side lines is lower, reaching the average of 248.6 mcd/lx/m^2 for the right-side line and 239.8 mcd/lx/m^2 for the left side line. Consequently, the maximum retroreflection and retroreflection after thirty days are also higher for center than for side lines. On average, the retroreflection of all markings on all five roads increased by 23.82% (with a standard deviation of 10.23%), from the initial 268.00 mcd/lx/m^2 to the maximum of 328.33 mcd/lx/m^2. The center lines, on average, reached the maximum value of the retroreflection after 11.4 days. On the other hand, side lines reached the maximum value after about 14 days. This is due to the fact that vehicles pass more often over the center than side lines. With each passage, the “fog” on the glass beads gets slightly removed, i.e. glass beads get polished and the markings retroreflection increases. From all the above, it can be concluded that the thermoplastic markings will reach the maximum retroreflection level after 13.20 days with a standard deviation of 1.87.

The average results of the measurements of the solvent-borne paint are shown in Table 2.

Table 2 – The retroreflection values of solvent-borne paint markings

Road No.	Line	Initial R_L (mcd/lx/m^2)	Maximal R_L (mcd/lx/m^2)	Increase of R_L (mcd/lx/m^2)	R_L after 30 days (mcd/lx/m^2)	Number of days until max R_L
1.	Center	282	310	9.93%	295	9
	Right side	244	277	13.52%	254	10
	Left side	252	282	11.90%	263	10
2.	Center	260	295	13.46%	271	8
	Right side	236	260	10.17%	230	11
	Left side	245	263	7.35%	241	10
3.	Center	302	330	9.27%	309	10
	Right side	273	299	9.52%	282	9
	Left side	269	281	4.46%	264	12
4.	Center	252	286	13.49%	270	9
	Right side	255	279	9.41%	268	11
	Left side	260	285	9.62%	275	9
5.	Center	311	327	5.14%	318	9
	Right side	244	265	8.61%	254	10
	Left side	251	270	7.57%	259	10
Average		262.40	287.27	9.56%	270.20	9.80
Std.		20.91	20.81	2.68%	22.78	0.98

The average initial retroreflection of the center lines made of solvent-borne paint is 281.4 mcd/lx/m^2 and, as well as with thermoplastic, initial retroreflection of side lines is lower with an average slightly more than 250 mcd/lx/m^2. The average maximum retroreflection of solvent-borne paint on all the analyzed roads is 287.27 mcd/lx/m^2, which represents an average increase of 9.56% in relation to the initial values. In the case of solvent-borne paint, the center lines reached the maximum value of retroreflection on average after 9 days and side lines after 10 days. From the results shown in Table 2 it can be concluded that the solvent-borne paints achieve maximum value of retroreflection after 9.80 days with a standard deviation of 0.98.

5. CONCLUSION

Road markings represent an important part of the traffic control plan and considering that drivers receive the largest amount of information through sight, the quality of their visual guidance largely depends on the visibility of road markings.

In general, visibility of the markings is influenced by many factors, of which the quality level and knowledge of the contractor is certainly one of the most significant. In order to check the quality of contractor, markings visibility should be tested after the application. Depending on the technical

guidelines of a country, the period after the application in which the visibility of the markings is tested differs. In the Republic of Croatia this period is between 30 and 60 days after the application while in other countries (such as Poland and Austria) testing period is between 14 and 30 days after the application. The reason for this lies in the fact that “fog”, which covers the glass beads during the application, reduces beads retroreflection properties. In a short time period after the application, “fog” is slowly removed, which causes the increase of the retroreflection. After reaching the maximum, the markings retroreflection then begins to slowly decrease. The aim of this paper was to determine the period in which thermoplastic and solvent-borne paint road markings reach maximum retroreflection after the application.

For this purpose, five roads with thermoplastic markings and five roads with solvent-borne paints were analyzed in the period between 2015 and 2017. On every road, five measuring locations were randomly selected and their retroreflection was measured at the same spot each day for thirty days after the application.

Retroreflection of thermoplastic markings increased on average by 23.82% reaching the average maximum of 328.33 mcd/lx/m^2 after 13.20 days. For solvent-borne paints, the average maximum of 287.27 mcd/lx/m^2 was reached after the 9.80 days which in average represents the increase by 9.56%.

The obtained results confirm the practical fact that the markings retroreflection increases in the short period after the application. Considering the diversity of the road markings testing methodologies used in the EU countries, it is recommended to define a universal time period in which road markings retroreflection must be measured. This time period for thermoplastic and solvent-borne paints, in accordance with the results obtained here, should be between 12 and 30 days after their application.

In addition, it is recommended to conduct follow-up studies which will encompass other commonly used road markings materials such as flat and structured cold plastics and waterborne paint as well as the impact of different glass beads quality[1] on retroreflection of road markings after application.

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LOGISTICS SERVICE PROVIDER'S WAREHOUSE OPERATIONS EFFICIENCY ANALYSIS – CASE STUDY

ABSTRACT

Resources within the logistic process are important part, which are directly related with business system. The main reason that generated costs in business is surplus or deficit, to avoid that we need to optimize our resources. If we manage to do that with optimization it will bring us better reeling in system, increase working efficiency and reduce costs. In case that is possible to calculate working efficiency of each resources than it's also possible to show which resource if efficient and set scales for standardization in performing activities in specified time. All of the above is important for planning logistics process carefully.

KEY WORDS

supply chain; warehouse; processing; process time; case study (ABS);

1. INTRODUCTION

Warehouse operations have significant impact on the movement of goods throughout the supply chain while resource analysis begins by selecting the area and/or processes that will be part of evaluation. Accordingly, warehouse processes logistics service provider located in Republic of Croatia. Warehousing processes are represented by a flowchart showing the flow of processes within the logistics service provider warehouse. Specific goods being manipulated in the observed warehouse are tires. Time-based analysis in the form of a case study is provided to define the time needed to carry out a particular warehouse process. Figures will implicate the time taken to complete a particular warehouse process. The measured time will be compared to time norms predefined by logistics service provider, used for salary calculation.

2. WAREHOUSE OPERATIONS

Warehouses are the points in the supply chain where product pauses its throughput, warehouse can provide additional services and forward products to the next level of the supply chain. [1] According to Bartholdi and Hackman [2] basic way of classifying the warehouse operation would be on the inbound processes (receiving and put-away) and outbound processes (order-picking, checking, packing and shipping). Besides this processes, there are also value added services which are not obligatory but depend on the warehouse type and various provided services. [3]

Figure 1 presents warehouses processes flowchart.

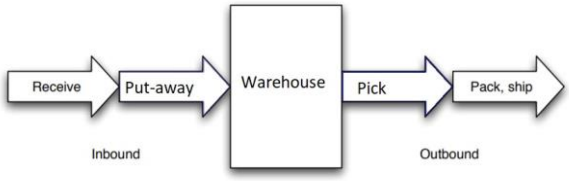


Figure 1 – Flowchart of warehouse operations
Source: [2]

2.1 Receiving

Receiving may begin with advance notification of the arrival of goods. This allows the warehouse to schedule receipt and unloading coordinated efficiently with available resources and other activities within the warehouse. It is not unusual for warehouses to schedule truck arrivals within 30-minute time windows. Once the product has arrived, it is unloaded and usually temporarily positioned for put away. Depending on informational level, it is likely for goods to be scanned, registering its arrival in WMS detecting ownership, activating possible payments and goods availability to fulfil customer demand. Products will during the process be inspected and any exceptions noted, such as potential damage, incorrect counts, wrong descriptions, etc. [2] This process usually does not take much time compared to other, but it is as much relevant as any. Especially, if incorrect put away occurs and causes errors in further processing. [3]

2.2 Put-away

Put-away is the process of moving material from the receiving area to a storage location or, in the case of cross-docking, directly to the shipping area. [4]

Every SKU in a warehouse has its own location, determined in advance, whether the positioning is predefined or random. Precisely, there are several storage policies. A predefined storage policy prescribes a particular location for SKU to be stored, while random policy leaves the decision to the WMS or the operator. Both of these storage policies can be used in some warehouses. Furthermore, a class-based storage system allocates zones to specific product which is based upon products turnover rate as ABC zoning. Another storage policy includes correlated storage of family groups, that is, storing products at nearby positions if they are often required simultaneously. This step in the process is of large importance. It can reduce time defined for picking and in the end decrease total duration of outbound processes. For put-away the inventory management needs to be up to date and accurate. Storage locations availability should be known at all times what, how much weight they can bear, etc. [5]

2.3 Order Picking

The process of order picking in a warehouse involves selecting and gathering specified amount of right SKUs in accordance with the order and it is composed of lifting, moving, picking, putting, packing, and other related activities. During the order picking process, the orders are generally assigned to several pickers. However, in order to prevent control problems, the total pick area is often divided into picking zones. After this, the zones are generally served by different pickers, through the zoning policy. Orders are picked one by one or in batches in a predetermined order. Further, order picking can be manual or automated. In manual order picking, the picker gathers units from their locations and then transports them to a packing area. In the case of automated picking, that is, automated storage and retrieval systems, system retrieves one or more unit loads and place them to a picking station. After that, the picker takes products on orders, and the remaining items on the unit loads are transferred to storage again. [5]

A picking strategy defines the manner in which pickers navigate the order picking area to pick items from storage locations. The primary objective of a picking strategy is to maximize throughput or minimize cost or response time. [6] [7]

Lee, Chang and Cho [8] compared typical manual order picking and manual order picking with digit system. Digit system helps pickers search for locations and amount of the items on the storage or shelves, and provide efficiencies such as searching for picking items, counting the quantity of items and checking remaining works. The results showed that the device affects minimizing fluctuation of picking time, as well as the reduction of time consumption for picking.

Gu, Goetschalckx and McGinnis [9] differentiate order picking methods, such as: single-order picking, batching with sort-while-pick, batching with sort-after pick, sequential zone picking with single order, sequential zone picking with batching, concurrent zone picking without batching in the zones, and concurrent zone picking with batching in the zones.

2.4 Shipping

Shipping generally handles larger units than picking, because packing has consolidated the items into fewer containers (cases, pallets). Consequently, there is still less labor here. There may be some walking if product is staged before being loaded into freight carriers. Product is likely to be staged if it must be loaded in reverse order of delivery or if shipping long distances, when one must work hard to completely fill each trailer. Staging freight creates more work because staged freight must be double-handled. The trailer is likely to be scanned here to register its departure from the warehouse. In addition, an inventory update may be sent to the customer. [2]

3. NORMING

Norming time or standard time can be specified for each individual operation. **Standardization is the** time required for an average trained and qualified worker to perform, in a specific manner, with normal effort and fatigue, under normal operating conditions, with the prescribed means. This is the total time in which an operation should be completed at standard performance. [10]

3.1 Motion Study

It is defined as a systematic and critical study of existing method of doing a task with a view to evolve the most efficient and economic method of doing it. It is a method for setting up employee productivity standards in which: [11]

- A complex job is broken down into small or simple steps.
- The sequence of movements taken by the employee in performing those steps is carefully observed to detect and eliminate wasteful motion.
- Precise time taken for each correct movement is measured.
- The objectives of motion study are:
- To improve the procedure of doing a work improve the workplace layout (ultimately plant layout).
- To minimize the human motion for minimum fatigue of operators.
- To maximize the utility of resources (men, m/c, materials).
- To improve the overall working environment.

3.2 Time Study

Time study technique is probably most widely used technique. It involves the recording of the times and rates of working for clearly identified short elements of a job, usually by direct observation. A stopwatch or an electronic timing device is used. [12]

The stages of time study are as follows: [12]

1. Select the job to be studied.

   Ideally, methods should have been already applied to the job. There's no point in measuring work which is known to use inefficient procedures.

2. Break down the job into short parts or phases called elements.

   Elements are short distinct task (such as moving an item from one location to another). It is important that each element is separately recognizable. Normally jobs are broken down into elements which take no more than half a minute to complete.

3. Record the activity to obtain the observed time for each element.

   There are several difficulties attached to observation, not the least of which is that people tend to behave differently when they are being watched.

4. Calculate the standard time for the job.

4. TIME ANALYSIS OF WAREHOUSE PROCESSES - CASE STUDY

The warehouse processes are significant to optimize in the supply chain. Every process, from receiving until shipping, is vital since it causes certain costs. (Bajor et al., 2016) Measurement of the time needed for warehouse operations was carried out at location of logistics service provider on the Croatian market. The primary focus of company is transport and storage of tires for certain buyer. The manipulation unit for tire storage is called KSP (Käfig Standard Pallet). KSP are made of steel for heavy loads where at standard KSP it is possible to fit in 5 rows and 6 tires per row calculating cca 30 pieces per KSP. This applies to the standard tires of their manufacturer, namely: R14 and R15. The standard R14 tires are 165x630 [mm], while standard R15 tires are 195x655 [mm]. The average weight of the tire is 7.5 kg.

4.1 Analysis of Receiving Warehouse Process

Warehouse process of receiving tires begins with arrival of a transport truck. After that worker receives transportation documentation and photographing of truck labels and seals. The documentation provided is a CMR (Contrat de transport international de Marchandises par Route) control that serves to check the order deviations and packing lists, if there are any deviations, the worker puts a note on the CMR and creates the packing list log. After reviewing the documentation, the means of transport is positioned at the incoming ramp, and during that time the forklifts deliver and prepare the KSP at the entry ramp. When the transport device is positioned on the ramp, removal of the seal and opening of the door starts. This is a visual inspection of the tire condition which is shown in Figure 2.

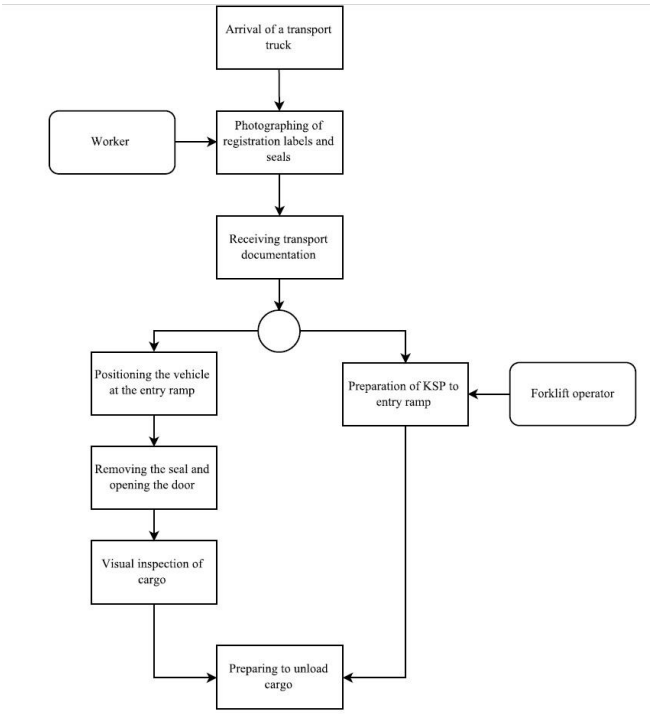
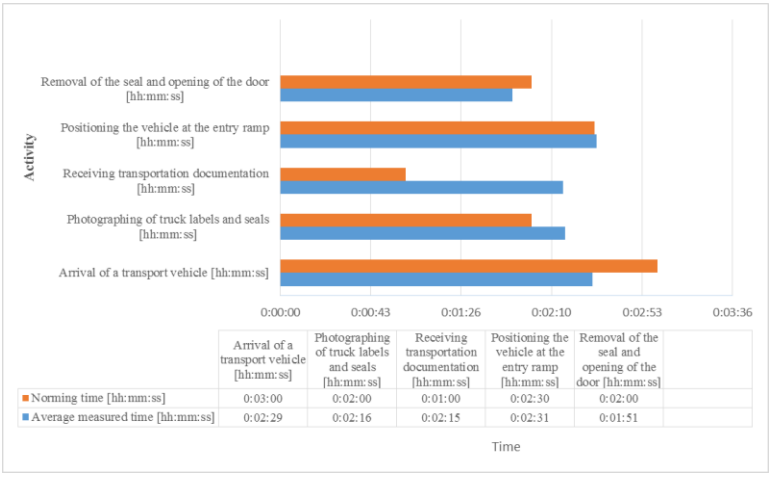


Figure 2 – Flowchart of receiving warehouse process
Source: Created by authors

Receiving goods is a process that is divided into certain activities and time is measured in accordance to these activities. The process measurements where prolonged at the very beginning of the observed process due to truck being late to predefined time window.

Figure 3 shows relationship between average measured time and norming time. The average arrival time is 2 minutes and 29 seconds where norming time is longer estimated 3 minutes. After arriving, photographing of the registration signs and the seals was followed. The average recording time of the registration marks and seals was 2 minutes and 16 seconds, while norming time is less, 2 minutes. During that time, transport documentation was received. The average reception time was 2 minutes and 15 seconds depending on whether the driver had prepared or requested the documentation. The position of the vehicle at the incline ramp averaged 2 minutes and 31 seconds depending on the driver's abilities. Following the positioning of the vehicle at the incoming ramp was followed by removal of the seals which lasted for 1 minute and 51 seconds on average. The norming time for observed was almost the same.



	Arrival of a transport vehicle [hh:mm:ss]	Photographing of truck labels and seals [hh:mm:ss]	Receiving transportation documentation [hh:mm:ss]	Positioning the vehicle at the entry ramp [hh:mm:ss]	Removal of the seal and opening of the door [hh:mm:ss]
Norming time [hh:mm:ss]	0:03:00	0:02:00	0:01:00	0:02:30	0:02:00
Average measured time [hh:mm:ss]	0:02:29	0:02:16	0:02:15	0:02:31	0:01:51

Figure 3 – Relationship between average measured time and norming time for receiving goods process
Source: Created by authors

4.2 Analysis of Put-Away Warehouse Process

After the tire's visual inspection, begins unloading tire from the transport truck. The unloading is carried out by two workers in the cargo area of the means of transport and the tires are released from it. The third employee counts the tires and controls the DOT number. Tire unloading is in most cases done manually as the tires come in the form of a fish bone and it is not possible to use a manipulator in that part of the operation. After unloading, two workers put the tires in the KSPs, while the third worker creates a log of deviations. When the log is finished and tires are assembled in the KSPs, a Tire Receipt is made and the KSPs are transported to the positions by a forklift. The storage process is over when the last KSP reaches its position. All this is shown in Figure 4.

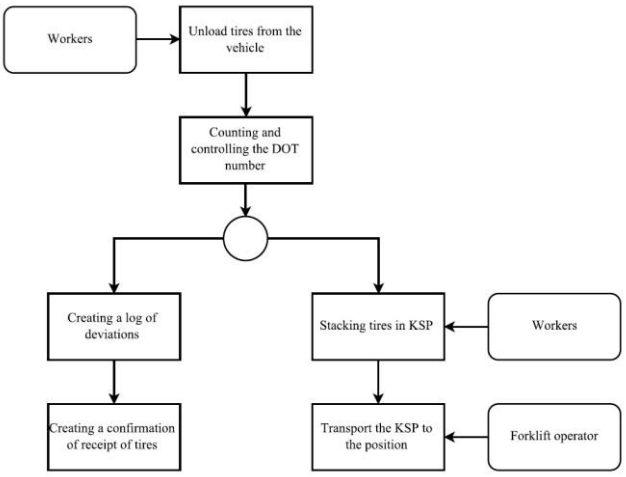
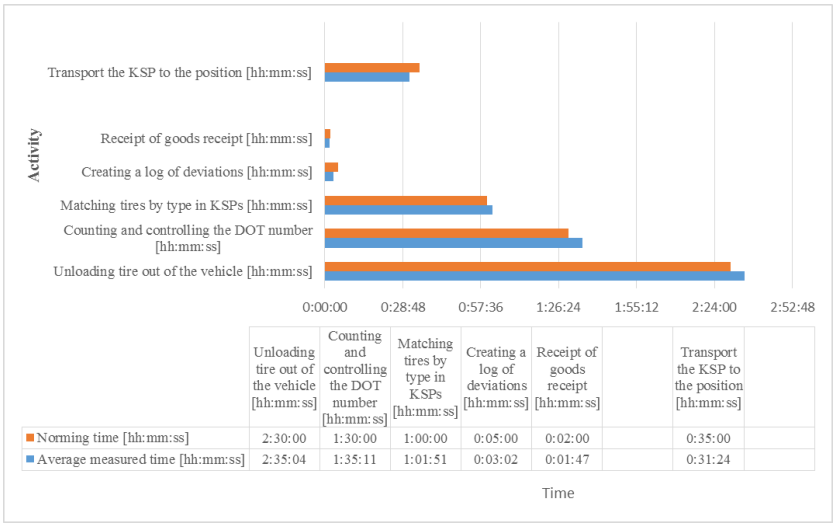


Figure 4 – Flowchart of put-away warehouse process
Source: Created by authors

When measuring the storage time for put-away of the goods most attention was paid to the tire discharging from the vehicle. Figure 5 shows relationship between average measured time and norming time. The average tire retention time was 2 hours 35 minutes and 4 seconds. The norming time is less, 2 hours and 30 minutes. The extremes between the longest and shortest disembarkation were: fastest 2 hours 18 minutes and 32 seconds and the longest 2 hours 57 minutes and 31 seconds. Extras appeared to track two groups of workers. The occupied group of workers had to be 40 minutes less for disembarkation than the newly formed group of workers. During disembarkation, one worker is set to control DOT numbers and numbered tires. The average time for this was 1 hour 35 minutes and 11 seconds, the norming time is less, 1 hour and 30 minutes. Well-run worker needs 1 hour 22 minutes and 45 seconds to complete this process, while the new employed worker needs 2 hours 1 minute and 54 seconds. After checking and counting, follows the tire positioning in the KSPs. The average time for stacking the tire in the KSP for the storage process is 1 hour 1 minute and 51 seconds. The norming time is almost the same, 1 hour. After the tire is assembled in the KSP, a log of the deviations is created if there is one. The duration of the log creation averaged 3 minutes and 2 seconds depending on the size of the deviation. The norming time is bigger 5 minutes. After the creation of the minutes, a receipts certificate is issued that lasts 1 minute and 47 seconds on average. After confirmation, KSPs are transported to positions. This works for a forklift and averaged for 31 minutes and 24 seconds during the measurement. The norming time is bigger, 35 minutes.



	Unloading tire out of the vehicle [hh:mm:ss]	Counting and controlling the DOT number [hh:mm:ss]	Matching tires by type in KSPs [hh:mm:ss]	Creating a log of deviations [hh:mm:ss]	Receipt of goods receipt [hh:mm:ss]	Transport the KSP to the position [hh:mm:ss]
Norming time [hh:mm:ss]	2:30:00	1:30:00	1:00:00	0:05:00	0:02:00	0:35:00
Average measured time [hh:mm:ss]	2:35:04	1:35:11	1:01:51	0:03:02	0:01:47	0:31:24

Figure 5 – Relationship between average measured time and norming time for process put-away
Source: Created by authors

4.3 Analysis of Order Picking Warehouse Process

Storage operations order picking provider of logistics services in Croatia begins by checking the SAP. SAP is a program that reads incoming shipping orders. It contains the parameters of the shipment, namely: number of pieces of tires, weight, CBM (cubic meter) shipment. After the SAP check is completed, the preparation of the tire shipping documentation begins. The documentation is produced by a SAP monitoring agent. The documentation is checked and commissions start. The commissioning is done according to the sender's remittances received by the workers. The warehouse commissioning work is done by workers, and their number depends on the size of the shipment. At the end of commissioning, the disponent contacts the driver about the time of embarkation. When the commissioning ends the tires fit into the KSPs and are shipped to the embarkation position. Tire transport to the position of embarkation is done by a forklift. When all KSPs are in the position of embarkation, the commissioning operation ends. All this is shown in Figure 6.

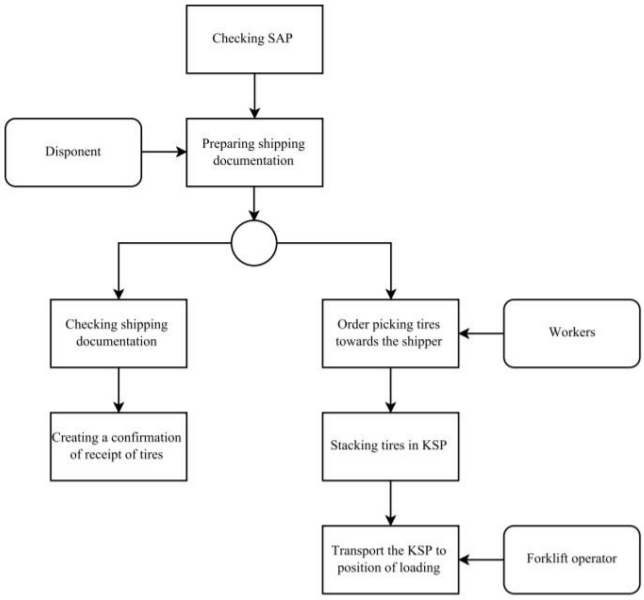


Figure 6 – Flowchart of order picking warehouse process
Source: Created by authors

When measuring the storage time following the receipt of the goods most attention was paid to the tire discharging from the vehicle. Figure 7 shows relationship between average measured time and norming time. Measuring the time needed for order picking began with the preparation of shipping documentation. The average preparation time was 11 minutes and 4 seconds, depending on the order number. The norming time is almost the same, 10 minutes. After the documentation has been prepared, the process of order picking the tire starts with the sender. The average duration of the order picking process was 1 hour 19 minutes and 18 seconds while norming time is 1 hour. It greatly depended on the amount of rubber that is being commissioned under what is considered a type of tire. The extras within the commissioning process were: the shortest commissioning lasted 52 minutes and 35 seconds, and the length of 1 hour 58 minutes and 2 seconds. The difference in these two commissioning is that the shortest commissioning had fewer types of tires for the exception. At the end of the commissioned, the documentation is checked and the driver is notified of the time of embarkation. The average duration of this operation was 5 minutes and 45 seconds, while norming time is 5 minutes. Thereafter, the tire is assembled and the KSP is dispatched to the dispatch position. The average tire fit in the KSPs lasted for 5 minutes and 30 seconds as they were assembled in KSPs by 30 pieces in one and only need to add several tire pieces, the norming time for this is 5 minutes. The average duration of KSP delivery to the embarkation position was 35 minutes and 28 seconds, while norming time for this is 35 minutes.

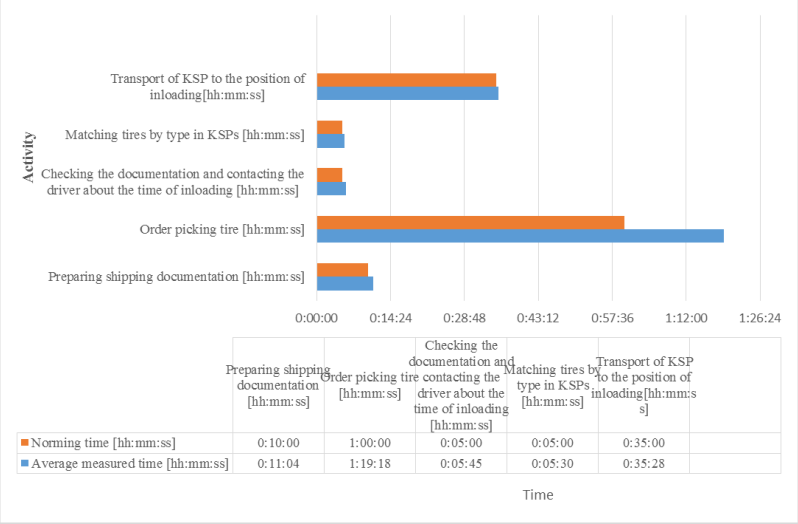


Figure 7 – Relationship between average measured time and norming time for process order-picking
Source: Created by authors

4.4 Analysis of Shipping Warehouse Process

With the arrival of the transport vehicle, the warehousing operation of the goods is started. Upon arrival, the transport device is positioned on the exit ramp and the loading space is opened. A visual inspection of the vehicle, table and personal data of the driver begins. After the inspection is completed, the loading of the tire begins in the transport space of the vehicle. The loading of the tire in the transport means is done manually according to the principle of a fish bone. When tire is loaded and complex dispatch documentation is delivered to the driver, the door of the loading space of the means of transport is closed and an overpressure is placed thereon. All this is shown in Figure 8.

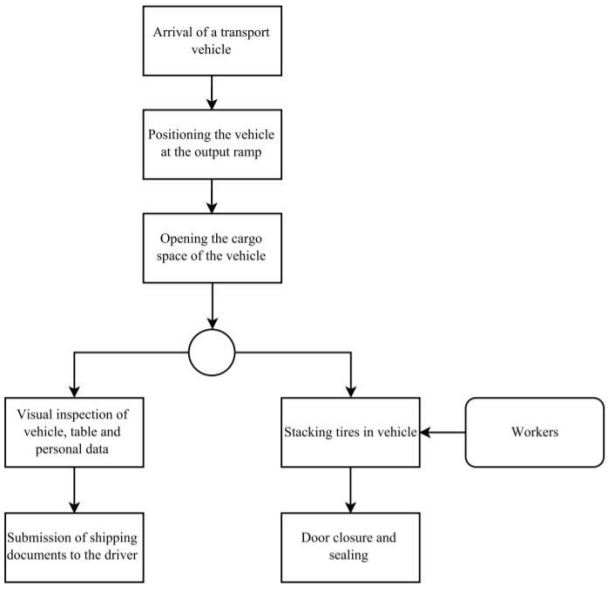
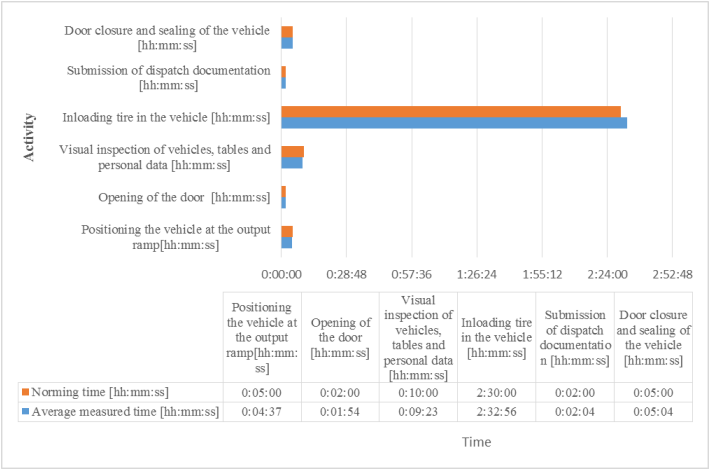


Figure 8 – Flowchart of shipping warehouse process
Source: Created by authors

Measuring the time needed for shipping began with positioning the vehicle at the input ramp. Figure 9 shows relationship between average measured time and norming time. The average positioning time of the vehicle at the output ramp was 4 minutes and 37 seconds, while norming time is 5 minutes. After that, the opening of the loading space door, which averaged 1 minute and 54 seconds, followed. Norming time for this is 2 minutes. After that, a visual inspection of the vehicle, table and personal data of the driver is performed. The average viewing time is 9 minutes and 23 seconds depending on whether the driver has prepared documents or not. Norming time for this is 10 minutes. After checking, follow the loading part. The tire begins to fit into the loading space of the transport device. The average duration of this operation was 2 hours 32 minutes and 56 seconds, while norming time is 2 hours and 30 minutes. It was about the speed and the skill of the tire fitter in the structure called the fish bone. The fastest measurement time was 2 hours 27 minutes and 12 seconds. After the loading part, the shipping documentation is delivered to the driver. The average time of transmission is 2 minutes and 4 seconds and the length of time 3 minutes and 16 seconds when documentation is being searched. After loading the documents, the loading area door closes and fades. The average duration of this operation is 5 minutes and 4 seconds.



	Positioning the vehicle at the output ramp[hh:mm:ss]	Opening of the door [hh:mm:ss]	Visual inspection of vehicles, tables and personal data [hh:mm:ss]	Inloading tire in the vehicle [hh:mm:ss]	Submission of dispatch documentation [hh:mm:ss]	Door closure and sealing of the vehicle [hh:mm:ss]
Norming time [hh:mm:ss]	0:05:00	0:02:00	0:10:00	2:30:00	0:02:00	0:05:00
Average measured time [hh:mm:ss]	0:04:37	0:01:54	0:09:23	2:32:56	0:02:04	0:05:04

Figure 9 – Relationship between average measured time and norming time for process shipping
Source: Created by authors

5. CONCLUSION

Human resource analysis in planning logistics processes is a very complex and demanding process. Human resources are an essential factor in every business as well as in planning logistic processes. Each of the resources is important and carries a certain share in the business.

The first warehouse operation is the receipt of the goods. After that, put-away goods in the warehouse. Then, when the goods are shipped, they are initially order picking and then placed in a certain position before loading of the goods into the means of transport. The delivery ends when the goods are loaded into the means of transport and documents handed over.

It is important to note that workers and machinery are involved in warehouse operations.

The analysis of warehouse operations with providers of logistics services in the Republic of Croatian founded the complexity of analyzing the effectiveness of the monitored resources. Warehouse operations are divided into smaller operations and are carried out against them weather measurements to recognized the difference between the actual time required to perform an operation and standardized time to perform the same operations. Standards were received by the provider of logistics services, and measurements are made time analysis in the form of case studies. Measurements took place in real time, so there is a possibility of error. From the time measurement table, the average time was taken and compared to the given norms. The measured times were slightly higher than the default time, but due to the possibility of error measurement, they remain in the frame of a good time.

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CYCLELOGISTICS MANAGEMENT IN ZAGREB URBAN AREA

ABSTRACT

Fright transport in the cities has a mayor role, and it depends on successful flow of motorized and non-motorized fright vehicles in a sustainable ecological and economical way. In order to achieve sustainable mobility in cities, one of the solutions imposed by the exclusion of motorized freight vehicles, and the introduction of bicycle logistics. Bicycle logistics is one of the ways of developing goods and goods delivery in urban areas of cities using bicycles and freight bicycles. Such a delivery system is one of the ways of achieving a new organization of traffic in cities with the aim of reduction in urban areas from motorized personal and delivery vehicles. This paper analyses the purpose and objectives of bicycle application in delivery, and types of bicycle delivery in urban areas. Examples of two European cities are given and their way of bicycle delivery organization. A research has been conducted in the urban area of Zagreb, which will include the analysis of motorized delivery traffic and a new concept, based on the research, of bicycle freight delivery. Also, the paper includes an example of delivery organization by bicycle in the centre of Zagreb through a commercial company.

KEY WORDS

freight vehicles; bicycle; logistics; urban area;

1. INTRODUCTION

The introduction of bicycles in freight delivery in city centres is one of the most efficient and environmentally acceptable delivery methods in urban areas. The main goals are to reduce congestion and pollution in cities, as well as stimulate a healthier lifestyle. This kind of traffic organization would improve the development of non-motorized transport, which is one of the main goals of the concept in improving urban mobility. Previous research has shown that at the very centres of cities, bicycles can completely replace motorized freight vehicles. Organization of freight delivery in city centres is currently carried out mostly by trucks and vans. Such a way of delivery further confuses traffic in cities and puts pressure on the transportation network. Further on, in not providing adequate parking places for delivery vehicles, is a direct result of additional congestion and contribution to increasing number of traffic accidents. Attempting to replace trucks with bicycles would greatly reduce all these problems and reduce the emission of harmful gases. The purpose of this article is to analyse the possibility of switching delivery of goods from motorized freight vehicles to bicycles or freight bicycles. The main objective is to increase the use of non-motorized transport and development of bicycle infrastructure, and to improve the quality of life in cities by reducing the emission of harmful gases.

2. THE PURPOSE AND MAIN OBJECTIVES OF APPLYING BICYCLES IN FREIGHT DELIVERY

2.1 The Purpose of Applying Bicycles

The present situation in the delivery of goods within cities is such that 100% of the transported goods are carried out by motorized means of transport, starting from motorcycles and cars to commercial trucks. One of the major problems is that small packages and light goods are also being transported by trucks, completely ignoring that any other journey within the urban environment is less than five kilometres and can simply be done by bicycle. [1]

Approximately every second trip involves the transport of goods. If we take into account the length of travel and the possibility of a travel chain[1], there remains a possibility of moving 25% of all trips from motorized vehicles to solutions using bicycles. [2]

The alternative to freight transport in city centres that is organization of freight delivery in urban areas using bicycles is the primary purpose of reducing energy use in freight transport in the urban areas of the city. Some of the steps that can be taken are:

- Finding potential in the transport sector with the aim of switching goods from car to cargo bikes. Encourage current bicycle delivery companies to transport larger packages using new technologies (electric cargo bikes)
- Motivate the state administration to create a favourable framework plan for freight bicycle delivery, analyse the internal potential by introducing bicycles to perform jobs within cities, encourage local businesses to use this type of delivery
- Stimulating people to use freight bicycles, trailers and baskets for private freight transport, while at the same time traders should provide potential buyers with incentives to use bicycles for the purpose of delivery and in the same time providing appropriate bicycle infrastructure
- Testing and reporting on various products in the bicycle industry, thereby promoting the growth of this industry to potential consumers (private, business and municipal) across Europe with access to useful information. Including on-line product information
- Establishing ECF – European Cyclelogistics Federation, as the first professional institution to represent and support the needs of cycling logistics companies throughout Europe [3]

2.2 Main Objectives of Applying Bicycles

When we look at all the data from the studies conducted, cycling logistics has great potential. On average, 51% of all motorized journeys in European cities, including freight transport, can be transferred to bicycles or freight bicycles. Such a change would pose as a great shock to cities with a worrying traffic, ecological and economic situation. The fact remains that cycling logistics completely changes the city's appearance and contributes to sustainable mobility in cities making it a better living environment for all citizens. By applying the steps of the predictions from the conducted studies, will manifest in several ways for municipalities, local businesses and the population as well. The main goals that ultimately want to be achieved are: [4]

- Lower energy consumption and reductions of CO_2 emissions
- Reduction of traffic congestion, noise pollutions and emission of harmful gases
- Increasing “green” space and freeing up spaces for pedestrians
- Overall increase of quality of life in urban environments

[1] Travel chain - a series of trips passengers make every day; a direct trip between two links, or a trip with a delay of 30 minutes or less

3 TYPES OF BICYCLE FREGITH DELIVERY IN URBAN AREAS

Mail – a very capable alternative to the current type of postal services. Compared to the state postal service, this type of delivery provides significant savings for customers.

Delivery is made using standard bikes with or without trailer. The best application would be in densely populated residential or commercial areas. Delivery can be done at any time. This service will be of most interest to the local government and utility companies. It will greatly improve the connection between the municipalities with the residence and consumers, and educational institutions with students.

Point to point – an on-demand service where the consumer of the service has the item that must be received at point "x" and delivered to point "y". Different delivery methods can be provided depending on delivery time (i.e. delivery within 1 hour or within 4 hours).

Delivery is done via standard bicycles (with or without trailer) or cargo bicycles, but depending on the size of the cargo. The reliability of the delivery depends on the readiness and level of preparation, and the client's call can come at any time of the day. It is necessary to optimize the efficiency of the available bicycle capacity and the driver itself (i.e. there is no control over the time of the delivery request, or the point of receipt and delivery of the package, and the size of the cargo to be delivered).

Last mile – large volume of delivery to the city centre from the warehouse located on the edges of the city limit. Large quantities of cargo delivery is carried out by motorized freight vehicles to the warehouse.

Delivery is adjusted to fit freight bicycles and tricycles. Mostly, domestic or international carriers are contracted, and standards need to be adapted to the standards of these companies and use of their technology (i.e. manual devices for confirmation of delivery). The best application would be in densely populated residential or commercial areas. Due to the size of the freight bicycles the distance to the point of delivery is limited. Because of the issue of securing of goods and the safety of the bicycles themselves, protected warehouses are required on multiple locations, where goods and bicycles can be stored for an indefinite period of time. [5]

3.1 Organization of Delivery in European Cities - Wiesbaden

The city of Wiesbaden is located in the western part of Germany, near Frankfurt, with about 280,000 inhabitants. In November 2012, Wiesbaden launched a new concept of delivering goods by means of a bicycle called "Kiezkaufhaus". The name comes from two independent words which in translation make up a "neighbourhood shopping centre".

The service they provide is delivery via electric bicycles from local shops to the users' homes. Buying is done online where local stores provide their products. Delivery takes place on the same day the order was sent. Some of the products that are offered include fruit, vegetables, bakery and dairy products, alcohol, tea, coffee, etc., but also non-food products such as books, flowers, toys or theatre tickets.

After filling the online basket you need to register and give the address, the order is then divided individually to each merchant and the employee goes to collection of the products and performs delivery to the given address. The delivery price is between €5 - €7 and it is free if the total price of the order is €50 or more.

This start-up company reduces the emission of harmful gases in the field of delivery, supports the local economy, and has a major impact on the social life of the city. Bicycle workers are not only young but delivery is also done by retirees.

The next step to modernize the company is delivery through an application made by a delivery company from Amsterdam, Netherlands. "TrinTring" is an application that can be used to order food from local retailers. The delivery time is guaranteed within 60 minutes. This form of delivery is called "point-to-point" or "peer-to-peer". [6]

3.2 Organization of Delivery in European Cities - Cambridge

The city of Cambridge is located in the western area of England, 100 kilometres north of London. The population is about 123,000. Within the city, a successful company has developed, which deals with the delivery of goods by means of a bicycle called "Outpoken Delivery".

The services provided within the city include delivery of daily mail, exchange of documents and collection and delivery services of the city council's internal mail. Delivery is done by cargo bicycles and tricycles that are part of the companies fleet. Part of the delivery service is also walking because in larger areas it is necessary to deliver on different floors of office buildings and to different departments of a supplying company that is not possible with a bicycle. Employees and drivers of the company are trained according to national cycling standards and regular assessments of their performance are carried out. They are also checked whether they have a criminal record.

Delivery to members of the city council is extremely important, and deliveries are required 3 times a month. The organization is very demanding because the collection of documents takes place from 15 different locations and the delivery is provided to homes of 42 members of the council. Goods that are delivered are mostly papers from held meetings, daily agenda documents and accompanying documentation.

The company's attempt was also to collect trade waste (packages, plastic and paper) from retailers within the city. The local authorities did not provide the opportunity because they tried to reduce this work to only one company. [7]

4 PROPOSAL OF A NEW DELIVERY CONCEPT USING FREIGHT BICYCLES BASED ON THE TRAILBLAZER PROJECT

By introducing delivery by means of freight bicycles and the complete omission of motorized freight vehicles is practically impossible predominantly because of the level of load capacity that motorized freight vehicles have. For a load capacity of 3.22 tonnes, it is necessary to have about 22 freight bicycles with an average weight of 150 kilograms. If you look at the average quantity of goods by delivery of 1.85 tons, it takes about 12 freight bicycles per delivery. Also the replacement of the category, over 3.5 tons of total capacity, is not possible with bicycles, but if we consider noise reduction and exhaust gases, there are certainly solutions for the introduction of electric freight bicycles. On the other hand, it is possible to replace the first and second categories of motorized cargo vehicles (cargo vehicle from 1.3 to 1.74 tonnes of total mass), which generate the replacement of nearly 47% of trucked cargo vehicles with freight bicycles.

By introducing bicycles as delivery vehicles, all major delivery problems can be solved in the area included in the project. All the goods listed can be transported by means of cargo bicycles, and all the larger commodities, such as technical goods and some pieces of furniture (i.e. coffee tables, armchairs) can also be transported and delivered via cargo tricycles which can have a maximum load capacity of up to 250 and 300 kilograms. Most goods are delivered by hand or by handcart. If we only include manual deliveries then delivery with a cargo bicycle we can replace 58% of delivery, and if the use of the handcart is only the distance between the parking space of the delivery vehicle and the delivery point, by using the freight bicycles this distance is reduced to a minimum and a handcart is not required. If we include only the sub-process of the type of goods delivery, then we replace as much as 92% of motorized cargo delivery. As stated in the previous paragraph, there is currently no way of fully replacing motorized cargo vehicles by bicycles, as there are still delivery places where the

forklifts are used, which means large quantities of goods unloaded at one time, with which freight bicycles have a difficulty competing with.

The delivery area is the urban centre of the city, where there is a large movement of, not only delivery trucks, but also all forms of city traffic and transportation, such as: personal motorized vehicles, trams for public transport of passengers and large amounts of non-motorized traffic, especially pedestrians. Replacing motorized freight vehicles with freight bicycles would help relieve the traffic in the observed area. Just by looking at the width and length of bicycles, they would drastically reduce the space that is currently occupied by motorized vehicles. As bicycles are required by law to move along the roads together with cars, if there are no bicycle lanes plotted, the “yellow” lanes, which are in use for only public transport vehicles and in this case trams, would ideally serve for movement of freight bicycles. At the observed corridor of the project, other traffic participants can easily overtake them, and in the moments of passing trams the need for climbing on the sidewalk is not a problem due to the large number of levelled road edges (on average about 3 places every 100 meters street side).

When we consider the quantity of space reduction, we must include the size of parking lots for freight delivery. If we consider only small cargo of deliveries by freight bicycles, parking lots are not needed for those types of delivery. Thus, by removing parking spaces, it would free up space for other forms of traffic. Then delivery points of distribution would not be necessary to define because all the delivery points would become street delivery and regarding the size of the bicycle they would not pose as an obstruction for any form of motorized or non-motored traffic in the vicinity. This reduces the delivery time, if we look at the problem of length of delivery as the distance between the parking lot and the delivery location, the delivery duration can be reduced to 93% of all delivery being less than 15 minutes. On the other hand, by leaving these same parking spaces, a motorized freight vehicle parking space can usually hold up to four freight bicycles. The biggest problem would be, if there is a need for these parking spaces, the safety and security of these bicycles. That is why it is necessary to build a safe way to lock the bicycles in these parking places or apply one of the ideas currently used in the city of Copenhagen.

All the aforementioned solutions are based on the type of delivery called the last mile delivery. When considering motorized freight vehicles deliveries, delivery is conducted from the warehouse to the point of delivery. As the average length is about 76 kilometres, then it is virtually impossible to carry out this type of delivery by bicycle. On the other hand, research by the "Cargo Bike Croatia" student initiative has shown that the average driver with the load of 150 kilograms on a freight bicycle can travel up to 66 kilometres. If we add to that equation bicycles with electric assistance the average distance of 76 kilometres could be surmountable.

It should also be mentioned the possibility of using a bicycle-train-bicycle type of delivery. The distance to the main railway station in Zagreb is only 2 kilometres from the observed delivery area. By using this type of delivery system it will only depend on the connection of the railway line from the location of the warehouse of a particular company using this type of delivery.

Delivering goods by bicycle would greatly contribute to increasing sustainable mobility in the urban area of Zagreb. By not using motorized vehicles, we completely reduce the noise levels caused by freight vehicles and with less fuel usage and usage of diesel engines, reduction of exhaust emissions and CO_2 emissions will come to zero. During the research conducted, there was no detailed analysis of vehicle that carried furniture and other household goods, although carriers of such goods were marked, so a certain percentage of vehicles can be extracted from the current analysis.

When considering the size of a package that is transported, other than a pallet, cargo bikes have the option of transporting all forms of goods such as envelopes, boxes, chests and crates. The frequency of delivery is one of the most important segments in the observed area. Food products, primarily bread, and kiosk goods have the necessary daily delivery and thus become the ideal

candidates for deliveries by cargo bicycles. Such application of the solution reduces the amount of motorized freight vehicles to a minimum.

In conclusion, when comparing the smallest and midsized category of motorized cargo vehicles, one motorized van can be replaced by two freight bicycles by the number of deliveries. According to the load capacity, one motorized freight vehicle of category I (total masse of 1.3 tonnes) may be replaced by three freight bicycles. The average speed of three cargo bicycles, with electric assistance, exceeds the speed of motorized cargo vehicles by 2.3 kilometres, shown by the research project "Pro-E-Bike" of the “Hrvoje Požar” Energy Institute. [8]

5 BUSINESS CONCEPT - TRANSPORT SERVICE OF GOODS USING BICYCLES IN THE CITY OF ZAGREB

The establishment of a new company with the basic task of delivering goods by means of freight bicycles in the urban area of the city requires a good starting location for the distribution of cargo. For the city of Zagreb, the proposed location is Ulica kneza Branimira 24 located near the Main Railway Station. For the delivery concept, a test sample was used form the company TNT delivery form Brussels.

Beginning of a working day is originated form the business area of Buzin from where a truck hauls and transports a mobile storage container every day to the city centre location mentioned above, and this warehouse serves as the starting location of the distribution and ending point of every delivery route. The depot has the capability of supplying 5 freight bicycles with an average payload of about 100 kilograms and a possibility of carrying about 100 packages of an average payload of 3 kilograms with dimensions no larger then 34x32x10. The distribution of smaller packets from 0.5 to 1 kilograms is also possible (A4 documents, pictures, mobile phones, digital cameras) and larger packages from 12 to 25 kilograms (books, clothing, footwear, toys, smaller televisions or computers). Delivery will be based on supplying stores across 5 different zones and the concept will be making contracts with local small shops for faster and more efficient delivery, and also due to the lack of parking spaces for bicycles in the city of Zagreb the supply will be directed toward street and ground floor stores. The order of delivery services is only possible for next day delivery because of the need of resupply of the mobile depot with goods, but it provides services of collection and further distribution the goods.



Figure 1 – Mobile depot by TNT Express
Source: [9]

The zone where distribution of goods will take place are divided according to delivery price, the average number of deliveries and packages per day, and the delivery time for different locations. Delivery time is taken as an average of 30 minutes for all deliveries. For zones 1 and 2 the expected profit margin of 10% was taken and for other zones profit margin of 15%.

Delivery zones, delivery rates, and maximum number of deliveries and packages per delivery zone are:

- **Zone 1:** includes space from Main Train Station, Mihanovićeva, Jukićeva, Kačićeva, British square, Ilica, Gornji Grad, Kaptol, Ribnjak, Vlaška, Kvaternik square, Šubićeva, Branimirova Street and back toward Main Train Station

  Price: €5.1

  Max. **number of deliveries daily:** 10

  Max. number of packages daily: 30

- **Zone 2:** from public transport terminal Črnomerec, Trešnjevka neighbourhood, Selska and Horvaćanska intersection until Gojka Šuška Avenue and Mandlova Street

  Price: €5.1

  Max. **number of deliveries daily:** 10

  Max. number of packages daily: 30

- **Zone 3:** Dubrava, Novi Zagreb, Mlinovi, Rudeš, Vrbani and Pantovčak neighbourhood until Street number 150

  Price: €6.75

  Max. **number of deliveries daily:** 5

  Max. number of packages daily: 12

- **Zone 4:** Prečko, Špansko, Malešnica, Jankomir until Jankomir Street, Buzin, Žitnjak until the railroad, Mikulići, Šestine, Remete, G. Dubrava and Sesvete neighbourhood until Lj. Posavskog Street

  Price: €6.75

  Max. **number of deliveries daily:** 5

  Max. number of packages daily: 12

- **Zone 5:** Jankomir from Jankomir Street, Podsused, Blato, Botinec, Hrašće, Markuševac, Miroševac and Sesvete until Lj. Posavskog Street

  Price: €9.72

  Max. **number of deliveries daily:** 3

  Max. number of packages daily: 5

The package delivery price per zone is determined when the company's total costs are considered. The price is set at the level of the first year of business. If there is high income after the first year, it is possible to lower the cost of delivery per package. Also by increasing the number of packages the price is not doubled, but the average price is taken if two or more packages are delivered to the same costumer.

The company also offers advertising and promotions. Advertising spots are placed on the bicycle cargo spaces and on the mobile depot panels. Ads will be placed for 3 different companies "VIPnet", "Ožujsko - Zagrebačka pivovara" and "Sindikat biciklista". The calculation is made assuming that the company "VIP" contributes with €12 per day for advertising, "Ožujsko" with €8 and "Sindikat biciklista" with €4. Number of advertisements are counted as a number of bicycles (one

advertisement per bicycle) on an annual basis. Considering the size and the offer of advertising, all of the ads can make an income of €5,280 per year.

In ideal conditions, total revenue from delivery services and advertising amounts to €119,599 per year.

When considering company's sales costs, first agenda is driver costs. All drivers receive an equivalent of €4.6, employer's pay (gross 1) increased by extra allowances of 17.2%, and offer of free days (vacation and sick leave) is 6 weeks per year. Delivery services are only offered on working days, and thus the required working time is 220 hours per year, but due to the different conditions of delivery zones, a different cost per driver annually will be generated. Cumulatively the costs are €21,497 per year.

Other sales costs include maintenance of bicycles. The average annual repair of all bicycles is €267 per bicycle, and the budget for unforeseen situations adds up to 30% of the average annual maintenance of one freight bicycle.

The cumulative sum of sales costs is €23,230 per year.

Other company expenses are depreciation, insurance, and general expenses and costs of enterprise management. Depreciation is calculated as a combination of new store bought bicycle prices and bicycle life expectancy. The company operates with 5 freight bicycles, two "Sorte Jengerts Carr" freight tricycles with a new purchase price of €1,500 and life expectancy of 5 years with a maximum payload of 150 kilograms. Two "Bullit Red" bicycles with a price of €1,800 and a life expectancy of 6 years and a maximum payload of 100 kilograms. One "Hercules Cargo" freight bicycle with a life expectancy of 3 years and a maximum carrying capacity of 45 kilograms. Depreciation costs cumulatively fall to €1,500 per year.

Insurance costs total €11,160 per year, divided into bicycle insurance and driver insurance. Bicycle insurance was taken as a sum of 10% of the purchase price of each bicycle, while the driver's insurance is assumed as half of the minimum insurance compared to the insurance in case of an car accident for each driver.

Costs of management and general expenses include manager costs, purchase price and maintenance costs (computers, telephones, mobile depot), legal costs, marketing costs, truck and truck driver rental costs. Cumulative costs fall to €64,667 per year.

In the text above are all the costs of the company determined for the first year of operation, the total cost amounts to €100,557 per year. Expected gross profit on an annual basis, with no change in monthly profit, is €96,369 or 81% of total revenue, while the actual net profit of the company is €19,042 or 16% of total revenue.

It is difficult to expect such profits, especially in the first year of work. The calculation of profits does not include the changes of the seasons, the difficulty of weather conditions, and thus can not be taken as the final calculation of the profits of the enterprise, but that is why this chapter shows only profits in ideal conditions. The calculations were made by using real data from legal regulations of the Republic of Croatia, independently collected from employees of the company "BikeExpress d.o.o." and some data was independently determined by the author of the work to contribute to the concept of establishing a company supplying goods by means of freight bicycles in the city of Zagreb. It is also assumed that freight non-motorized vehicles can move on the “yellow” routes or public transport routes, but at the same time have no preference over the public transport services of passengers in the city of Zagreb. [10]

It is worth mentioning the key performance indicators of a company that show actual positive aspects of introducing delivery by means of cargo bicycles in the city of Zagreb and the omission of motorized freight vehicles. Key performance indictors can be found in Table 1.

Table 1 – Key Performance Indicators

Average speed (km/h)	*13*
Rider hours / Year	*3.630*
Total miles per year	*35.393*
Cost per km:	
Bike (€)	*0,05*
Rider (€)	*0,61*
Expenses (€)	*2,18*
***Overall cost per km** (€)*	*2,84*
Cost per hour:	
Bike (€)	*0,48*
Rider (€)	*5,92*
Expenses (€)	*21,30*
***Overall cost per rider hour worked** (€)*	*27,70*
CO_2 savings (kg/year)	*12.813*
Fuel savings (kg/year)	*3.834*

Source: by authors, based on [1]

Key performance indicators are, in the end, the most important indicators of changes between the use of freight bicycles and motorized freight vehicles for delivery services. The data is based on gross or net profits of the company. The average speed of cargo bicycles during delivery is about 13 km/h. Bicycle cost per kilometre is €0.05 and €0.48 per hour. Driver costs are slightly higher and amount to €2.18 per kilometre and €5.92 per hour. At the annual level, the total cost per kilometre is €2.85 and €21.30 per hour. Finally, the most important indicator, which is actually the primary purpose of this type of delivery system in the urban area of Zagreb, is the reduction of harmful gases (CO_2) to 12.813 kg/year, which is great result considering quality of life and health benefits to all citizens. Results are also formulated in fuel consumption savings, which at current market prices dictates a reduction of 3,834 kg/year.

6. CONCLUSION

The use of freight bicycles in freight transport would be of great benefit to the development of every city in Europe. Freight bicycles can be used to perform various tasks, not only limited to delivery of mail and packages, but can also be applied to the maintenance of city parks as well as collection and transportation of waste.

In the cases described in the article, municipal utilities and councilors using cargo bicycles are very satisfied with their vehicles. The continued expansion of interest in the use of freight bicycles is shown by demands of other employees, in state or city services, and their applications in new and diverse jobs that have not yet been discovered at a large scale. Introducing cargo bicycles to city officers as a test, is an excellent way of development of bicycle freight transport and would greatly contribute to increasing number of the bicycle fleet in the city.

By applying these measures from chapter four, proposal of a new delivery concept using freight bicycles based on the "Trailblazer" project, it would be possible to solve not only the problems of high numbers of motorized freight vehicles in cities but also personal motorized vehicles. The promotion of non-motorized forms of transportation, especially bicycles and freight bicycles, and increasing the awareness of the city's population about their benefits is the most important step in achieving sustainable mobility in urban areas of cities. The cost of implementing measures, compared to other forms of transport of goods and passengers in cities, is very small and therefore very achievable.

An example of applying freight bicycles as form of delivery in the city of Zagreb is given in the fifth chapter, business concept - transport service of goods using bicycles in the city of Zagreb, of this article. The research of setting up a small start-up company, based on the concept of the company TNT from Brussels, shows a very large net profit of €19,000 equivalent of 16% of total revenue. It should be noted that results of the research is shown on an annual basis and only for the first year operations of the company. There are also no monthly changes according to calculations, that is the impact of changes in weather conditions is not included in monthly changes and thus is not included in the company net profit. In order to establish the start-up company from the survey, big investments are needed, but the profitability of using non-motorized freight vehicles far surpasses using motorized delivery vehicles.

Future research on in this subject is still needed. For freight bicycles to have a larger impact in the modal split of the city, critical moves must be taken considering first the laws and regulations of the cities non-motorized traffic and also applying them correctly. Next move is designing and constructing appropriate infrastructure for bicycles and other forms of non-motorized transport. Only then can a start-up company have a regular flow of income and the way to change the mobility in the urban areas of the city.

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ROADSIDE SERVICE FACILITIES IN THE REPUBLIC OF CROATIA

ABSTRACT

The paper deals with the meaning, distribution, standardization and design solutions of the service facilities along motorways in the Republic of Croatia. It studies the future needs and provides guidelines for the implementation of new services and equipment keeping in mind the traffic safety, as well as additional possibilities of such facilities (impact on the development of the local community, contribution to the Croatian tourist offer). Based on the carried out survey and analysis of the locations and services of the road service facilities on motorway A1 the paper gives concrete proposals for the solution of the observed drawbacks.

KEY WORDS:

Roadside service facilities; designing; Croatian motorways;

1. INTRODUCTION

The roadside service facilities (RSFs) are components of motorways intended for the requirements of vehicles, drivers and passengers. Depending on the type of the accompanying service facility, it will provide rest, recreation, maintenance of hygiene, refreshment and information for drivers and passengers, and supply of fuel and consumables for vehicles with adequate area for vehicle parking. Apart from other road elements that include routing, facilities on the route, protection buildings, traffic equipment and traffic signalisation, they are important elements that ensure safe traffic flows.

The concept of roadside service facilities on the Croatian motorways has been made in accordance with the internal document "Proposal of the Layout of Roadside Service Facilities on Croatian Motorways" by HUC from 1993. It is based on RSFs siting according to the standardization and standardized distances between single types taking into consideration the terrain diversity (lowland and hilly terrain). The land for their requirements was purchased immediately while constructing the motorways. It should be noted here that while consulting the experiences of other countries (Germany, Austria, Italy, France), the German approach to solving the RSFs prevailed, in spite of the fact that their motorways are not toll-charged.

The factors that affect the location and design of different types of roadside service facilities are primarily traffic-related, and the most important among them that can be emphasised are: distances between grade-separated intersections, volume of the traffic (average annual daily traffic – AADT and average summer daily traffic – ASDT), traffic flow structure, fuel reserves, travelling speed, travelling time. The design and capacity (type) of the service facility depends on the volume and structure of the traffic flow. The design and selection of the locations of roadside service facilities require good analysis of the traffic flow and take into consideration the share of cargo vehicles, purpose of passenger trips,

origin and destination of passenger trips, national structure of passengers, habits of passengers, and estimate their structural changes in the near future.

In the future, the roadside service facilities in the Republic of Croatia will have to increase their capacities because of the tendency of traffic growth on motorways, and thus opening the possibility to improve and expand the scope of services provided by the roadside service facilities.

This paper proposes a solution of siting electrical charging stations along the Croatian motorways to connect with other countries of the TEN-T network.

2. ANALYSIS OF ROADSIDE SERVICE FACILITIES

2.1 Practice of Locating Roadside Service Facilities in the Republic of Croatia

The practice of locating the roadside service facilities in the Republic of Croatia originates from the 1950s, and one of the first roadside service facilities not only in Croatia but also in the region, was the "Old Oaks" as part of the motorway which stretched from Zagreb to Belgrade.

In the latest National Report of the Croatian Association of Motorway Concessionaires (HUKA) for 2016, the Croatian motorways in their length of 1,313.8 km in one direction (which is approximately 2,628 km in both directions) being managed by four companies, had a total of 123 rest areas along the motorway, on average every 22 kilometres (Table 1).

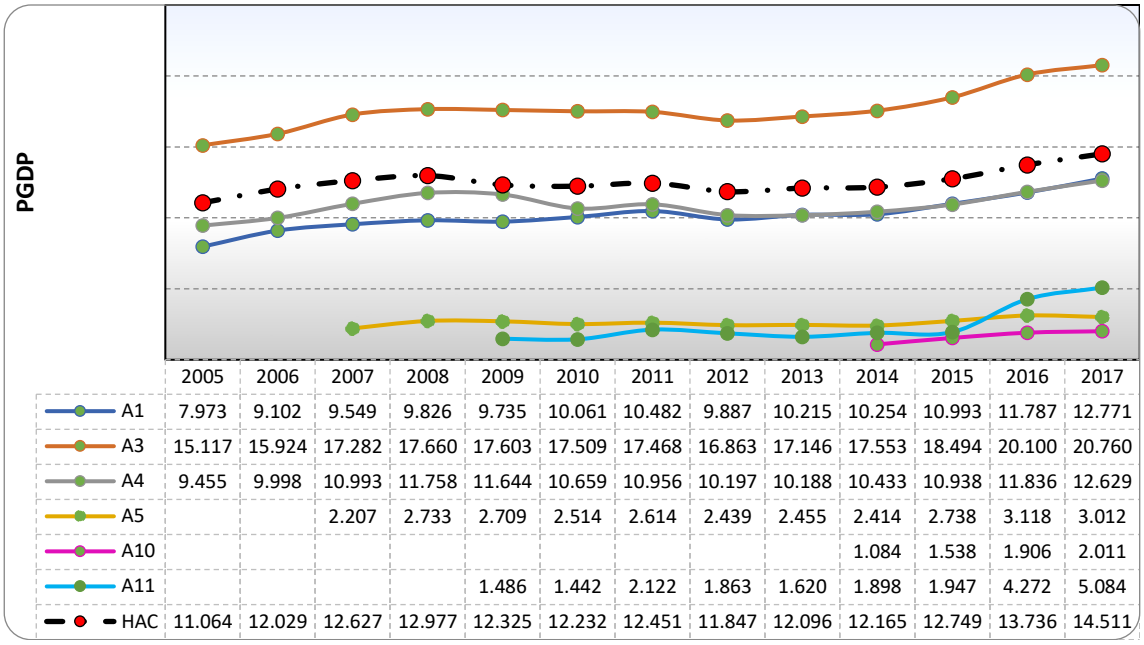
Table 1 – Total number of service facilities in Croatia

	Total number of rest areas	**Petrol stations**	**Coffee bars**	**Restaurants**	**Parking areas for heavy vehicles**	**Hotels**
Total number of facilities along the Croatian motorways	123	75	85	24	118	10
Average distance between the facilities	23 km	29 km	21 km	48 km	24 km	262 km

Source: [1]

In planning, defining and designing the RSF on motorways as roads of high level of service, the basic models, distribution, types and services of the RSF locations as the components and functional parts of motorways are defined and included in its corridor. They are based on the traffic volume of motorways and facilities based on the average annual daily traffic and growth index of the total traffic on motorways (Figure 1).

The traffic volume on the Croatian motorways according to the HAC report for 2017 amounted to 14,511 veh/day. For the Republic of Croatia, the average summer daily traffic (ASDT) is also of great importance, which is very significant in the selection of locations, defining and setting of service facilities, and according to the mentioned report it amounted to 26,338 veh/day (Table2).



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
A1	7.973	9.102	9.549	9.826	9.735	10.061	10.482	9.887	10.215	10.254	10.993	11.787	12.771
A3	15.117	15.924	17.282	17.660	17.603	17.509	17.468	16.863	17.146	17.553	18.494	20.100	20.760
A4	9.455	9.998	10.993	11.758	11.644	10.659	10.956	10.197	10.188	10.433	10.938	11.836	12.629
A5			2.207	2.733	2.709	2.514	2.614	2.439	2.455	2.414	2.738	3.118	3.012
A10										1.084	1.538	1.906	2.011
A11					1.486	1.442	2.122	1.863	1.620	1.898	1.947	4.272	5.084
HAC	11.064	12.029	12.627	12.977	12.325	12.232	12.451	11.847	12.096	12.165	12.749	13.736	14.511

Figure 1 – AADT on Croatian motorways from 2005 to 2017
Source: [2]

Table 2 – Traffic effects on motorways managed by HAC in 2016 and 2017

Ord.No.	Motorway	Motorway length (km)	Traffic - AADT	Traffic - AADT		Traffic - ASDT	Traffic - ASDT		Veh-km (mil.)
			2016	2017	Relation 2017/2016	2016	2017	Relation 2017/2016	
1	A1 Bosiljevo-ČCP Karamatići	415.7	11,787	12,771	1.083	29,322	31.121	1.061	1,943,059
2	A3 Bregana - Lipovac	306.4	20,100	20,760	1.033	27,670	28.153	1.017	2,328,085
3	A4 Goričan - Zagreb	96.4	11,836	12,629	1.067	19,270	21.356	1.108	445,569
4	A5 Osijek - Svilaj	56.2	3,118	3,012	0.967	3,229	3.593	1.113	61,962
5	A10 Border B&H-node Ploče	6.7	1,906	2,011	1.055	3,949	3.950	1.000	4,931
6	A11 V.Gorica South - Lekenik	29.7	4,272	5,084	1.190	4,387	4.919	1.121	55,453
TOTAL AC		911.1	13,736	14,511	1.056	25,092	26,338	1.050	4.839.059

Source: [2]

Table 2 shows a positive annual change of AADT, as well as of ASDT. With the growth of traffic both of AADT and ASDT, it may be concluded that in the future the needs for the number of rest areas and their services will increase, in order to provide high-quality service for safe journey of the users. The

future requirements can be satisfied by expanding the services and capacities of the existing RSFs, and by constructing new ones in favourable locations that would attract even more users i.e. passengers.

For the selection of RSF micro locations in Croatia the following practice has been implemented:

- Approach to the facility is constructed on the section of the motorway with good visibility ($L_p \geq 6V_p$; L_p- length of visibility [m]; V_p- design speed [km/h], and in less favourable conditions exceptionally $L_p=4\ V_p$); regarding the layout this means that locating is possible in the area of larger route radii $R \geq 2R_{min}$ (at least twice as large as those stipulated for the design speed, V_p) [3];
- Avoiding locations on bigger longitudinal slopes (over 3%), since these sections include lanes for slow vehicles and they cause weaving of the transit traffic with the traffic towards roadside service facilities;
- Attention is focused on generally accepted distances of the service areas from the tunnel portals due to traffic safety, clear signalization, and motorway capacity;
- The distance between the exit/entry area in RSFs and adjacent intersections needs to ensure the required level of service and traffic safety, and the limit distance is 1,500 m.;
- Provision of necessary visibility length in the area of entries and exits to and from the roadside area;
- Attraction of the RSF micro location depends also on the quality and attractiveness of the respective area;
- It is desirable to locate RSFs of higher level on sections along the urban areas;
- Great attention is given to the location that allows access to a watercourse, lake or a lookout point on attractive terrains in order to make the maximum use of the RSF location.

2.2 Conceiving the roadside service facilities in the Republic of Croatia

The starting point of conceiving an RSF along Croatian motorways is the division into four types of facilities (A, B, C and D) regarding the services they provide. Type A contains a rest area with a parking lot, sanitary appliances and potable water, fuel supply station with a shop and a café, restaurant and a motel. Type B contains a rest area with a parking lot, sanitary appliances and potable water, station for fuel supply with a shop and a café and a restaurant. Type C contains a rest area with a parking lot, sanitary appliances and potable water, fuel filling station with a café. Type D is the simplest form of the rest area with a parking lot, sanitary appliances and potable water. Their distribution along the motorway with the applied criteria for distance measurement has been presented in Table 3.

Table 3 – Program standard and criteria of locating RSFs along the Croatian motorways

Type of facility (RSF)	Lowland terrain	Hilly terrain
A	120 – 180 km	80 – 120 km
B	60-90 km	40 – 60 km
C	30-45 km	20 – 30 km
D	15 – 22,5 km	10 – 15 km
Average driving speed on the motorway	90 – 110 km /h	80 – 100 km/h
Travelling time of effective driving	8 – 10 h/day	8 h/day
Rest	every 3 hours	every 2 hours
Fuel reserve	25 – 50 km	25 – 30 km
Minimal distance between adjacent junctions	25 km	20 km

Source: [4]

2.3 Siting of Roadside Service Facilities in the Republic of Croatia

Siting of roadside service facilities along toll-charging motorways in the Republic of Croatia is far from ideal. The reason for poor siting is the late adopted regulation of constructing RSFs in Croatia, brought in 2005 when more than 60% of the current motorway network had already been built.

Therefore, the roadside service facilities have been constructed in an elongated form along the motorway in the stress zones.

While siting the roadside service facilities along motorways in Croatia, great attention has been paid to siting in relation to the intersection. Intersections on motorways, regarding the choice of location and design method, have advantage over all other facilities. Because of the analysis of determining the optimal, limited and exceptional distances of RSFs from the intersections, a distribution of the roadside service facilities has been defined. The distance of RSF from the junction area includes the section of signalisation setting for the requirements of exit from the motorway (TSZ_1) and entry to the motorway (TSZ_2), grade-separated intersection (GSI), and traffic calming zone (TCZ). The traffic calming zone contributes to the relaxation of the driver and driving comfort, and it is desirable that it is of bigger length (even 5,000 m) (Figure 2). [3]

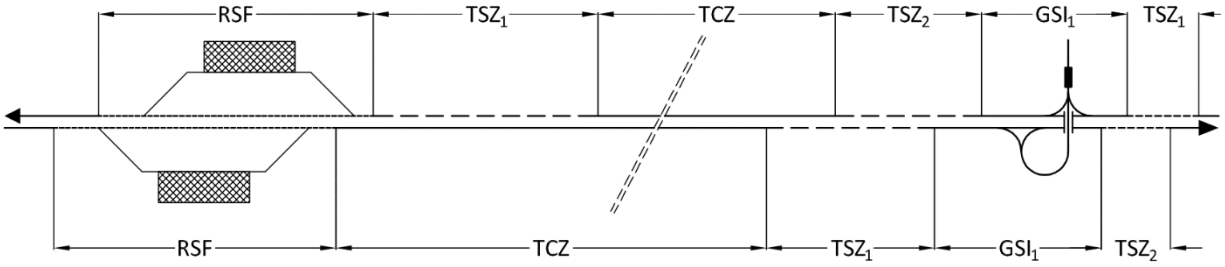


Figure 2 – Locating roadside service facility on the motorway segment

Minimal distance of the roadside service facilities from the grade separated intersection on Croatian motorways (minimal distance between the end of the accelerating lane from the previous connection and the beginning of the lane for diverging towards the roadside service facility) should amount to (regardless of the terrain configuration) at least 600 m. The condition for vertical signalisation is that pre-signalisation is set at 1 km distance from the roadside service facility. Only in exceptional cases (space limitation, terrain configuration, etc.) it is possible to perform the entry to the roadside service facility and exit from the motorway as joint exit from the motorway towards RSF, and design on the exit or in the interspace different horizontal or vertical signalisation (supplemented by portals and semi-portals).

2.4 Design Solution of Roadside Service Facilities

The exit from the motorway for the purposes of RSFs is performed by designing deceleration lane L'_E which consist of a widening section (l_c) and length of deceleration (l_d). In the exit area the expected speed is $0.8V_p$ (V_p is the motorway design speed in km/h). The required length of widening is determined from the conditions of the vehicle running at adapted speed through time t=3s. The frame deceleration values d is taken from 1.2 to 1.5 m/s^2, and V_p' is the design speed of the diverging road in km/h. The lane elements for exit from the motorway are presented in Figure 3, and they are determined from the following formulas:

$$l_c = \frac{0{,}8 * V_p * t}{3{,}6} \ [m] \qquad (1)$$

$$l_d = \frac{(0{,}8 * V_p)^2 - (V'_p)^2}{26 * d} \ [m] \qquad (2)$$

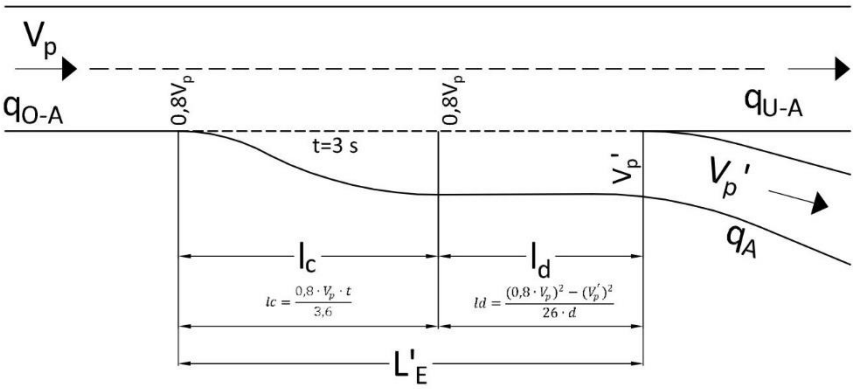


Figure 3 – Design solution of diverging from the motorway to enter RSF with the basics of calculation
Source: [5]

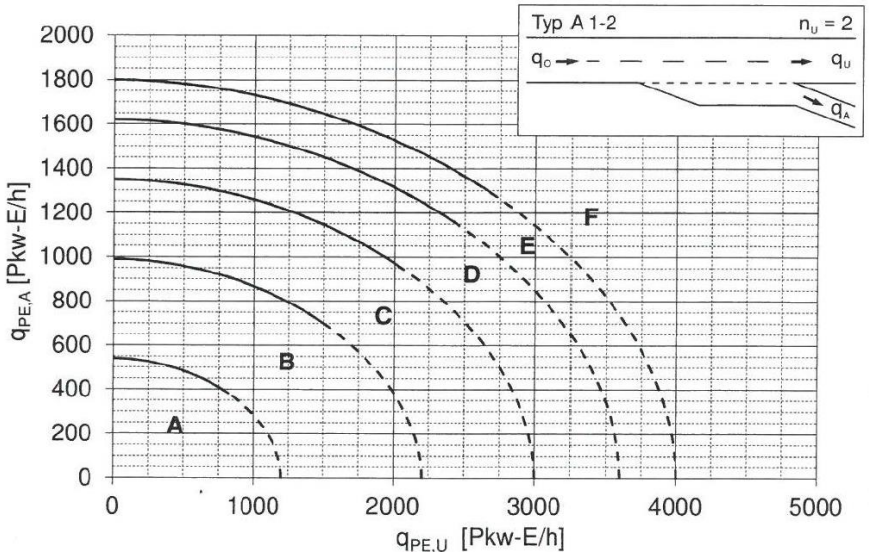


Figure 4 – Volumes of traffic flows in the exit area with the respective Level of Service
Source: [6]

In order to determine the volume of traffic flows with respective level of service a graph may be used in the exit area (Figure 4), where $q_{PE,U}/q_{U-A}$ is the flow of passenger cars on a two-lane motorway, and $q_{PE,U}/q_A$ is the exit flow.

Entry to the motorway from RSF (Figure 5) is performed by a specially designed acceleration lane L_E" which consists of the length of acceleration (l_a) and lane narrowing section (l_c). Length l_c is determined as in the previous case for the widening, and the necessary length of acceleration section is determined for the acceleration values a=0.8 to 1.0 m/s^2. V_p" is the design speed on the exit road from RSF in km/h. Since the merging of the traffic flow needs to be harmonised with the occurrence of free time gaps on the motorway lane, the merging/including lane is of greater length than the diverging/excluding lane. The acceleration section is determined from the formula:

$$l_a = \frac{(0{,}8 * V_p)^2 - (V''_p)^2}{26 * a} \ [m] \quad (3)$$

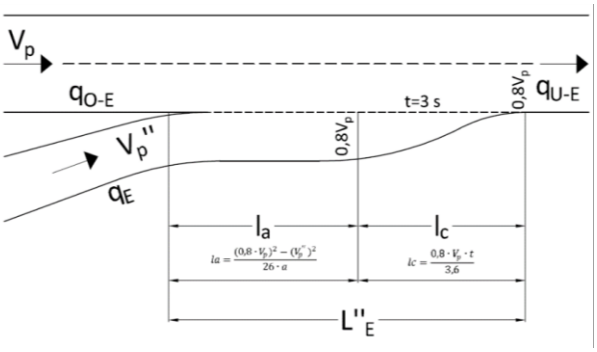


Figure 5 – Design solution of merging into the motorway from RSF with the basics of calculation
Source: [5]

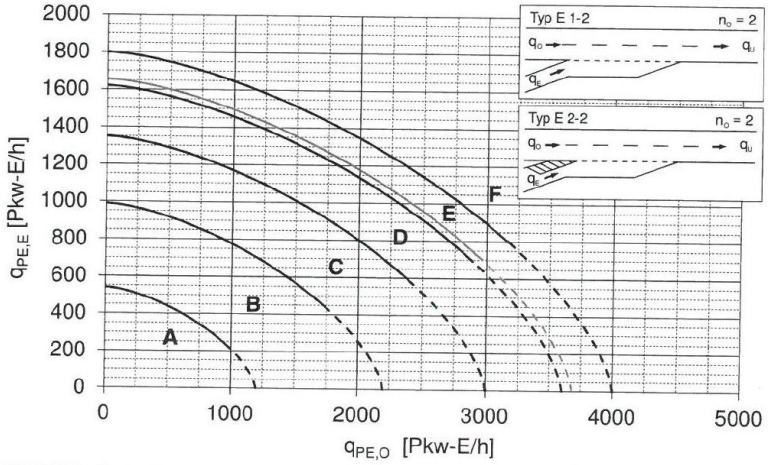


Figure 6 – Volumes of traffic flows in the entry area with respective Level of Service
Source: [6]

In order to determine the volume of the traffic flows with respective level of service a graph may be used in the entry area (Figure 6), where $q_{PE,O}/q_{O-E}$ is the flow of passenger cars on a two-lane motorway, and $q_{PE,E}/q_E$ is the entry flow. The volumes of traffic flows in the entry and exit area can also be determined according to the HCM (Highway Capacity Manual) methodology.

The method of solving the merging manoeuvre onto the motorway and diverging from the motorway has been regulated by the Regulations about the conditions for the design and construction of connections and approaches to public road (NN 84/11, 22/13, 54/13, 148/13).

2.5 Internal and External Design of the Roadside Service Facilities in Croatia

Good external design and orientation means that the driver decides on time and unambiguously for the manoeuvre of diverging from the motorway and that the manoeuvre is done on time and without any risk, both for oneself and for other traffic users. Good external orientation needs to be provided by vertical and horizontal signalisation before the roadside service facility as well as by good visibility. Apart from good signalisation, in external design of the roadside service facility the appropriate position of the roadside service facility itself needs to be ensured, as presented in Figure 7.



Figure 7 – External orientation of the roadside service facility on the motorway in relation to the driving direction
Source: [7]

In internal design of roadside service facilities, the clear meaning of the elements distribution is of great significance. The driver needs this internal comprehensibility at the moment when they get with their vehicle to the beginning of the entry ramp, i.e. in the RSF area. Good internal organization and design are especially important to the drivers of heavy vehicles that due to their dimensions are limited in movements.

Instructions for internal design of the roadside facilities along Croatian motorways are:

- Traffic guidance along the shortest possible ways to parking lots intended for particular types of vehicles;
- Unambiguous and simple signalisation that follows within such intervals that the driver can understand it effortlessly;
- Heavy vehicles are to be guided to the parking lot along the shortest possible route;
- Internal traffic has to operate in the same direction as the traffic on the motorway;
- Vehicles that use this break only to fill up their tanks have to be provided with return to the motorway without having to drive across the entire platform of the roadside service facility;
- Internal traffic in the facility itself shall not be mixed with transit traffic (in case of joint exit to diverge from the motorway to the roadside service facility);
- The order of services provided at the roadside service facility should be as follows: filling up fuel, parking, refreshment, rest, overnight stay;
- Arrangement of vehicles according to type and size (passenger cars closer to the rest facility), introduction of oblique parking (entry, exit) for the sake of space saving. [3]

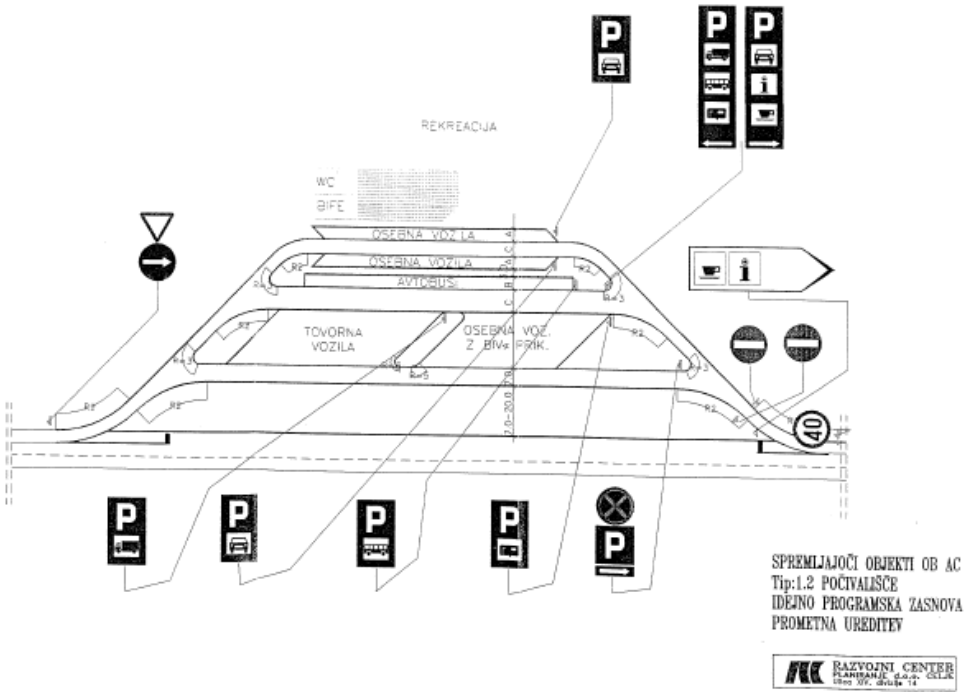


Figure 8 – Roadside service facility, design solution
Source: [8]

Figure 8 presents an example of a good organization, design solution and marking of the parking area within the RSF.

2.6 Analysis and Proposals for Improving the Roadside Service Facilities on Motorway A1 Zagreb - Split - Dubrovnik

Based on the carried out survey of the RFS users on Motorway A1 conclusions can be made and proposals given for the improvement of the roadside service facilities in the Republic of Croatia. The

survey contained 19 questions, and all of them were of closed type. The survey was e-mailed also to truck drivers in two transportation companies, in order to obtain the opinions of professional drivers, and to professors at the secondary vocational school in Daruvar – transportation course, in order to obtain the opinion from the transport profession. The size of the collected sample in the survey was 123, and the collected sample includes all adult age groups, in order to obtain best possible representativeness of the sample thus achieving maximal reliability of the results. [9]

Modern designed roadside service facilities on Motorway A1 should provide, apart from primary necessary safety, also secondary requirements during travelling that would include all kinds of information, exploring tourist attractions, banking, specific needs of disabled persons, etc. From the carried out survey one may conclude that the roadside service facilities on Motorway A1 lag behind regarding the secondary needs because the users visited RSFs exclusively for primary needs (short rests or fuel supply). Since the passengers visit RSFs on Motorway A1 mostly to satisfy their primary needs, they should be provided maximum safety by better designing and distributing the roadside service facilities in relation to the grade separated intersections so as to avoid failures such as the case at RSF Zir where not enough space has been provided for the traffic calming zone and traffic signalisation.

Apart from these shortcomings of the distribution of the roadside service facilities on Motorway A1, it should be mentioned that some rest areas are just desolate and empty parking zones, such as RSFs Jadova, Brloška Dubrava, Ličko Lešće, Pristeg, Sitno and Radošić. Those roadside service facilities that provide certain services are often located at poorly selected or poorly used locations. As an example of a poorly used location there is the roadside service facility Jezerane West since there is no catering facility that would complete the tourist offer at a well-selected location, and some RSFs have been uneconomically designed (RSF Marune and RSF Rašćane Gornje).

The increase of traffic will result in the reduction of safety at RSFs, which had not been planned during the construction, and some RSFs are laid out too close to the grade separated intersections without having provided enough space for the traffic calming zone. Such an example can be seen at RSF Zir. At Zir location there was the possibility of designing the traffic calming zone and the signalisation so as to provide maximum safety to passengers and for the RSF to be in compliance with the standards for four characteristic zones (Figure 2). The proposal for the improvement of RSF Zir is as follows.

The distance from RSF Jadova to RSF Zir is 10,400 m, and the distance from RSF Zir to RSF Marune is 27,070 m, and the distance from RSF Marune to RSF Jasenice is 11,320 m. When proposing the siting and design of these four RSFs, first the volume and dynamics of the traffic flow on the motorway section from junction Gospić to junction Maslenica had to be considered. The reason lies in the fact that every design, service and location of the RSF depends on the national structure of passengers, their habits, purpose of travelling, trip origin and destination, share of heavy vehicles, knowing the road, frequency of travelling, etc. For the mentioned four RSFs, it may be determined that their distribution is not good in relation to the grade separated intersections, and that the services at RSF Zir and RSF Marune are not good because both RSFs have a facility for overnight stay, i.e. motels. Such a service is unnecessary at RSF Marune where the motel is exposed during the entire year to strong winds and represents a desolate parking zone the whole year round. When selecting the site for the construction of RSF Marune, the aim was to site the RSF on an attractive tourist location with the view of the Croatian coast, not taking into account the economic feasibility of the facility, distance of the RSF from the tunnel Sv. Rok and the rationality of constructing an RSF with a motel. The reason lies in the fact that at some 27 km further there is RSF Zir which offers 32 motel rooms.

The proposal for the distribution of these four facilities is to move RSF Zir towards RSF Jadova which closes down during the winter months and offers then only a parking zone. Such shifting would meet the standards of the traffic calming zone distances and the signalisation zone from the grade separated intersection, not losing the attractiveness of the location. The RSF Zir service would remain the same, except only in case of high traffic increase when it should be supplemented, i.e. expanded.

Another proposal for improvement would be at the RSF Marune. RSF Marune was constructed with unnecessary hotel accommodation capacity and a huge restaurant which is exposed to constant hits of the bora wind (Figure 9).

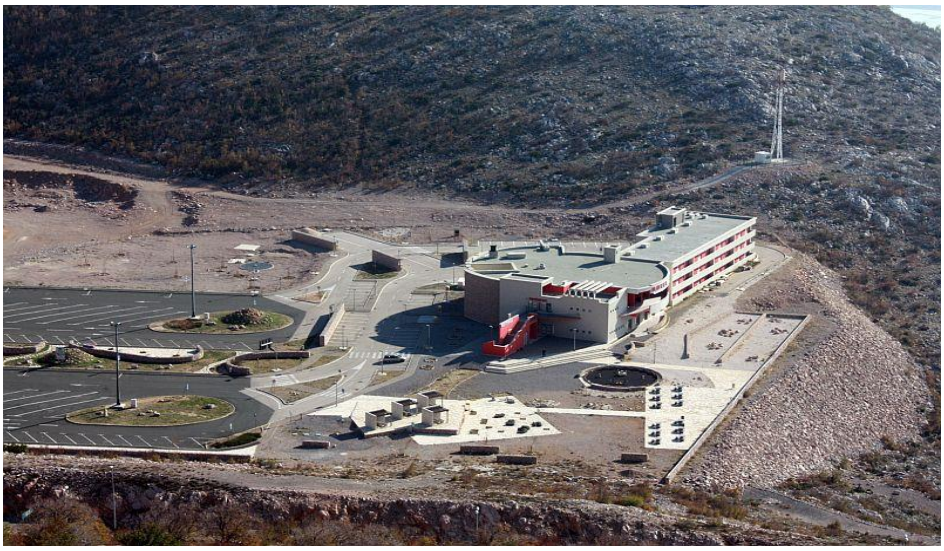


Figure 9 – External design of the roadside service facility Marune
Source: [10]

Apart from strong winds during the whole year, the reason for the deterioration of the roadside service facility lies in the fact that not far away there is RSF Zir which offers in beautiful nature, accommodation to tourists in comfortable ambient with rich restaurant offer of Lika and Dalmatian specialities. Also, the reason may be found in the fact that some ten kilometres further towards the Adriatic coast there is RSF Jasenice, also providing rich restaurant offer, petrol station services, children's playground and an area for passengers' integral vacation, thus attracting a larger number of visitors. If the aim had been to take advantage of the attractive tourist location, this could have been done in a much more cost-effective way. The proposal how RSF Marune should have been constructed, would have been based on the principle of services and design as in case of RSF Krka, of smaller capacity, no petrol station, only with a small shop and small coffee bar. RSF Marune could have been built with good traffic signalisation zone, and better protection against the wind, thus increasing the safety of passengers, economic feasibility of the facility, and the tourist location of the roadside service facility would maintain its use.

The proposals for the improvement of the roadside service facilities on Motorway A1 based on the mentioned survey, apart from expanding the service itself, should be carried out by planning new RSFs at attractive tourist locations where they would enhance the tourist offer of the region through which the motorway is passing, thus motivating the motorway users to use the roadside service facilities not only for their primary but also rather for their secondary needs.

3. FURTHER DEVELOPMENT OF ROADSIDE SERVICE FACILITIES

The Republic of Croatia has a closed traffic system on motorways and therefore, the requirements that need to be satisfied by RSFs are higher. Their accessibility, services, and capacities need to follow the vehicle development trends and passengers' needs and meet the requirements of environmental protection. In the period of RSF revitalisation, they need to assure supply of vehicles with alternative fuels.

The national policy frame for establishing the infrastructure for alternative fuels in Croatia puts emphasis on electrical energy and natural gas. The need to install liquefied natural gas filling stations on the periphery of the cities of Zagreb and Rijeka by 2025, and on the peripheries of the cities of

Zadar, Split, Ploče and Osijek by the year 2030 has been estimated. According to the needs mobile units for the supply of heavy vehicles with liquefied natural gas on motorway rest areas will be provided [11].

On roadside service facilities, the charging of electric vehicles needs to be provided as well. The project NEXT-E from 2017 ensured funds for financing the construction of a network of electric vehicles charging stations within six countries of the Central and Eastern Europe: the Czech Republic, Slovakia, Hungary, Croatia and Romania. As part of this project, the consortium will install 222 multi-standard fast charging stations (50 kW) and 30 ultra-fast charging stations (150 – 350 kW) along central TEN-T corridors and the central network. The realisation of the project will enable covering large distances along six Cohesion countries completely using electric drive. With this project, HEP (the Croatian Electric Company) can install 26 fast and 4 ultra-fast charging stations of the latest technology on the motorways in Croatia. [12]

In the age of care for the environment there are other options regarding RSFs. A positive example is given by Slovenia where the fuel supply stations provide the service of liquefied natural gas supply and charging of electric vehicles. The stations "Petrol" have the roofing construction with embedded solar plates, and within some RSFs even wind power stations have been installed (RSF Ravne / Kozina on Motorway A1 in the Republic of Slovenia).

The application of advanced technologies will also reflect on the future of RSFs. The current project CROCODILE 2 CROATIA should provide coordinated management and control of traffic which will result in high-quality services of informing passengers and more efficient usage of RSFs (e.g. reservation of parking lot for a heavy vehicle). The application of DATEX II standard allows information exchange between traffic control and management centres, traffic information centres and traffic service providers and users. [13]

The improvement of RSFs can be achieved with a multidisciplinary approach to their design and project solution (traffic experts, civil engineering experts, architects, landscape architects). Such approach has been implemented on the French motorways and it does not offer uniform solutions but diverse carefully blended facilities in the ambient, offering an entire series of different additional services (tourist atmosphere of a "Catalan village", horse farm, car museum, getting familiar with local characteristics, etc.).

In relation with the RSF revitalisation on the Croatian motorways also the possibilities of promoting tourist and local values of the area through which the motorway is passing should be considered, and they should provide additional dimension of rest for passengers on long trips. Such approach would reflect positively on the operation of RSFs and on the local community.

4. CONCLUSION

Uniform solutions of the roadside service facilities located at recommended distances prevail in the Republic of Croatia. In selecting the locations the safe driving requirements have not always been respected, the rest and recreation areas have not been located in quiet zones but rather mainly along the motorway, and there is a lack of services that would satisfy the secondary needs of passengers. Therefore, the current solutions should be improved during the process of revitalisation of the facilities having in mind the future needs of the users.

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COMPARATIVE ANALYSIS OF EXTERNAL COSTS OF DIFFERENT MODES OF TRANSPORT

ABSTRACT

This paper gives a comparative look into the differences between intermodal and road transport in terms of external costs. It gives an insight into the contributing factors of intermodal transport external costs. The analysis was made using the data from different studies on external costs of transport and by translating the given data so it could be used for a clear comparison. The results of the analysis indicate how intermodal external costs are higher than those of road transport until a certain length of the trip. In order to make intermodal transport more competitive than road transport on short trips, emphasis should be on reducing the external costs of intermodal transport.

KEY WORDS

logistics; external costs; intermodal transport; sustainability;

1. INTRODUCTION

External costs in the process of transport represent costs which cannot be easily internalised, costs which cannot be directly dealt with, only indirectly by the various effects of external costs. The need for more detailed research into the impact of external costs is in line with the development of logistics and the recognition of the way the external costs affect the population and the planet Earth. Logistics development presents a problem in terms of logistics taking up large amount of physical space, both in needed infastructure and in needed vehicles necessary to carry out the logistics processes, and as such has a role in shaping the landscape and shaping the way of life with different kinds of emmisions ie. electromagnetic emissions or emissions of exhaust gases etc. From those causes comes the need for bringing down the emissions of exhaust gases, by bringing down the number of road freight vehicles and implementing new technologies, as it is known that road freight vehicles after aircrafts have the highest rate of emission of harmful exhaust gases. Resolving the given problem according to European union iniciative lies in reducing the transport of cargo by road and transffering it to railway transport or inland waterway trasnport where intermodality has a big role.

Authors Groothedde and Tavasszy (1999) used the simulated annealing technique to minimize generalised and external costs in order to find the optimal location of intermodal rail/road terminals. Terminals were added to the network randomly in order to find the optimal locations of terminals and the total generalised and external costs were calculated for each network configuration in order to find the optimal locations. [1]

2. COMPARATIVE ANALYSIS OF INTERMODAL TRANSPORT EXTERNAL COSTS AND EXTERNAL COSTS OF VARIOUS MODES OF TRANSPORT

The analysis is going to, as much as possible, show relation of external costs of intermodal transport and external costs of road and/or rail transport. While comparing, not every type of external costs is going to be compared, due to the lack of research and differences in measurement units. The main source of data for external costs of intermodal transport is going to be „RECORDIT Final Report, Actions to Promote Intermodal transport“. The focus of this paper is going to be placed onto external costs of accidents, air pollution, climate change and noise, even though there are many more which shouldn't be ignored in general.

It is worth showing the relations of external costs between different types of unimodal transport. The different types of unimodal transport include as follows, Bus/Coach, Motorcycles and Mopeds (MC), Light Duty Vehicle (LDV), Heavy Duty Vehicle (HDV), Rail passenger transport, Rail freight transport, with the addition of external costs of Air transport and Inland waterways transport (IWW). As shown in Figure 1. which shows how even in unimodal transport the only mode of transport able to compete with Rail transport is IWW transport, but the Rail transports advantage lies within the fact that it is widely available (man-made) while IWW (mostly nature made) are not.

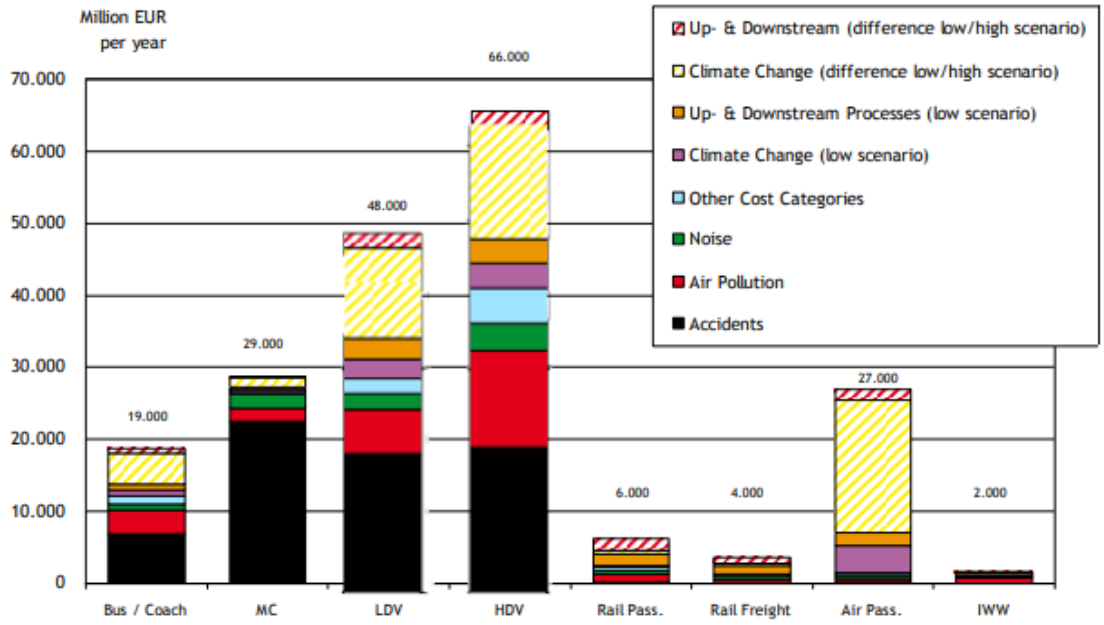


Figure 1 – External costs of different types of unimodal transport and types of vehicles (excluding passenger car transport and the costs of congestion)
Source: [2]

External costs of intermodal transport are expressed in €/40' container, which represents a problem when comparing the costs of intermodal transport with other modes of transport. For this reason the comparisons shown represent door-to-door delivery on given corridors, that is, in its own the point of intermodal transport. The results represent the latest data on the external costs of intermodal transport and as such should be viewed as competent.

To evaluate the external costs it is important to be familiar with the terms of operations „Pre-haulage“ (First mile operations) which represent the trip from the sender to the departure terminal and „Post-haulage“ (Last mile operations) which represent the trip from the destination terminal to the final destination (receiver).[3]

The external cost of transhipping is an element which plays an important role in intermodal transport, depending on the energy capabilities of a country. With that in mind, RECORDIT made a

table which shows the external costs of transshipment in various countries. Table 1. shows the data collected by RECORDIT.

Table 1 – External cost of transhipment (€/40' container)

Country	Air pollution	Climate change	Total
France	0.04	0.01	0.05
Germany	0.07	0.10	0.17
Greece	0.06	0.15	0.21
Hungary	0.19	0.07	0.26
Italy	0.08	0.09	0.16
Netherlands	0.03	0.05	0.07
Poland	0.20	0.16	0.36
Spain	0.07	0.08	0.15
Sweden	0.01	0.01	0.02
Switzerland	0.02	0.01	0.02
United Kingdom	0.08	0.07	0.15

Source: [3]

Figure 2. shows the external costs in intermodal transport, which will further explain and show the relation of external costs within the process of intermodal transport. The Figure 2. also shows the relation of external costs of intermodal transport and road transport. It shows three corridors on which the research was done during the RECORDIT study. Abbreviation „SSS“ represents the external costs of Short Sea Shipping. Corridors covered by the RECORDIT study are [4]:

- The freight freeway:
  - *(Patras -) Brindisi - Munich - Hamburg - Gothenburg*
- The tri-modal transport chain:
  - *Genova - Basel - Rotterdam - Manchester*
- The door-to-door intermodal chain:
  - *Barcelona - Lyon - Torino - Trieste - Ljubliana - Budapest Warsaw*

Even though the external costs of road transport are much higher, a significant source of external costs of intermodal transport is generated by the Pre-haulage and Post-haulage operations, except the Geneva – Manchester corridor which includes Short Sea Shipping, which generates a great amount of external costs. External costs of intermodal transport are 0.08 – 0.15 €/40' container, which is more than the rail transport average of 0.06 €/40' container, [3] the difference can be appointed to the Pre-haulage and Post haulage operations.

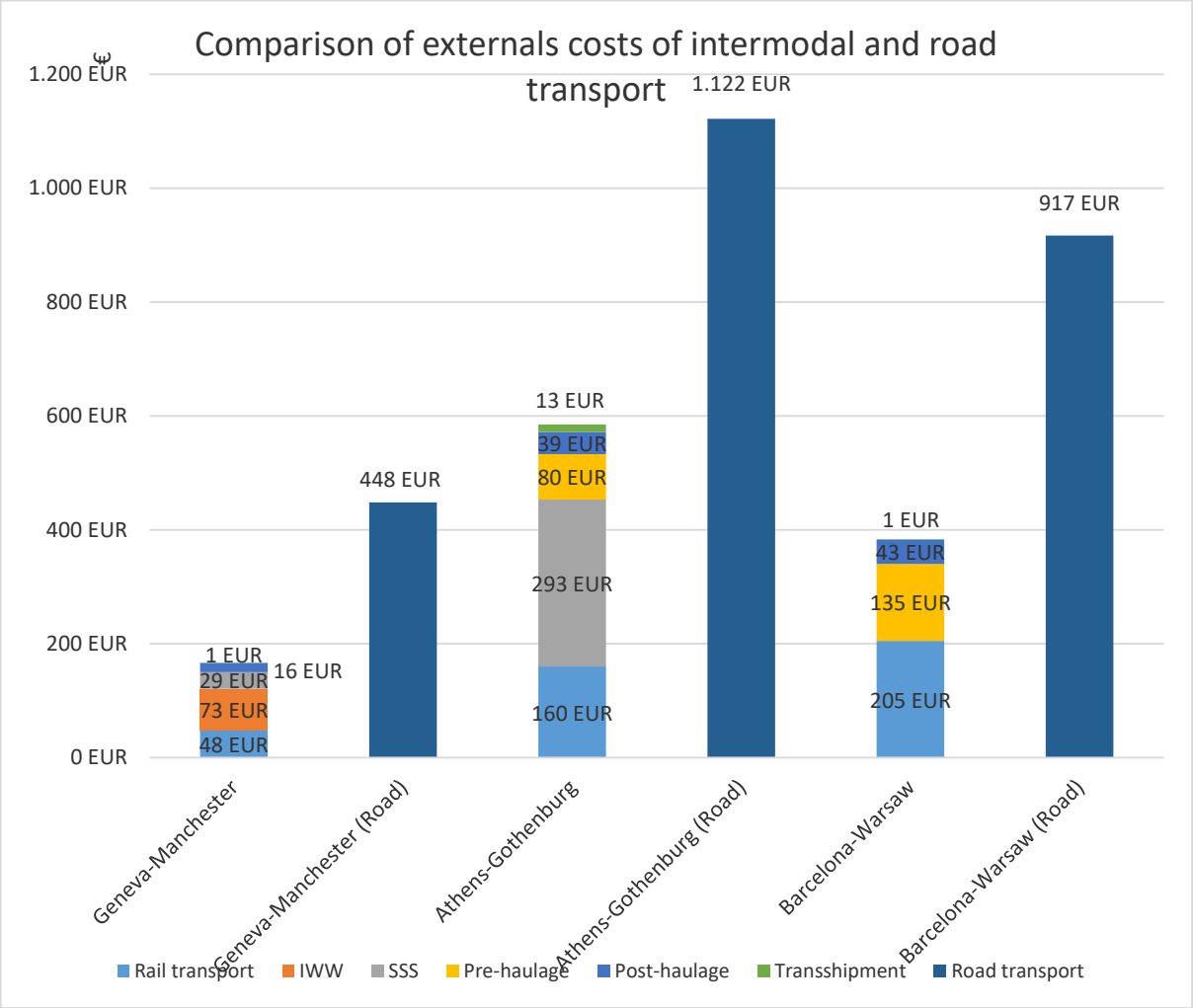


Figure 2 – Comparison of externals costs of intermodal and road transport
Source: [3]

Janic (2007) calculation is also important to mention, it represents the relations of door to door delivery distances and the external costs of intermodal and road transport, meaning it shows on which distance the intermodal external costs become lower than those of road transport. Column two (Cint(1)) represents the costs of Pre-haulage and Post-haulage operations, column three (Cint(2)) represents the costs of transshipment, the fourth column (Cint(3)) represents the cost of the transport, and the fifth column (Cint) represents the total external costs of intermodal transport. Sixth column (Croad) represents the total external costs of road transport. [5]

Table 2 – External costs of intermodal and road transport in relation to the distance covered.

Distance (km)	$C_{int(1)}$ (€)	$C_{int(2)}$ (€)	$C_{int(3)}$ (€)	C_{int}(€)	C_{road}(€)
300	10483.69	385.40	3751.56	25104.35	14515.48
400	10483.69	385.40	4285.15	25637.93	16173.67
500	10483.69	385.40	4709.02	26061.80	17589.22
600	10483.69	385.40	5066.38	26419.17	18837.30
700	10483.69	385.40	5378.35	26731.14	19941.39
800	10483.69	385.40	5657.02	27009.81	20989.19
900	10483.69	385.40	5710.03	27262.81	21939.62

1000	10483.69	385.40	6142.54	27495.33	22826.21
1100	10483.69	385.40	6358.26	27711.04	23659.06
1200	10483.69	385.40	6559.89	27912.68	24445.90
1300	10483.69	385.40	6749.54	28102.32	25195.81
1901	10483.69	385.40	7709.35	29062.12	29062.38

Source: [5]

Figure 3. follows as a visual representation of the data given in the Table 2. and it shows the equalization point of intermodal transport external costs and the road transport external costs.

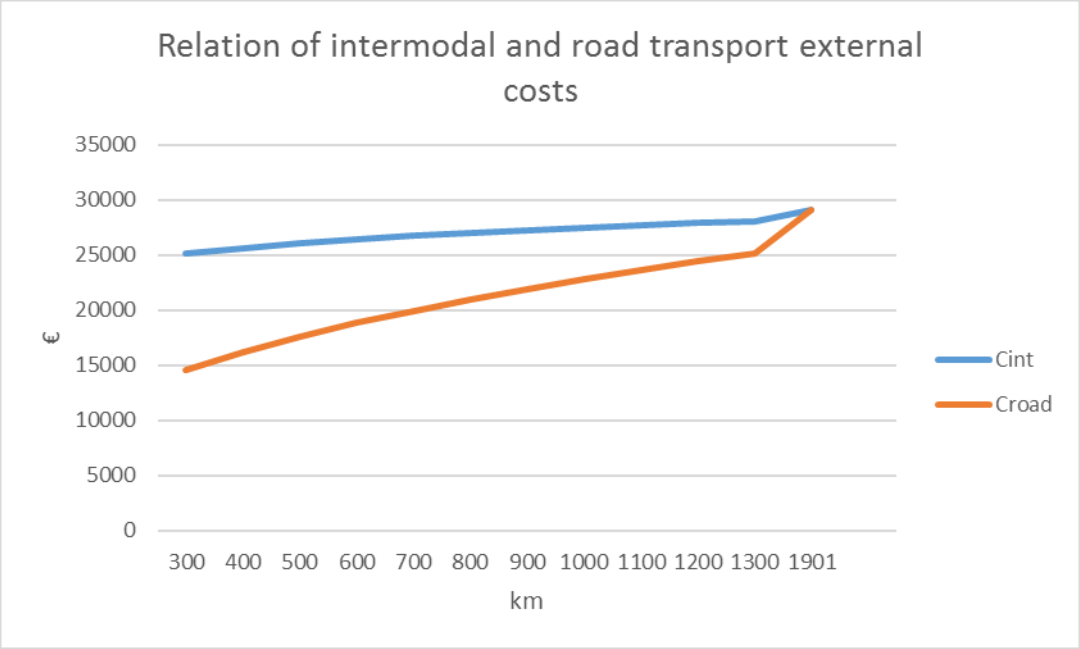


Figure 3 – Visual representation of external costs relations between road and intermodal external costs.
Source: Made by authors using the data from Table 2.

As it can be seen from the data above (Figure 3.) intermodal external costs reduction and justification of intermodal transport depend on the distances of transport. According to this research after the distance of 1900 km the intermodal transport has lower costs than road transport. The problem, as it can be seen (Table 2.) lies in the Pre-haulage and Post-haulage operations, those are the factors that contribute the most to intermodal external costs being relatively high on short trips. Pre and Post-haulage operations including road transport, transshipment, and other terminal actions can generate up to 90% of all external costs of intermodal transport.

3. CONCLUSION

As shown in this paper, intermodal transport displays higher external costs than those of unimodal road transport. But until a certain length, where intermodal external costs become lower than those of road transport. It's easily noticeable how rail transport generates lower external costs than those of unimodal road transport, but the problem lies within the fact that in order to have a unimodal rail transport both the sender and the receiver must possess railway track within their premises. While that might be the case in general, the results vary greatly, depending on the complexity of Pre-haulage and Post-haulage operations, especially the first and last mile delivery lengths. The problem with first and last mile deliveries is that they are carried out most frequently via road transport and can contribute to equal or greater external costs than the main transportation process (main transportation process meaning the moving of goods via transportation mode from terminal to terminal). It points out the need for the development of ways to reduce external costs of

road transport, and the need for implementing the technologies which would make intermodal transport more profitable (in the terms of external costs as well as internal in general) on short distance transport. Contributing factors that would make intermodal transport more appealing are that the intermodal transport is easier to organize in terms of documentation needed and that it has an increased safety of goods in terms of greater package safety, etc., which are sufficient reasons for further research and development of technologies to be carried out with the goal of reducing the external costs of intermodal transport.

External costs require attention equal to internal costs. Familiarizing the masses with the term of external costs presents a necessary goal. That is especially important due to the fact that personal vehicles, as the greatest external costs contributors, became inevitable means in everyday life, and no longer represent luxury, rather, they represent a need. Internalization of external costs would achieve greater external costs awareness and a better way of choosing the means of transport, which would return positively result in the cause of total external costs reduction. Of course, achieving the external costs reduction is not possible in developing countries and countries of weaker economic state, because those populations don't have the luxury to choose between different means of transport. Internalization can be carried out, by national authority (charging), within the fees for fuel (part of the fuel price would contain the fee for external costs), congestion charges, a fee within the charge for MOT test of the vehicle depending on the amount of harmful exhaust gasses emission, with promotion and discounted price for choosing a different mode of transport with lower external costs (e.g. Railway), with advancement and development of rail as a mode of transport with low external costs and a relative accessibility.

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NEW AERODROME OPERATING PROCEDURES FOR OPERATIONAL AIR TRAFFIC IN THE VICINITY OF ZADAR AIRPORT

ABSTRACT

The implementation of the new military training areas and aerodrome operating procedures is based on several researches of the airspace characteristics, flight safety, traffic flow, evaluation of legislative, traffic demand and air traffic control and surveillance. This paper contains an analysis of airspace characteristics in the vicinity of Zadar airport, present military training areas and proposal for the implementation of new military training areas for operational air traffic (OAT). The factors which affect flying operations and complexity of creating new military training areas and aerodrome operating procedures are defined and analysed. Conducted research is based on the aerodrome operating procedures for Pilatus PC-9M aircraft and parameters of various regimes. The efficiency analysis is done using flight time and fuel consumption.

KEY WORDS

military training areas; aerodrome operating procedures; operational air traffic; general air traffic; Zadar Airport; Pilatus PC-9;

1. INTRODUCTION

Civil-military cooperation has more and more effect on flight efficiency and effective use of airspace in scope of air traffic due to continuous growth of air operations. According to the flexible use of airspace (FUA) concept, which has recently been fully implemented in the Republic of Croatia, civil-military coordination is taking place at all provided levels of airspace management (ASM). Research for this paper was conducted in 2014 due to favourable conditions for that kind of research. This paper is still up-to-date because the similar research has not been repeated yet and neither the reconstruction of the military flying organization has taken place. The proposal of a part of airspace reservation shown in this paper, is suitable to FUA concept requirements [1]. That kind of implementation of military training area allows the inner structural setup of reserved airspace at tactical level which optimizes the entire air traffic. This kind of airspace can be reserved as temporary reserved area (TRA) or temporary segregated area (TSA), entirely or partially. Reservation criteria of the same airspace can be changed within a day if needed. The presented aerodrome operating procedures positively affect airspace capacity and air traffic flow within the controlled airspace, decrease the air traffic controllers' workload and impact on the environment. Reconstruction of the Croatian Air Force military training areas, according to the new organization and airspace usage models should contribute to the optimization of the Croatian airspace. Presented characteristics of Zadar airport surrounding airspace and statistical traffic data discovere a huge potential for airpace reconstruction. Presented proposals of aerodrome

operating procedures and military training areas meet all factors defined in this paper to prove economic benefits.

2. CHARACTERISTICS OF ZADAR AIRPORT AND THE SURROUNDING AIRSPACE

Zadar Airport characteristics refer to the geographical position and characteristics of manoeuvring areas. The most important elements are number and direction of runways and their equipment. Characteristics of the surrounding airspace are described in detail the organization of the surrounding airspace by the Croatia Control Ltd. and the Ministry of Defence of the Republic of Croatia. They also describe the meteorological conditions of the mentioned airspace. Those data are important for flight planning which affects other users of the airspace and flight safety as well.

2.1 Basic Information

Zadar Airport is one of nine airports in the Republic of Croatia. It is situated near Donji Zemunik village which is seven kilometers away from Zadar city after which it was named. It has two perpendicularly positioned runways, which allows different flying operations to be performed in almost all meteorological conditions. Zadar airport is a home base of 93rd Air Force base of Croatian Air Force, i.e. for Pilatus PC-9M, Zlin Z242L, Bell 206B Jet Ranger 3, Kiowa Warrior OH-58D, Canadair CL-415, Airtractor AT-802 and AT-802F aircraft. Zadar airport meets 4E category of equipment and firefighting equipment meets the category CAT5 (CAT6 for summer flight schedule). Zadar Airport is equipped with approach lights CAT1 (A) on runway 14 and SALS (E) system on runway 32, 04 and 22. Precision approach path indicator (PAPI) is situated on runways 14, 32 and 04 and runway 22 does not have any. Geographical position of Zadar airport is presented further in this paper in Figure 1.



Figure 1 – Geographical position of Zadar airport
Source: [2]

2.2 Meteorological Characteristics

Meteorological characteristics consist of data on suitable and unsuitable meteorological conditions, cloudiness, number of sunny and rainy days, possibility of fog, value and type of rainfalls and winds. According to these parameters, Zadar Airport is one of the most suitable airports in the Republic of Croatia which provides future pilots huge opportunity for conducting training flights. Meteorological characteristics of Zadar Airport are presented in Table 1.

Table 1 – Meteorological conditions of Zadar Airport

Description		Value		
Average annual days with unsuitable conditions for jet flying		19		
Average annual cloud coverage		4 / 8		
Average annual sunny days		98		
Average annual cloudy days		55		
Average annual rainy days		129		
Average annual foggy days		26		
Average annual precipitation		966 mm		
Average annual snowy days		5	The earliest 23rd Nov.1965	
			The latest 22nd March,1958	
Fog appearance	Mostly	Autumn / Winter		
	Rarely	Summer		
Average annual thunder days		42		
Characteristic winds			Mostly directions	Highest speed
		Bura	030°- 060°	34 m/s 1958. g.
		Jugo	None	None

Source [3]

2.3 Airspace – CTR, TMA, OAT Training Areas

Zadar Airport controlled airspace consists of control zone (CTR) and terminal area (TMA). CTR is limited by geographical coordinates and vertical limit. Zadar Airport CTR is categorized as Class D and flight rules specific to that class are applied. Transition altitude is set at 9500 ft above ground level (AGL) above which it is necessary to set the adequate pressure of 1013 hPa. Lower limit of TMA is 1000 ft AGL and upper limit is flight level 155 (FL155). CTR and TMA limits are presented in Figure 2.



Figure 2 – Cartographic display of Zadar CTR and TMA limits
Source: [4]

OAT means all flights, which do not comply with the provisions stated for GAT and for which rules and procedures have been specified by appropriate national authorities [5]. OAT training areas are situated in the vicinity of Zadar Airport and are defined in a document *''Naputak o načinima, postupcima i drugim uvjetima za sigurno uslijetanje i slijetanje vojnih zrakoplova na Aerodrom Zadar''* [3]. Visual flight rules (VFR) military training areas are presented in Figure 3.

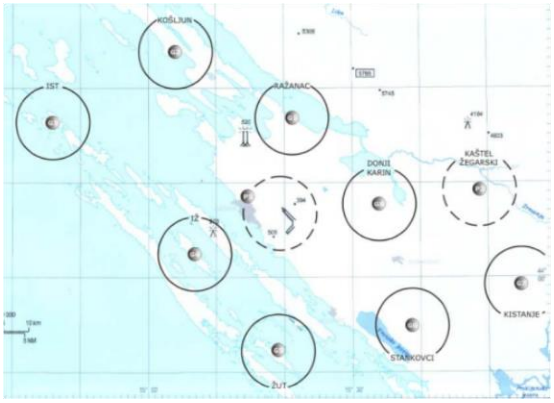


Figure 3 – VFR training areas for PC-9M aircraft
Source: [3]

As it can be seen in Figure 3, there are ten VFR military training areas for Pilatus PC-9M. Eight of them are set as main and two of them are set as auxiliary. Main VFR military training areas are Ražanac, Košljun, Ist, Iž, Žut, Stankovci, Kistanje and Donji Karin. Auxiliary VFR military training areas are Aerodrome and Kaštel Žegarski. By joining the already mentioned military training areas: Ražanac-Povljana, Molat-Premuda, Iž-Žut, Stankovci-Kistanje and Donji Karin-Kaštel Žegarski VFR military training areas for formation flying of two or more aircraft are created. Reserved Aerodrome is auxiliary VFR military training area for formation flying. They are presented in Figure 4.

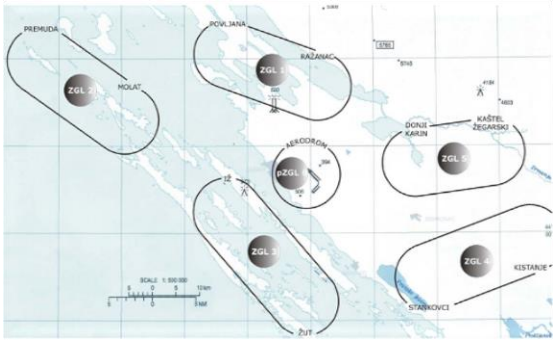


Figure 4 – Military training areas forPC-9M aircraft formation flying
Source: [3]

Five instrument flight rules (IFR) military training areas (SIERRA 1A/B, TANGO 1A/B, HOTEL 3B, FOXTROT 4A/B and INDIA 5A) are defined in document *''Naputak o načinima, postupcima i drugim uvjetima za sigurno uzlijetanje i slijetanje vojnih zrakoplova na Aerodrom Zadar''*. In the mentioned IFR military training areas, letters A and B refer to the flight levels in certain areas. In this paper, IFR military training areas are described for better perception of airspace in which flight operations are performed. They did not affect the formation of new VFR military training areas and aerodrome operating procedures.

3. STATISTICAL TRAFFIC DATA

3.1 OAT and GAT Traffic

Statistical data of OAT and general air traffic (GAT) are unavoidable elements of usage and congestion analysis of a certain airspace. GAT traffic means all movements of civil aircraft, as well as all movements of State aircraft (including military, customs and police aircraft) when these movements are carried out in conformity with the procedures of the ICAO [5]. Analysis of the mentioned data

provides a real condition of the airspace within the observed area and reveals areas of different situations. While analysing these data, it is important to mention and present numbers of flight operation at a certain airport during the whole year presenting the variable traffic according to months. Certain destinations are more loaded in winter period, depending on the type of tourism, so the number of flight operations are different according the time of the year. Also, data depend on the flight rules that aircraft use: visual flight rules (VFR) and instrument flight rules (IFR). VFR are rules conducted in accordance with visual meteorological conditions. IFR are rules conducted in accordance with instrument meteorological conditions. Statistical data of OAT and GAT and relation between VFR OAT, IFR OAT, VFR GAT and IFR GAT within the same period are presented in Chart 1.

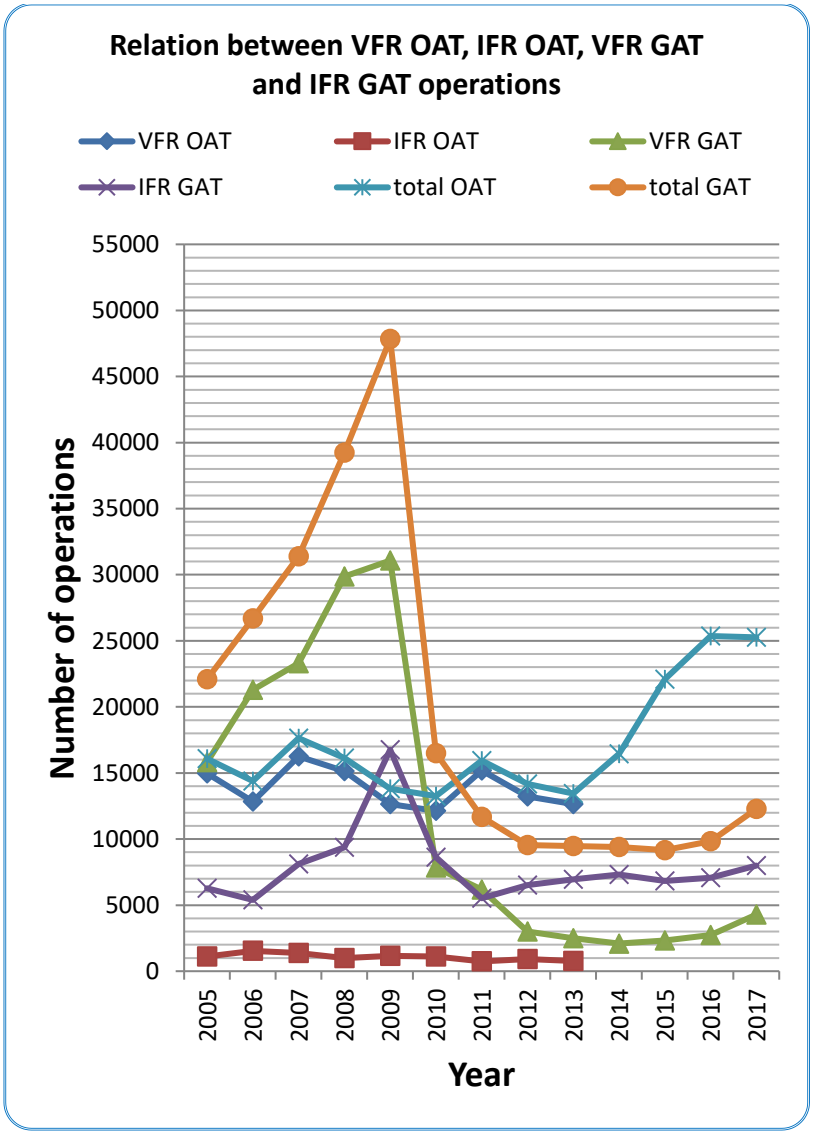


Chart 1 – Relation between VFR OAT, IFR OAT, VFR GAT and IFR GAT operations
Source: [6]

According to Chart 1, it can be concluded that years 2009 and 2010 were the milestones in the total number of OAT and GAT operations and, the aftermath of economic crisis can be seen. In the following years, the number GAT operations continued to fall due to the crisis. Since military traffic does not depend so much on the financial situation, OAT operations drop stopped. In 2011 the increase in the number of OAT operation is recorded, but just temporary. Until 2014, the number of OAT and GAT operations continued to decrease with the tendency to stabilize. In 2014, the number of total OAT operations rapidly increased until 2017 due to RAFO pilots training. Traffic data for OAT traffic are

given just for the total amount of operations between 2014 and 2017. These years don't show individual data for VFR OAT and IFR OAT operations. In the same period, number of GAT operations slowly increased. The effect of the economic crisis in the Republic of Croatia and the surrounding states that have established continuous airline connections with the Zadar Airport needs to be emphasized.

3.2 VFR and IFR Traffic

Relation of the number of VFR and IFR flight operations is important for determining the most common type of flight operation. During the mentioned years, the share relation of VFR and IFR operations of OAT and GAT, according to statistical data, was changing. Major changes happened with IFR GAT which has, unlike in the early years, made serious advance in the number of operations. The reason is, as mentioned, economic crisis which financially influenced the numerous private airspace users disabling them in using air traffic services (ATS). Airlines which provide commercial flight service succeed to sustain their own share of air traffic operations. After 2014, share relation between IFR GAT and VFR GAT operations started to equate and merge during 2017. Share relation, especially for VFR OAT and IFR OAT operations, between 2014 and 2017 is unknown. The relation of VFR and IFR, OAT and GAT operations from 2005 to 2017 is presented in Chart 2.

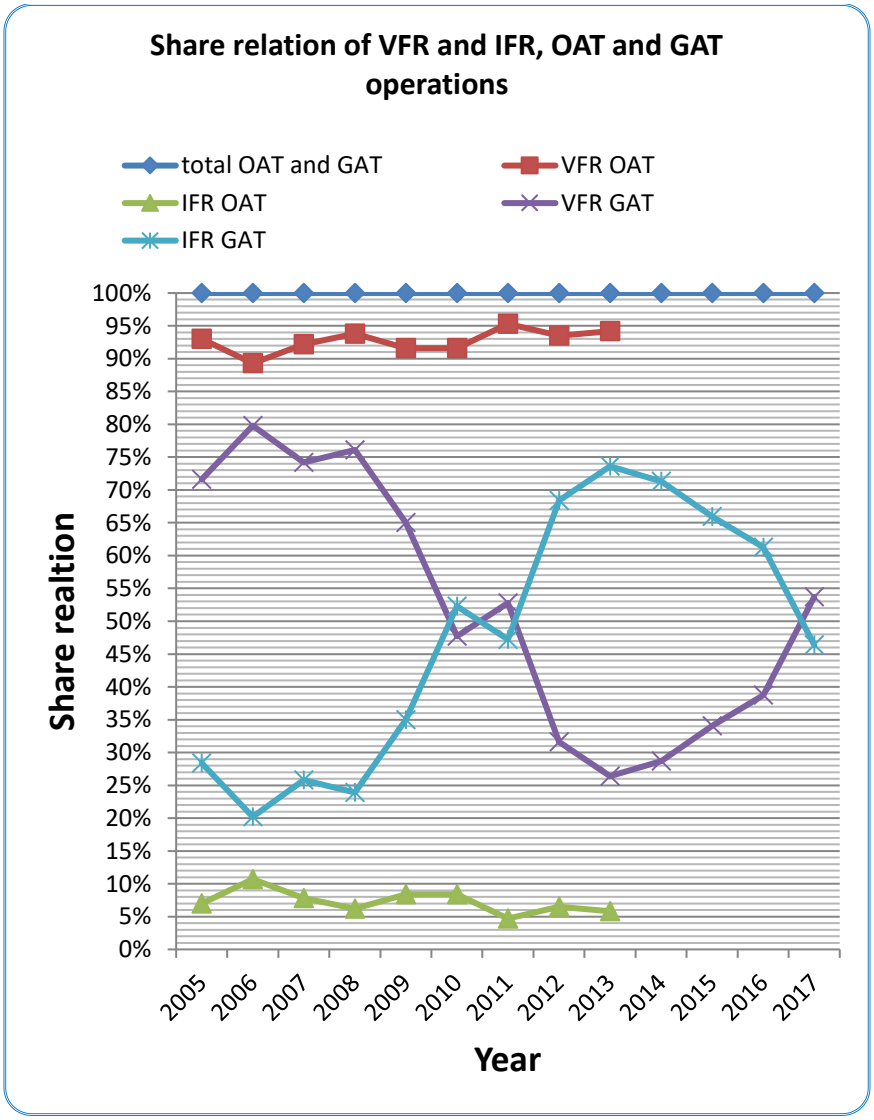


Chart 2 – relation of VFR and IFR, OAT and GAT operations
Source: [6]

3.3 Analysis of the Present OAT Aerodrome Operating Procedures

For a high-quality analysis of the present OAT aerodrome operating procedures it is necessary to conduct an analysis of the impact on factors that affect OAT aerodrome operating procedures. The mentioned factors contain components of airspace organization, general air traffic, meteorological conditions, flight safety and economics. These factors allow selection of the suitable airspace to construct the proposal of new military training areas and OAT aerodrome operating procedures and they are listed and shortly explained in the continuation of this paper.

3.4 Factors Witch Affect Oat Aerodrome Operating Procedures

3.4.1 Trajectory of GAT

During the military flight planning it is necessary to take into calculation GAT flights and foreseen times of GAT flight operations to avoid collision of the two or more aircraft and to decrease congestion in certain parts of the given airspace. Also, by avoiding trajectory of GAT, the possibility of endangering the flight safety decreases. Analysing the standard GAT flight routes and trajectories, the free airspace suitable for Croatian military aircraft missions is discovered.

3.4.2 Distance from the Airport

Distance from the airport is related to flight safety and emergency procedures. During the conduction of Croatian military aircraft flight operations, the possibility of the emergencies is increased in relation to the civil flights. The reason for this is higher intensity of aircraft and pilot/crew load caused by demanding way of flying and demanding manoeuvres. During the flight operations with two or more aircraft, the possibility of emergencies exponentially grows.

3.4.3 Vertical Limits of Military Training Areas

Military training area is set by geographical coordinates as lateral limits, and by vertical limits. There are lower and upper vertical limits. Lower vertical limit is defined according to flight safety and the upper vertical limit is defined according to the operational abilities and legal regulations of the airspace. Higher altitude of military training area is more adequate during the emergencies because a pilot/crew has greater possibility to reach distant points or airports from the present position, using the aircraft glide ration. That gives the pilot/crew additional safety and greater range of possibilities for emergencies which directly contributes to the higher level of flight safety.

3.4.4 Meteorological Conditions

Meteorological conditions are important factor for flight planning. To decrease the number of cancelled flights due to unsuitable meteorological conditions it is necessary, if possible, to plan flight over the areas with more favourable meteorological conditions. Areas over the open sea or lowlands have steadier atmosphere in relation to mountainous areas. Surrounding area of Zadar Airport is specific with a great surface variety. Impact of the Velebit mountain, its downwashes and turbulences, are highly recommended to be avoided and the western area from Zadar Airport, mostly unused, is presented as a possible solution for planning and conducting flight missions.

3.4.5 Air Traffic Control

Air traffic control (ATC) provides service in the controlled airspace with the special emphasis on the vicinity of Zadar Airport where great number of military and civil flight operations are being performed. Zadar Airport is recording a large number of flight operations, especially during the summer. To reduce the air traffic controller workload, it is necessary to move the traffic outside the CTR and leave it under radar supervision. In case of Croatian military aircraft flights, there are pre-arranged aerodrome operating instructions for home base so the radio-communication between pilot/crew and air traffic controller is minimized. Additional decrease of radio-communication load can be achieved by

shortening or simplifying aerodrome operating procedures in the vicinity of the airport. It is mostly achieved by direct routing to specific points in the airspace after departure.

3.4.6 Direction of the Runway-in-use

Direction of the runway-in-use affects the flight time of aerodrome operating procedure. It is ideal to plan military training areas which are perpendicular to the extended runway centreline. In that way, the time of departure and recovery does not depend on runway-in-use which decreases the possibility of flight time extension in case of active runway changing. As it was mentioned before, there is a huge unused airspace west of Zadar Airport. That airspace can easily be used for more intensive conducting of flights than it is used nowadays and, thus, it can contribute to flight mission economics of the Croatian military aircraft.

3.4.7 Civilian Population and Environmental Impact

Civilian population safety and preservation of infrastructure necessary for living and business represent the basic mission within the safety scope. To decrease the possibility of threats to human life it is necessary to plan flights over the less populated areas. The area west of Zadar Airport meets that requirement. Islands and sea area contain significantly lower percentage of population than mainland areas. It should be taken into consideration that military flights are more often exposed to higher mechanical loads on the aircraft construction, so the possibility of emergencies is increased. The impact of noise and exhaust gases pollution on the civilian population and agricultural goods, should be minimized to the lowest possible level. Today, modern aircraft power-plant systems are constantly being tested and meet the highest standards of ecological protection. The awareness of nature conservation and people's health should be constantly developed and sustained at the highest level.

3.5 Restricted Areas

Restricted areas in the vicinity of Zadar Airport do not affect greatly the entire air traffic. Restricted area LD(R) 22 is located west of Zadar Airport and west of Dugi otok island. Airspace between the mentioned restricted area and Zadar Airport CTR is mostly free. At present it is being used for Croatian military flights but not entirely. The rest of the Zadar Airport surrounding airspace does not contain restricted areas except for certain parts of airspace that are sometimes temporarily closed as military training areas.

4. METHODOLOGY OF DETERMINING NEW AERODROME OPERATING PROCEDURES FOR OAT

Methodology of determining new military training areas and aerodrome operating procedures contains four parts: statistical data processing of the present airspace status, discovering free and suitable airspace, defining lateral and vertical limits of the military training areas and production of aerodrome operating procedures for the particular military training area. Tendency of air traffic within a certain airspace is revealed through statistical data processing. These data are used for detection of free i.e. unused airspace. The same airspace is tested according to the parameters explained in the previous chapter. A military training area, or more than one, is constructed within the suitable airspace by defining lateral and vertical limits. During this phase of construction, it is necessary to consider the flight characteristics of the aircraft for which they are intended. Flight characteristics of Pilatus PC-9M aircraft are published in Aircraft Flight Manual (AFM). They are important in this phase so that military training area can be adjusted to all possible flight elements. First and foremost, there are acrobatic elements being the most demanding flight elements. After the construction of military training areas, aerodrome operating procedures are made for every military training area with the adjusted flight characteristics for PC-9M aircraft to assure conduction within the aircraft performance limits and flight safety.

4.1 An Example of the Proposed New Military Training Area

Military training area ''X'' is shown in this paper as the main airspace suitable for military fight organization. There are four proposals of the organization of military flights situated within that area in terms of new military training areas and new aerodrome operating procedures. The mentioned proposals are based on the previously listed factors that affect OAT aerodrome operating procedures. One proposal of the airspace organization within the military training area 'X'' is presented in Figure 5.



Figure 5 – Organisation of military training area ''X'' (proposal 1)
Source: [7]

According to Figure 5, training areas ''X1'', ''X2'' and ''X3'' are approximately of the same size which has been proved by mathematical calculation. Each of the presented areas in their size and volume is suitable for the conduction of all types of single aircraft flight missions.

The size of the military training area was chosen according to the present size of the military training areas intended for PC-9M aircraft. Vertical limits in this proposal are from 5000 ft to FL150. The mentioned military training areas can be divided in half with safety buffers which enables implementation of two military training areas. Each proposal is elaborated in detail in this paper.

4.2 Flight Parameters

During the determination of new military training areas and aerodrome operating procedures, PC-9M aircraft flight parameters were considered for climb, steady level flight and descent phase and took during flight. Listed parameters are necessary for economic analysis and they are presented in Table 2.

Table 2 – Parameters for economic analysis of new aerodrome operating procedures

Flight regime	Airspeed (IAS) (kt)	Vertical speed (ft/min)	Fuel consumption (lb/min)
Climb	180	3000	9 (8000')
	140	3500	9 (9000')
			8,8 (FL 130)
Steady Level Flight	210	-	6 (5000')
			5,9 (6000')
			5,8 (7000')
			5,7 (8000')
			5,6 (9000')
			5,5 (FL 110)
			5,3 (FL 130)
Descent	210	3500	4 (5000')
			3,9 (6000')
		4500 (airbrake)	3,8 (7000')
			3,6 (FL 110)

Source: [7]

The presented Table 2 consists of data which shows flight regimes of PC-9M aircraft. Airspeed is defined according to the flight regime, vertical speed is read from the instrument during the flight, and the fuel consumption is expressed as the average fuel consumption during level change or during steady level flight. Climb is a regime where altitude is increased. There are two climb regimes with different airspeeds. The first regime requires indicated airspeed (IAS) of 210 kt and the rate of climb (ROC) 3000 ft/min. The same data are presented for the regime at IAS of 140 kt. In that regime ROC is 3500 ft/min and fuel consumption, as during the first regime, depends on the altitude. Steady level flight is a regime at IAS of 210 kt and fuel consumption depends on air density. Fuel consumption is presented in (Table 2) and detailed data can be checked in fuel consumption chart within the AFM for PC-9M. Descent is a regime during which altitude is decreased. There are two descent regimes. The difference is in airbrakes usage. IAS 210 kt is the same during both regimes. Without airbrakes, the rate of descent (ROD) is 3500 ft/min and with airbrakes ROD is 4500 ft/min, while IAS stays fixed. Fuel consumption depends on the altitude and it is presented in Table 2.

5. RESULT – ECONOMIC ANALYSIS

Economic analysis presented in this paper verifies the well conducted analysis of the current airspace state and research into new organization solutions of Zadar Airport surrounding airspace. Comparative analysis of the current military training area ''Iž'' and the new military training area ''X2L'' is presented in Table 3.

Table 3 – Comparison of the military training area ''Iž'' and military training area ''X2L"

Military training area	Iž				X2L			
RUNWAY DIRECTION	14		32		14		32	
AERODROME OPERATING PROCEDURES	DEPARTURE	RECOVERY	DEPARTURE	RECOVERY	DEPARTURE	RECOVERY	DEPARTURE	RECOVERY
Flight time (min)	5	8	4	9	3,7	3,5	3,1	3,7
Fuel consumption (lb)	36,5	54,1	30,7	51,1	30,4	16,9	26,9	18,1
Total fuel used (lb)	90,6		81,8		47,3		45	
Fuel saved (lb)	-		-		43,3 (47,8 %)		36,8 (45 %)	

Source: [7]

Comparison of the mentioned training areas has been considered because they have almost identical positions but different aerodrome operating procedures. The shape of the area and its lateral limits have been changed which provides larger military training area. Even though the vertical limit has been decreased, it is still suitable for all flight missions for PC-9M aircraft.

Fuel consumption data in the specific military areas during the aerodrome operating procedures can be read from the Table 3. Fuel used depends on the direction of runway-in- use. Total fuel used necessary for aerodrome operating procedures shows the difference between military training areas. The most important is percentage of fuel saved. According to fuel savings based on single flight of single aircraft, the difference is not great. However, when the number of PC-9M aircraft flight operations is considered, according to percentage of fuel saving, a major amount of saved fuel can be calculated annually.

6. CONCLUSION

During the last decade, the number of flight operations at Zadar Airport constantly changed. OAT statistical data show that economic crisis left consequences even on the strongest user – air force. Trend of changing the number of flight operations and types of flights in a specific airspace leads to increased frequency of flight operations in certain parts of airspace and leaves the other parts unused. To eliminate this negative phenomenon, it is necessary to reroute air traffic, if possible, to less used airspace. Croatian Air Force flights are independent in relation to civil commercial flights so they can be adjusted in time and space.

Zadar Airport surrounding airspace is specific due to its diversity of Earth's surface. The best suitable airspace is west of Zadar Airport. That airspace is unused by the civil air traffic. Commercial flights do not have implemented routes in that area and GAT is trying to avoid flights above the sea. As it can be concluded from the mentioned data, airspace above the sea stays free. By reviewing the restricted areas and published routes of civil air traffic, there is a huge empty airspace ideal for Croatian military flights.

Military training areas intended for PC-9M aircraft are scattered in almost all directions from the Zadar Airport. Some of them are unsuitable due to several reasons if factors for improvement of military flights are being considered. As mentioned, the best suitable position for military training areas is the one perpendicular to the runway. Implemented military training area ''X'', explained in this paper, is placed in such a way. The same military training area would allow decreased impact of military flights to civil flights and vice versa, decreased flight time for aerodrome operating procedures which directly affect the fuel consumption and pilot/crew and air traffic controller workload.

Further research is conditioned by practical checks during flights and measuring of the parameters in real situations for obtaining more precise results. Will it happen depends on the will and persistence of the leading individuals in the Croatian Air Force. The undertaken effort will result in the reduction of the Croatian Air Force flights costs, system improvement and the awareness of the Croatian military pilots to constantly monitor the supply and demand balance in the Croatian airspace.

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BIOMASS TERMINALS DEVELOPMENT

ABSTRACT

The demand for energy is high and is expected to increase over the years. Biomass can deliver a significant contribution in this respect. Biomass terminals are developing for offering the best facilities for biomass trade, transport, storage, transhipment, processing and production. In nearly feature in line with promotion and utilization of bio-based economy, biomass will play an increasingly important role in the realization of economic and sustainability aspect of ports development.

KEY WORDS

biomass; wood; terminal; water transport;

1. INTRODUCTION

A global transition is currently made in the energy sector from fossil fuel technologies towards renewable energy technologies. [1]. As a result, the interest in the use of biomass as a renewable energy source and as a low carbon fuel is growing worldwide from an annual production of 12 million tons of wood pellets in 2012 to an expected 100 million tons by 2020 [2]. Many studies underline importance of biomass in the energy supply industry forecasting the increase as significant in the coming years, and no agreement is made on the maximum level of biomass exploitation [3], [4].

According to the European Parliament, biomass is the biodegradable fraction of products, waste and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste [5]. There are five types of biomass: wood products, agricultural products, solid waste, landfill gas and alcohol fuels.

In this paper, authors present actual trend of biomass terminals development. This paper presents wood biomass types that are existing in transport system as a cargo in water transport and terminal handling capacities and equipment. Terminals are needed to balance temporal differences of supply and demand over time in the supply chain and therefore in this paper it is researched technical and technological aspects of biomass terminal planning according to biomass demand.

In biomass logistics, the need for terminals is the highest when the peak seasons of heating and harvests are short and non-simultaneous. Terminal solutions are case-dependent and based on different factors, important aspect is availability of more than one transport mode.

The concept of a biomass terminal can be considered as a stopover for biomass between the origin and destination points in the supply chain. It can be separated from power plant yards and

roadside storages (or farms) so that at least one logistical operation precedes (e.g. road transportation) or follows (e.g. measurement at plant reception) the terminal in the chain. Usually, terminals are required somewhere between the roadside storage and the plant because there is a lack of sufficient space to store or handle the biomass. A terminal can also boost the transportation performance by enabling intermodality or by levelling the unstable need for transport capacity. [6].

2. BIOMASS – A NEWCOMER AT THE TRANSPORT MARKET

Biomass is an industry term for getting energy by burning wood, and other organic matter. Burning biomass releases carbon emissions, but has been classed as a renewable energy source in the EU and UN legal frameworks, because plant stocks can be replaced with new growth.

The aim of the integrated policy framework for biomass in Croatia is:

"to sustain relatively high share of biomass in heat and Combined Heat and Power (CHP) sectors through support of more resource and energy efficient use of forest biomass as well as to further mobilize, especially currently untapped, residue and waste potential for second generation biofuels".

Studies such as [7-9] have been done to explore the long term global technical potential amount of biomass for energy use, based on different biomass resources, different assumptions and scenarios.

Biomass is a versatile raw material that can be used for production of heat, power, transport fuels, and bio-products. When produced and used on a sustainable basis, it is a carbon-neutral carrier and can make a large contribution to reducing greenhouse gas emissions. [7]

The analysis in [10] and [11] showed that there are many elements that can affect the performance of biomass supply chain, such as fuel prices, transport distance, and equipment operation windows. Raw biomass (e.g. wood chips, bales) should be avoided over long distance transport, due to dry matter loss and potential health hazard. As for transport mode over long distances, ship transport will be the favourable way. It contributes only a modest part of total costs and it shows a low energy use per ton-km.

The most used biomass energy source today is wood, including forest residues (such as dead trees, branches and tree stumps), yard clippings and wood chips. Wood energy is derived by using lignocellulosic biomass as fuel. Harvested wood may be used directly as a fuel or processed into pellet or other forms of fuels. Biomasses have a loose structure and transport activities generate significant value addition simply by moving biomasses from their origin to the place of use or refining. This added value should be also considered as a cost in the value chain. Terminal capacities as a transshipment nodes are an important part of the bio-economy. Cost savings are achieved by developing terminals as effective as possible and gains can be realized by understanding all features and characteristics of harvested biomasses and minimizing losses while maximizing benefits in transport systems.

The most traded biomass fuel is pellets, because pellets are the most compact form of solid biofuels, so the transport costs per energy unit is lowest, which is important especially with longer distances. Pellets are products obtained by basic pre-treatment, for stabilization of humid biomasses to eliminate its bio-degradation and for increasing its specific energy content. This transformation gives to pellets advantages in comparison with other biomasses in terms of storage (low moisture content and therefore a better conservation of the product in the time) and transport due to the high energy-content and therefore the smaller volume to be handled.

Wood pellets, wood chips and torrefied pellets as solid biomass forms are harvest residues from the forest product industry. A schematic representation of this solid biomass material flow is illustrated in Figure 1.

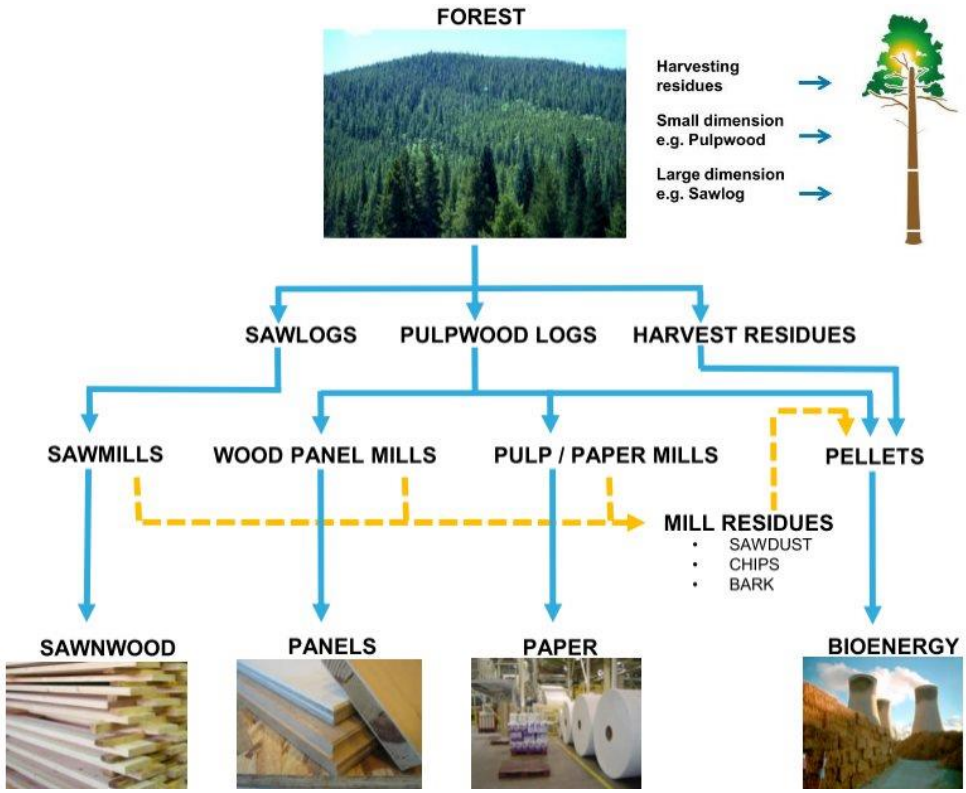


Figure 1 – Global forest product industry
Source: [12]

Wood pellets consist of dried and densified sawdust, wood shavings or wood powder and are the most compact form of solid biomass [13]. Wood pellets are one of the fastest growing forms of upgraded biomass in Europe, because the pelletization process is currently the most economic and energy saving way to convert biomass into a fuel with high energy density and consistent quality [2].

Wood chips are larger pieces from forest residues made by cutting or chipping, big advantage of wood chips is low cost, because wood chips are a waste material and do not undergo expensive treatment steps. A downside of wood chips is that they have a higher moisture content, a lower energy con- tent and a lower bulk density in comparison to the other solid biomass types. Since the wood chips can be used for gasification to generate electricity, the percentage of wood chips in the energy sector is increasing.

Torrefied pellets are produced by torrefaction, a relatively new technology, is a pre-treatment technique, carried out at 200-300 °C in absence of oxygen, to upgrade the fuel quality of biomass. This is commonly combined with pelletization. Bergman and Kiel [2005] states that the occurring decomposition reactions, at this temperature level, cause the biomass to become completely dry and to lose its tenacious and fibrous structure. As a result, the grindability of the subjected biomass is improved significantly. Furthermore, torrefied pellets have several advantages over wood pellets. Torrefied pellets are chemical stable and do not decompose, which decreases fire hazards. They can be stored outdoors, because they do not easily absorb water. [14]

3. WOOD BIOMASS TERMINAL HANDLING ACTIVITIES AND EQUIPMENT

Several considerations are required to be taken into consideration while planning biomass terminal development, such as the material properties of biomass (e.g. bulk density, angle of repose, viscosity), equipment options (e.g. open storage versus enclosed storage), operation processes (e.g.

ocean side unloading/loading process). The interactions between these elements and how they affect the terminal is summarized by Figure 2.

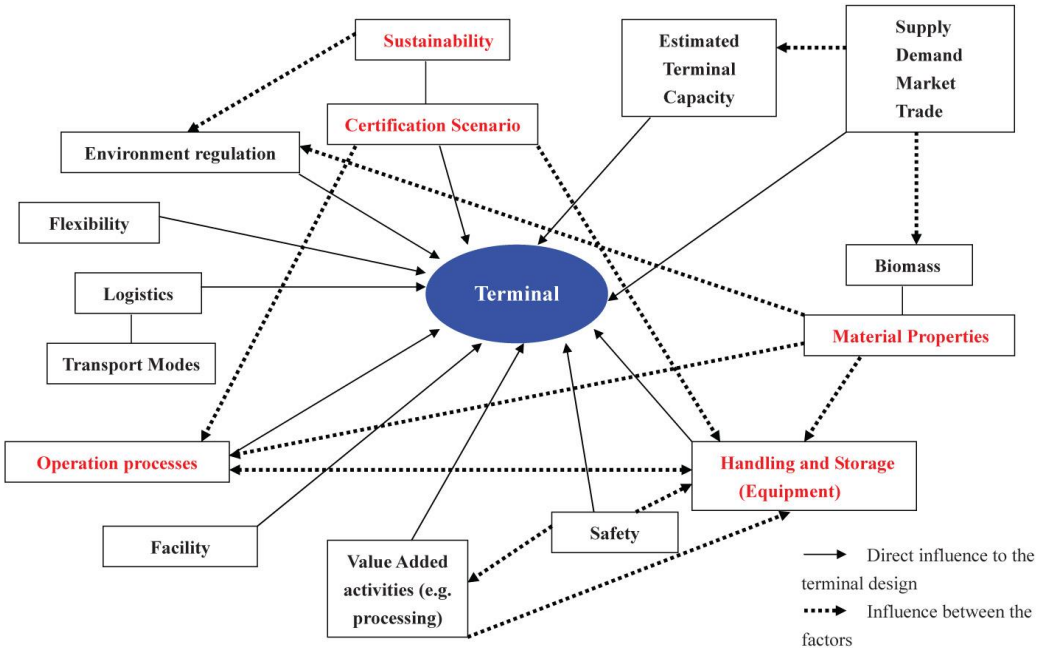


Figure 2 – Significant factors for a large-scale biomass bulk terminal
Source: [15]

From Figure 2, it can be seen, that among the significant factors, the ones that bring most impact to the terminal are biomass material properties, equipment, operation process, and sustainability certification systems.

While handling biomass there is a large diversity of process steps. An example of commonly used process phases within the woody biomass supply chain is illustrated in Figure 3. Each step requires its own handling equipment. In this paper only the terminal handling equipment of the port storage and handling is included in the scope (the highlighted process steps in Figure 3.). So only the handling and storage equipment for processed loose biomass from the transshipment phase up to the loading phase are discussed in this paper. The focus of this paper is on the biomass bulk handling industry present in European ports.



Figure 3 – The supply chain of woody biomass
Source: [12]

There are three main types of biomass handling functions at the terminal (Figure 4):

- transshipment,
- transportation and transfer,
- storage.

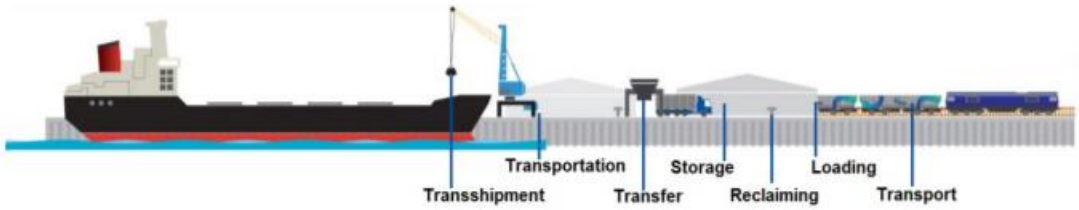


Figure 4 – Terminal activities
Source: [12]

Transshipment - the first step when handling the solid biomass at a port terminal is to transship the solid biomass from the delivering transportation vessel, which can be a ship/barge, truck or train. This can be done via multiple options, a grab, vertical conveyor, pneumatic systems, bucket elevators or a self-unloader.

There is no specific type of grab for biomass, but existing types for grabbing which are also suitable for biomass. When using a grab to unload the solid biomass one of the things that requires extra attention is the reduction of (wood) pellet degradation. The company Nemag states that, by experience, breaking is reduced by 50% when using a closed clam-shell grab for wood pellets instead of pneumatic, continuous unloading devices. Also, some companies offer the closed clam-shell design as their grab for handling. Closed clam-shell design reduces dust emission and breaking.

A widely used pneumatic transshipment system is the vacuum unloader, which is mainly used for ships. Even thought, it is recommended that pneumatic ship unloaders need to be avoided where possible, because it causes a relatively large particle degradation. Ship vacuum unloaders can reach a high throughput with their flexible design.

Three types of wood biomass materials are mostly common biomass cargo in maritime and river transport Their basic properties (i.e. energy content, density, and moisture content) are described as follows:

1. Wood pellets - LHV: 16-18 GJ/ton, density: 600-750 kg/m^3, moisture content: 10%. Currently most of the wood pellets are made from saw dust. It can be expected in the future to be significant volumes of available sawdust, which represents a large opportunity for wood pellets in the future. The wood pellets also have other applications than energy use, such as in fireboard or particle board industries. Since wood pellets are the most compact form of solid biomass, the wood pellet trade is an already existing large-scale international trade flow. [16, 13]
2. Wood chips - LHV: 14-17 GJ/ton, density: 150-400 kg/m^3, moisture content: 30-45%. Compared to wood pellets, wood chips have a lower energy content, lower density and higher moisture content. Nevertheless, wood chips are widely used in paper industry. Demand for wood chips in energy sector is increasing, since they can be used for electricity producing. Wood chips are mostly made from forest residues thus the available amounts are affluent. [10, 13]
3. Torrefied pellets - LHV: 8-21 GJ/ton (highly depends on input biomass type and torrefaction condition), Density: depends on input biomass type, Moisture content: 1-6 % [13, 17] Torrefaction is a relatively new technology that is developed under market demand. Torrefaction is a pre-treatment technique to upgrade the fuel quality of biomass, and it is usually combined with pelletization [17]. It is a technology that can be applied to agro-residues as well as forest residues. Although the available amount is not clear, the potential available amount is assumed to be affluent, because it is widely applicable. Torrefaction also improves the logistical properties of biomass (e.g. higher energy content compared to

original state and torrefied pellets are hydrophobic), thus it is expected that it will be one of the major trade flows in the future.

With respect to the design of a terminal dedicated to biomass materials and products the following recommendations apply to all **storage** options: [18]

- measures against dry matter loss and material degradation, such as a good ventilation system and pre-drying before storage, should be applied
- measures against self-heating should be applied. Such measures consider handling with homogeneous storage piles (in terms of material particle size distribution), taking the geometry of storage piles into account, avoiding compacted storage piles etc.
- the storage time of solid biomass should be controlled. Depending on the moisture content of the material, the recommended storage time varies from three weeks (for fresh wood chips) to three months (wood pellets).
- both storage capacity and storage time are sensitive to arrival and departure patterns, meaning that good logistic control is required.

When considering potential volume measurements in future biomass at terminal practical measurement unit is based on the annual fuel output: [19]

Small terminal is classified as one producing 0.1 TWh/a, medium-sized terminals considers 0.3 TWh/a and the large terminal considers 0.7-1.0 TWh/a. In small terminals (0.1 TWh/a) weighing is done during material handling by using timber scales and loader scales. A weighbridge is not used. Estimation and prediction of moisture is done based on drying models.

In medium-sized terminals (0.3 TWh/a) weighing is done likewise during material handling by using timber scales, loader scales and material handlers. A weighbridge is not used. Weighing of forest chip and measuring of the frame volume can be done in the conveyor belt after chipping (applied also for mobile chippers) or alternatively the frame volume can be measured in the truck. At the medium size terminals stock accounting is also used.

In large terminals (0.7-1.0 TWh/a), weighing of incoming and outcoming material is performed with a weighbridge. Weighing and measuring of the frame volume of forest chips is performed in the conveyor belt or measuring of frame volume of the forest chips in the truck. A stock management system takes care of the amounts of coming and delivered biomass and of the moisture variation of the storages.

While planning terminal's capacities as biomass node handling and storage activities are to be search as issues of poor handling or storage characteristics can create considerable problems. It is crucial that the biomass is not degraded and that quality is maintained throughout the entire logistic chain (from the point of view of biomass producers, biomass end-users, and traders).

It is necessary to take care on following potential situations which can destroy or damage biomass or biomass quality degradation: [1]

- material degradation
- cross contamination
- self-heating and fires
- dust emission and explosions
- wear and corrosion
- unwanted chemical reaction.

During the handling of the dry biomass (with a low density and a high drag coefficient) significant amounts of dust are airborne. The dust particles can be inhaled, which results in irritations of the lungs, nasals, respiratory systems and eyes. It can increase allergic reactions and severe illness. Next to the health hazards, dust can also create explosive hazards, because it is very flammable.

Explosions can occur when there is an interphase between biomass and air and it is ignited by electrostatic discharges, friction or hot surfaces.

While planning of the terminal's storage capacities particular consideration should be given to the security aspect. Transfer points and towers are key locations in terms of dust emissions and need to be avoided to protect the health of workers from the inhalation hazards of dust and spores, and to prevent explosions, that can occur if a small fire or localized dust explosion brings down a residue of settled dust. Stored dry biomass is sensitive for problems, like material degradation, self-heating (and fires) and unwanted chemical reactions. There are two ways of self-heating of biomass, by chemical oxidation reactions and/ or microbiological decay. The risk of self-heating and self-ignition is higher when the biomass is fresh and has a high moisture content. Due to the moisture content fungi and bacteria can grow (microbiological decay) and particle size and temperature will rise depending on the surface area and of course moisture content.

4. BIOMASS TERMINAL DEVELOPMENT REQUIREMENTS

Terminals are needed to balance temporal differences of supply and demand over time in the supply chain. In biomass logistics, the need for terminals is the highest when the peak seasons of heating and harvests are short and non-simultaneous. Terminal solutions are case- dependent and based on different factors.

An advantage of biomass, in comparison to other renewable energy sources, is that it can generate energy on demand throughout the year. However, handling and storage of biomass creates challenges, because for every new kind of bulk handling material, a new type of logistics is needed. A main challenge is limiting the effects of the handling and storage equipment on the physical properties of the biomass. [1]

With respect to the design of a terminal dedicated to biomass materials and products, a list of design requirements can be made: [15]

- The terminal's annual throughput should reasonably reflect the growing scale of demand for biomass materials and products in Western Europe.
- The handling and storage equipment deployed on the terminal should be able to cope with the material properties of biomass materials and products.
- Any potential threats to the wellbeing of the environment and the society due to the terminal operation of such a terminal should be taken into consideration.
- Such a terminal should be flexible enough to cope with any requirements (e.g. separated storage) from sustainability certification systems in the future.
- Concerns for terminal operation such as investment costs, trade-off between costs and the level of service provided are of importance and cannot be left out during conceptual design phase.
- Stochastic design parameters (e.g. seagoing ships arrival time, numbers of equipment, transport mode capacity) are to be taken into consideration during conceptual design phase.

Traditionally, a biomass terminal has been considered as an additional logistical stage increasing the costs to the supply chain. Despite this impression, the utilisation of biomass terminals in practice has in- creased steadily in recent years. A terminal is usually established when one or several of the following factors become meaningful in biomass procurement: [6]

- Balance factors: Direct supply of biomass fluctuates significantly and is incapable of meeting the more regular demand at the same time.

- Resource/capacity factors: The supply chain can perform with less resources (e.g. vehicles, machines, workforce) needed to achieve the same desired output than a supply chain without a terminal.
- Quality factors: The terminal can upgrade the quality of biomass from the level of a supply chain based on direct deliveries.
- Synergetic factors: The terminal can be used for other business purposes during the low-season of biomass storages or, e.g., a backhaul transportation of some other product is enabled (i.e. made economically feasible) by the terminal.
- Legislative factors: E.g. storing at roadside is periodically prohibited due to environmental reasons or the terminal is prerequisite for obtaining permission to build a new plant (e.g. in urban area).

Biomass supply and demand on a daily or weekly basis is often imbalanced because biomass harvesting depends on harvesting seasons and weather conditions. With regards to forest fuels, wood harvesting takes place all year round but the schedule of logging operations determines what kind of wood is directly available. Balancing is to be managed by storages as end-users need a steadier raw material flow for their processes.

5. CONCLUSION

According to the European Parliament, biomass is the biodegradable frac- tion of products, waste and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste.

Biomass is a sleeping giant, however as far as the vast potential offered by cellulosic biomass conversion and utilisation is concerned, variation in the entire production system for biofuels supply (feedstock production, pre-treatment, conversion, utilisation) will have to take into consideration the differences in local available resources potential, priority needs and economies, country by country.

Future research will be focused on development of biomass terminals in the Republic of Croatia, mainly in inland waterway transport.

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EURASIAN INTEGRATION «ONE BELT, ONE ROAD». THE DIGITAL AGENDA

ABSTRACT

Today, the Eurasian community faces serious challenges related to the formation of innovative infrastructure, favorable conditions for the implementation of transit potential, the development of international transport corridors, the creation of the digitalization transport space using the most advanced technologies.

These challenges are particularly important in large-scale projects of Eurasian integration. The idea of "One Belt One Road" is to create the necessary infrastructure and establish relationships between the countries of Eurasia. The economic corridor connecting the Asia-Pacific region in the East with the developed European countries in the West is impossible without Russia's participation. The development of Russia's transit potential will ensure the integration into the global transport system. Within the framework of Eurasian integration "One Belt One Road" the digital agenda is one of the most important areas of common work. Strategic opportunities and place of Russia in the project are discussed in the article.

KEY WORDS

eurasian integration; transport system; international transportation; transport complex; transport corridors; digitalization; digital space; single digital transport space;

1. INTRODUCTION

The New Silk Road (Eurasian land bridge NSR) is a concept of a new pan-Eurasian transport system promoted by China, in cooperation with Kazakhstan, Russia and other countries, for the movement of goods and passengers by land from China to Europe. The aim of the project is a common transport infrastructure, which provides growth within the Eurasian trade and intensification of economic development of vast internal territories of Eurasia, as well as countries of South and South - East Asia, the Middle East and Africa.

The strategic concept of the "Silk Road Economic Belt" (SREB) was advanced at the meeting of economic leaders in October 2013 by Chinese President XI Jinping, stressing China's interest in the "Sea Silk Road of the XXI century". That allowed numerous Chinese experts to announce the strategic project "One Belt One Road" (OBOR) uniting both concepts. According to Chinese Ambassador to Russia Li Hui, the main idea of the concept of OBOR is "five connecting elements": political coherence, a common infrastructure, trade relations, monetary and financial flows, humanitarian communication. On this basis, countries can fully promote practical cooperation, political cooperation, economic integration and cultural tolerance. [1]

The OBOR project involves the creation of a powerful transport network in the Eurasian region, including Railways, highways, air and sea routes, oil and gas pipelines, power lines and communication hubs. Along the transport roads, the necessary infrastructure to service these networks and industrial clusters will be created. Thus, industrial production, construction, metallurgy, energy, Finance, communication, logistics and tourism, concentrated in the project regions will form an integrated economic corridor. This transport network will link the Pacific region with the EU, with a globally important economic space, creating qualitatively new economic opportunities for the parties involved in the project, in this way. [2]

The aim of the project is also to facilitate the conditions for trade and investment, promote economic and technical cooperation and create free trade zones from which a common Eurasian market can ultimately emerge. The establishment of the Eurasian continental free trade area is expected to have a significant impact on the economic map of the world and contribute to the formation of a new political and economic order.

Participation in the OBOR may come with certain benefits for many involved countries. First, the integration of transportation system into the logistics network of the Eurasian region will give the transit and associated logistical services access to growing regional markets. Second, the OBOR creates opportunities to strengthen industrial cooperation between neighboring countries and to develop new economic clusters. Third, the integration may support the more ambitious project of cooperation in the greater Eurasia area and transform the region into a new centre of economic development on the global level.

The idea of collaboration offers advantages to all its participants. It provides central Eurasian states with the resources necessary for economic development. Formal OBOR projects often involve container terminals and railways. Among the port projects, the port of Piraeus in Greece stands out as the most prominent case. China's shipping and logistics giant COSCO has been operating and modernizing part of the port since 2009, and COSCO greatly expanded its involvement in summer 2016 when it acquired a controlling share in the Piraeus Port Authority. COSCO and other Chinese port companies have invested (or have expressed an interest in doing so) in seaports in Belgium, the Netherlands, Croatia, Slovenia, Italy, Portugal, Spain, Latvia and Lithuania[1]. With regard to railways, the planned construction of a new Belgrade–Budapest railway by Chinese companies is a notable OBOR-related project. In addition, several other China–Europe rail services are increasing in number and frequency. Chinese local governments and companies are involved in these freight services, which connect various cities in China with destinations in Poland, Germany, the Netherlands, Belgium, France and Spain. It should be noted that OBOR projects outside the European Union that involve European actors also play an important role in Sino–European relations. This may apply to infrastructure projects in Africa or Asia in which European capital or companies are involved.

The Rail Baltica project in which all three Baltic states are involved is also important to mentioned. Under this project a logistic park is designed to be built near Riga, in the town of Salaspils. Railroad lines of gauge 1520 and 1435 mm will meet there and will allow this logistic park to become a significant node for processing cargoes being carried. Potentially, the impact of the Rail Baltica project on the segment of container carriage may be very positive in the future. Combining railroads with two types of the gauge track in one dry port will become yet another competitive advantage of transport infrastructure.

OBOR-related activities that have been initiated by the European side also tend not to be designated as formal OBOR projects. The Five Ports Alliance, a major container terminal project in the northern Adriatic that involves ports in Italy, Slovenia and Croatia appears to be a regional response to the New Silk Road. Chinese investors have shown an interest in participating in this project. The European Union responded to OBOR by proposing the Connectivity Platform for EU–

[1] https://www.ifri.org/sites/default/files/atoms/files/etnc_2016-europe_and_chinas_new_silk_roads.pdf

China cooperation on infrastructure and transport. The Chinese government accepted this proposal, and several meetings have already been held as part of the Connectivity Platform.

2. MANY OPTIONS-MORE POSSIBILITIES

It is no secret that most of the world's industry is concentrated in China. Due to the low cost of labor, production there is incredibly profitable. However, for continuous development, it is necessary to increase the number of buyers, and deliver goods as quickly as possible. In addition, China's domestic market by reducing the overall level of world trade in the period of economic crisis is not able to consume the quantity of goods which it produces. The growth of economic indicators such as wages and the cost of doing business increases the price of products, so, in order to avoid sharp fluctuations in the Chinese economy and maintain the level of GDP growth, the Chinese government decided to recreate the new silk road. It is assumed that on the basis of the experience already available in ancient times, this trade route will contribute to the development of remote areas of China, which are traditionally far behind the center. But the new silk road is not only a high-speed railway. If in ancient times China built a transport corridor exclusively for itself, now the country declares that it creates an economic platform for integration with other participants. [3]

The land belt of the Silk Road suggests three main routes at the moment:

- North (China-Central Asia-Russia – Europe (to the Baltic sea));
- Central (China-Central and West Asia-Persian Gulf and Mediterranean Sea);
- South (China-Southeast Asia – South Asia-Indian Ocean or connection to Central route).

The sea silk road of the XXI century involves two main routes:

- From seaports of China through the South China Sea to the South Pacific.
- From seaports of China through the South China Sea to the Indian ocean and further to Europe.

The southern route (figure 1) includes countries such as Cambodia, Thailand, India, Pakistan, Afghanistan, Iran, Turkey, Iraq, Syria, Bulgaria, and other European countries.

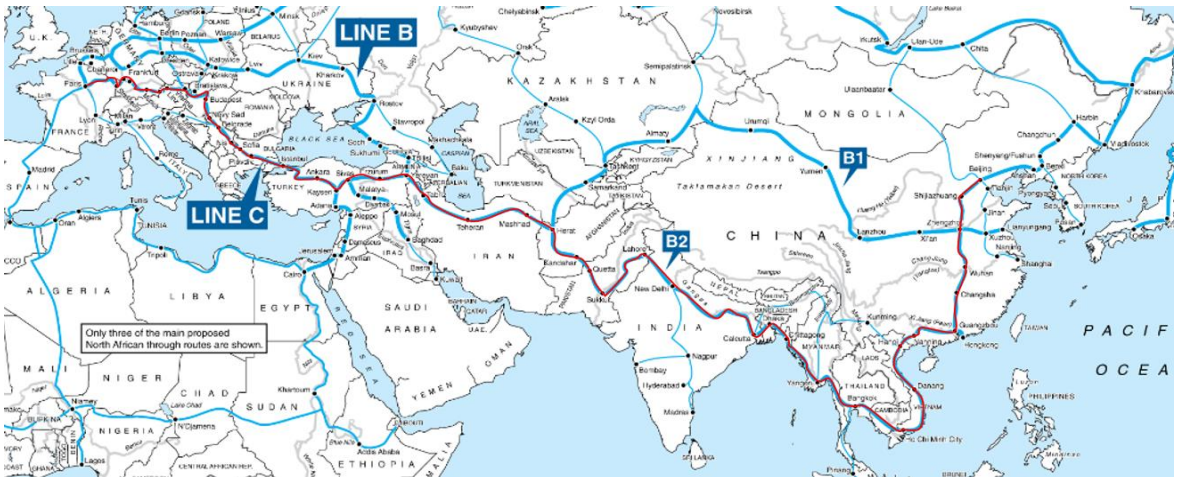


Figure 1 – Southern Route (highlighted in red)
Source: [4]

For the PRC this route is attractive because it runs through the most lagging areas of China, therefore, in the future there will be the development of South-Western lands.

However, this route is the most expensive and one of the least powerful among others (practically not tested). The cost of delivery of one TEU reaches $5,000 when using the railway and up to $4,000

when delivering by road and ferry. The theoretical capacity of the route is 50 thousand TEU per year. This route will also require large investments for infrastructure completion and reconstruction. There is also a need to cross the Black Sea.

The Central route (figure 2), by its geography, is the closest to the silk road of antiquity and the early middle ages.

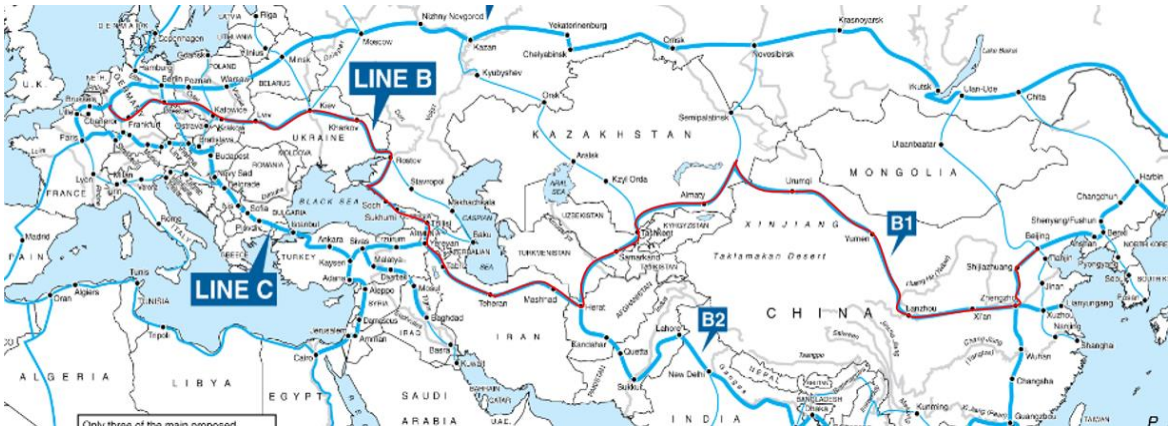


Figure 2 – Central route (highlighted in red)
Source: [4]

The main direction of the "New Silk Road" through Central Asia is expected to be about 6,500 kilometers long, 4,000 of which will pass through Chinese territory from the Pacific coast to the Xinjiang Uygur Autonomous region. The Central land route of the new silk road is now on the rise. This route effectively connects the three major customs zones-China, the Eurasian economic Union and the EU — that means just two border crossings on the route of more than nine thousand kilometers.

The negative side of the route:

- Underdeveloped transport infrastructure of some countries, namely Iran, Afghanistan, therefore, requires considerable investments in the construction of highways and Railways.
- Activation of the terrorist group "Islamic state".
- Political instability of a number of States on the route: Syria, Turkey, Ukraine.
- EU sanctions against Russia due to the Ukrainian conflict have caused a reactionary embargo by Russia against many EU products.

The Northern route includes the routes passing through the territory of China, Kazakhstan and Russia. The distance from Urumqi (China) to the Western border of Russia is 7,500 km by rail and 6,900 km by road. The cost of delivery of goods on this route depends on the type of transport: about $1300 per TEU – by rail, and at least $3,000 per TEU – by road. The estimated capacity of this route, one of the largest among all presented, is about 300 thousand TEU per year. Meanwhile only 20% of the total bandwidth of the route is used.

The most developed version of the route is the Western China — Western Europe transport corridor passing through the cities of Lianyungang, Zhengzhou, Lanzhou, Urumqi, Khorgos, Almaty, Kyzylorda, Aktobe, Orenburg, Kazan, Nizhny Novgorod, Moscow and St. Petersburg with access to the ports of the Baltic sea. This route – the only one of all – is already used, and most of the existing transit flows go through it. An important advantage of the route is the passage only of the customs border between China and Kazakhstan, Belarus and Poland (figure 3).

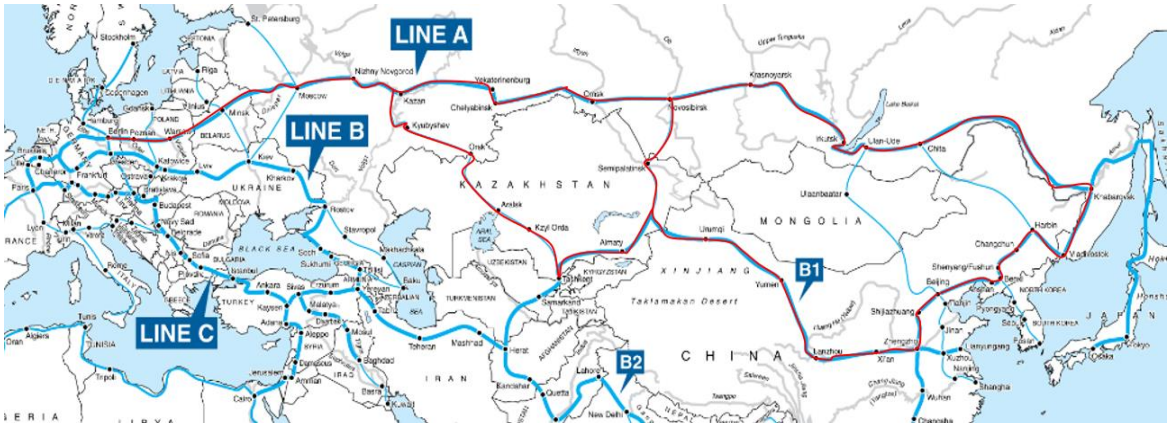


Figure 3 – Northern route (highlighted in red)
Source: [4]

But this route also has a number of problems:

- limited capacity of the TRANS-Siberian railway;
- EU sanctions against Russia due to the Ukrainian conflict.

In 2015, the authorities of Ukraine and Georgia were offered to rebuild the route bypassing Russia (excluding the Rostov region of our country). This route had to pass also on territories of Georgia and Ukraine, but with crossing on the Black sea. This option was considered by the Chinese authorities, and even tested: from China an empty train was sent to speed up customs operations, it arrived 4 days later than scheduled. Then the train was sent back to China, but never reached its destination point, simply lost on the territory of Kazakhstan. According to the media reports, the train was detained in Karaganda region due to non-payment of transit fees.

An alternative and competitive transit route through Kazakhstan bypassing the territory of Russia is the TRANS-Caspian international transport corridor, which China, Kazakhstan, Azerbaijan, Georgia and Turkey are members. The authorities of Kazakhstan announce the growth of traffic volumes to 300 thousand TEU on this route by 2020.

If transporting of transit cargo is from China by the southern route, Russia will not include in the cargo turnover at all. [5] The existence of such competition between potential transit countries enables China to obtain favorable conditions for itself in all the countries included in the project.

3. ANOTHER WAYS OF INTEGRATION – RUSSIAN REVIEW

One of the key components in the Chinese project is the construction of new and modernization of old railways in Eurasia and other parts of the world as an initial component of the transport projects implementa-tion. Russia benefits from such logistics, since the development of a vast territory largely depends on the transport corridors availability and their effectiveness. In addition to the current route from China to Europe via the TRANS-Siberian railway, on which more than 70,000 TEUs were transported in transit in 2017, China is interested in other options for cooperation with Russia in the transport sector within the NSR.

This is the Beijing – Moscow high-speed railway (HSR), with the launch of regular container trains. The distance of the railway track is 8000 km, and the delivery time will be reduced from 5 days to 30 hours. For the design and conduct of engineering operations, among others, the Chinese company China Railway Eryuan Engineering Group Co., Ltd. was invited. The first segment of the road on the Russian side – Moscow – Kazan high – speed line-is planned to be completed by 2021. The second planned section, which is also integrated into the high – speed transport corridor Moscow – Beijing,

was announced by the government of the Chelyabinsk region, is the Ekaterinburg-Chelyabinsk HSR project (the normative terms of construction and launch have not yet been determined).

Another variant of cooperation under the motto OBOR can be considered the integration of the Northeast Passage through the Arctic into the development of transit traffic from China. Technically, transit through the Northeast Passage is possible, it will reduce the time of delivery of goods from China to Europe by two weeks compared to transportation through the Suez canal.

The main problems of this route are a limited period of navigation-four months a year, the need to maintain an icebreaker fleet for the wiring of merchant ships and unpredictable ice conditions even in the summer. The undeniable advantage is that the Northeast Passage is located in the water area of the Russian Federation, and therefore is not subject to any sanctions and external restrictions for navigation.

Russia has benefited from the active participation in the project:

- possibility of integration into TRANS-Eurasian transport corridors in order to consolidate the position in the transit segment;
- increasing the investment attractiveness of Russian territories, through which the path will pass, activating the economy and accelerating the return on investment due to the growth of transit;
- strengthening and expansion of cooperation with the project countries, including within the framework of strategic projects, such as energy;
- possible reduction of political and economic problems with instability in the region, in particular in Afghanistan and Pakistan.

On the other hand, experts indicate if the main routes of the project NSR go through the South under the territory of Russia, and their passage through the territory of the countries of Central Asia, the former Soviet Union, it will lead to the decline of Russian participation in cooperation with the countries of Central Asia and reduce its influence in the region.

However, being at the intersection of global markets between Europe and East Asia, Russia, transforming its vast territories into an advantage, can become a link, connecting London with Tokyo, Beijing with new York, North America with Asia in the shortest possible way, which, in turn, will become one of the most preferred options for development and will allow controlling the flow of cargo between the Asia-Pacific region, Europe and Africa.

Today, Russian logisticians are designing new transit routes for integration with the NSR. Container transportation projects make up a significant part of them. For example, JSC "Russian Railways logistics" has expanded the railway service of non-raw materials exports, in which the Chinese side is interested no less, the possibility of sending goods requiring special temperature conditions in refrigerated containers. So, in September, together with The Russian export center, the first "circular" railway route "Vorsino-Chengdu-Vorsino" from Russia to China through Mongolia was opened. The first line-up with sweets of famous domestic brands went from the terminal Freight Village Vorsino on September 13, overcoming the route to the final destination in 14 days.

The company UTLC provides integrated transport and logistics services for carrying containers as part of the route trains moving in transit along the rail infrastructure of Russia, Kazakhstan, Republic of Belarus from the checkpoint Dostyk/Altynkol to Brest from China and the countries of South-East Asia to Europe and in the opposite direction. The company had some new directions of transportation, which allowed to us make more ambitious forecasts: transportation from the Chinese cities Xiamen Shenzhen to Poland, new routes from Prague to Yiwu and from Zhengzhou to Munich. There are directions across the new border crossings with Europe countries. In these directions they make today pilot shipments. All customers of UTLC demonstrate today the growth in traditional directions of transit.

In addition, Russia plans to expand the possibilities of transportation of goods through the territory of the 1520 gauge countries. In February 2018, in Vienna, Oleg Belozerov, CEO of Russian Railways, and Andreas Matte, CEO of Austrian Railways (ÖBB), signed an Addendum to the 2011 cooperation agreement providing for the construction of a 1520 (wide – gauge railway) highway to Central Europe. This section of the road can act as a prospect of extending the new Silk Road through Russia, i.e. the Northern route.

Alternative routes are less effective, unlike passing through the territory of Russia, which is proved in practice. So, the train loaded with Chinese goods passed along the Northern route and arrived in London on January 18, 2017, overcoming 12 thousand kilometers in 18 days without any overlays (figure 4). The success of this direction was quite predictable. There are no sea crossings or mountain ranges on the route, it is also optimal from the point of view of military and political risks, the States on which it runs are not subject to political cataclysms. Another advantage is the membership of Kazakhstan, Russia and Belarus in the Eurasian economic Union: common customs rules for easier transit of goods across borders.



Figure 4 – Yiwu 义乌 (China) – London Route[2]

The interest in such an active participation of Russia in the grand project is more than obvious. Thanks to the use of the TRANS-Siberian railway as the main route for the transit of Chinese goods, it is possible not only to update its state logistics system and infrastructure, but also access to wide investments by the PRC to direct them to the development of its own Railways and highways. Given that goods from China will be transported mainly in containers, and payment for the transit of such goods is the most expensive per unit weight, the purely financial aspect of Russian — Chinese cooperation will also be beneficial.

The absolute advantage of Russia should be the ability to quickly offer a variety of transit options with a flexible approach to pricing tariffs, facilitated procedures for customs clearance of goods, following to Europe and the unification of transportation documents.

Thus, OBOR strategy stimulates bilateral relations, creates opportunities for the Russian transport system integration into the transport and logistics network in the Eurasian region. It contributes to the strengthening of industrial cooperation between countries. Moreover, it creates opportunities for the formation of several new economic production clusters. «One Belt is One Way» strategy development will double the trade turnover between involved countries. All this allows us to conclude that the cooperation between Europe, Russia and Asia within the framework of the OBOR strategy has a favorable outlook.

[2] http://www.centerforfinancialstability.org/research/Chua_OneBeltOneRoad_7_6_17.pdf

4. FORMATION OF A SINGLE DIGITAL SPACE

The formation of a single digital space of the transport complex is a promising and important direction of the digital agenda of the Eurasian integration, it gives an additional impulse to the formation of new ideas and proposals that can be used in the transformation of transport. New opportunities are opened for the economies of States: E-commerce, change to e-document management, the adaptation of intelligent transport systems and “the single-window system” will contribute to the formation of a single market for goods, services, capital and labor. A priority and perspective direction of development of cargo transportation by all modes of transport is the use of digital technologies in the formatting of transportation and delivery control. Such technologies should be implemented at all stages of the movement of goods from the sender to the recipient.

The key directions of the digital agenda are: digital transformation of economic sectors, including transport, markets of goods, services, capital and labor; development of digital infrastructure and ensuring the security of digital processes.

In the field of digital transformation of transport, the main task is to ensure the technological connectivity of various market players in the organization and implementation of transportation. For these purposes, a large-scale integration of Internet technologies in the transport industry will be required, which, in the end, will improve the quality of transportation and reduce their costs. It is also equally important to develop end-to-end digital transport technologies and intelligent communication mechanisms between users, vehicles, traffic management systems and infrastructure.

Digital transport infrastructure as the basis, aims to provide an unified environment to interconnected systems, facilities, technology, traffic organization and management of the unified process that integrates all forms of transport, and participants of the transport market.

The digitalization of transport also includes the transition to electronic document management, the introduction of intelligent transport systems and electronic vehicle diagnostics, the implementation of the single window and digital logistics.

In 2017, the program "Digital economy of the Russian Federation" was approved. In the direction of "Digital transport and logistics" a project to develop and create the single Digital platform of the transport complex (DPTC) is included. Purpose of development: to create common digital environment for the effective exchange of transport industry data and technologies.

Main tasks of DPTS:

- Protection of the domestic transport system from monopolization of the global digital economy.
- Improving of the safety of passenger and freight transport.
- Implementation of the program of coordination and synchronization of shippers and consignees, carriers, ports, airports, freight forwarders, cargo terminals and other entities of the transport complex.
- Introduction of new technologies and new design approaches in the implementation of transport infrastructure projects, including the creation of project offices in the transport management system.
- Development of transport and logistics sector of digital economy with new infrastructure for knowledge and competence exchange.
- New quality of transport and logistics digital services management in Russian Federation and the Eurasian economic Union.
- Integration of existing information resources of the transport industry.
- Comprehensive monitoring of transport infrastructure, passenger and freight transport facilities.

- Creation and maintenance of digital transport standards that support the regulatory framework of the digital economy of the Russian Federation.
- Integration of transport and logistics processes of the Russian Federation into the world transport system

All services of the platform will be implemented on the principle of" single-window", where you can track the movement of goods by all modes of transport, receive all the necessary documents in electronic form, legally relevant for the Federal Tax Service and the Federal Customs Service. The main objective of the project is to significantly reduce costs both at the business level and in the state regulation of the transportation process, as well as in the unification of transport and logistics solutions on the same platform. [6]

The project will create a "green corridor" for the transit of goods along the fastest transport corridor between Asia and Europe. The New Digital Silk road will not only geographically pass through Russia, but will include convenient services for shippers and carriers - a single electronic seal and a fully electronic declaration using Blockchain technology. [7]

Special systems of intelligent electronic sealing Big Lock that operate using GLONASS technology, ensure the transfer of information into a single system, which will significantly reduce the time of delivery of goods, inspections at customs, improve transport security, as well as eliminate violations of customs legislation, will ensure the non-stop movement of goods and seamless border crossing. Shippers will be able to track online the route of movement of goods, to obtain a guarantee of their safety, as well as to enjoy the benefits of electronic document management in international transport.

Some elements of such a platform are already available to large Russian data operators — companies such as JSC "RZD", the operator of the system Platon by RT-invest Transport systems "(RTITS) (Russian system of charging trucks with a permissible maximum weight exceeding 12 tons) and GLONASS technologies.

The development of digital systems is designed primarily to improve the quality of life, make transport more convenient for people and business development, and innovative developments in the modeling of transport systems and traffic management should provide end users with greater information content and security, as well as qualitatively improve the level of interaction of participants.

Further implementation of the objectives of the Digital economy program will allow Russia to offer its partners in Eurasian integration proven solutions to simplify and improve the efficiency of cooperation. And first of all — to significantly reduce time and financial costs in transport, cross-border crossings, which will help in the implementation of international initiatives of Eurasian integration and the project OBOR.

5. CONCLUSION

Digital technologies offer significant potential for transformation of the economies, making it possible to eliminate barriers, create new opportunities for economic, social and cultural development and enhance the regional and global competitiveness. Today the partners in Eurasian integration can benefit from the new collaboration opportunities within the shared network infrastructure and common digital platforms, implement new digital solutions and develop areas of business activity that didn’t previously exist. Digital Agenda implementation through disruptive digital projects can maximize economic benefits.

It is of paramount importance to strengthen relevant governing institutions, reach political consensus and ensure high-level transformation management. Harmonized legislation and legal framework are crucial for the Eurasian integration and digital transformation as such. Various

organizations need to be involved in the process, including public authorities, private sector, academia, mass media as well as the general public.

Digital transformation also requires trained technical and managerial staff, constantly improving their skills, as well as consistent policy aimed to develop skills of the general public and improve their awareness of the digital dividends in both economic and social aspects of life.

Digital technologies will be implemented successfully provided technological compatibility, interoperability and scalability of digital infrastructures, platforms and solutions are ensured so as to deliver effective, inclusive and secure digital economy.

One shouldn`t disregard the risks related to neglecting the Digital Agenda. They include brain drain, growing influence of the global players in the Eurasian digital space, falling competitiveness of the goods and services and a threat to the digital sovereignty of the region.

Basic guidelines for the digital transport space are as following: intensification of integration processes and international cooperation, facilitating regional digital initiatives, common digital infrastructure and digital platforms, digitalization in the key sectors and transport markets. Also it is necessary to identify underlying enabling mechanisms within the basic guidelines including favorable legal framework, public private partnership for priority initiatives, fostering dialogue among all of the stakeholders within digital ecosystems, promotion of best digital practices and solutions.

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UTILISATION OF A CLOCK-FACE TIMETABLE IN RAILWAY TRANSPORT

ABSTRACT

The implementary plan of train traffic in railway transport - the timetable - is the foundation of the technological process of traffic management. Due to the necessity for making it easier for passengers to memorise the timetable, and ensure a higher operationality of operators, this new type of schedule, referred to as clock-face timetable (based on the German word Taktfahrplan), runs at consistent intervals. This paper examines the experiences and utilisations of such a timetable in railway transport, and outlines its benefits and drawbacks. The case study of adjusting to a clock-face timetable was made on the technological process of the main railway station in Zagreb (Zagreb GK) together with a comparative analysis of the previous and current state indicators. In the end, proposals for future research from the standpoint of clock-face scheduling were put forward.

KEY WORDS

timetable; clock-face timetable; integrated timetable; Zagreb GK;

1. INTRODUCTION

As a long-term solution of the underlying segment of technological operation of an organisational unit in charge of passenger transport and the transport of goods, a clock-face timetable marks a significant progress in today's technology and contributes substantially to the operation of the entire transport system. Modeled on the more developed railway systems whose long-term experience guarantees the quality of such a technology, attention should be confined to the provision of services that the clock-face scheduling enables.

The literature, Fischer et. al., Teng and Lai, Cheng et. al., Gašparik et. al., Abramović et. al., Finger et. al., Lukanić, Wies [1–8] gives reviews and analyses of the potential improvement of bus/rail line layout, timetables and trip planning of passengers. These papers deals with the clock-face timetable and its effects on railway transport. Finger et. al. [6] claims that the clock-face timetable have the potential to increase the quality and attractiveness of railway passenger services in comparison to other transport modes. The successful introduction of clock-face timetable requires a long-run implementation schedule which identifies the necessary investments in the railway infrastructure and points out the financial resources available to make those investments.

This article deals with the ways in which such timetables are established, with their feasibility, advantages, and disadvantages, based on the experiential facts of Swiss Federal Railways (German: Schweizerische Bundesbahnen (SBB)) - the model of a developed organisation in railway transport technology. The article also analyses the utilisation of clock-face timetable at the largest and busiest railway station in Croatia - Zagreb GK.

2. CLOCK-FACE TIMETABLE

A timetable is an implementary plan for train operation intended for the transport of passengers, cargo, and for the needs of the railway. At the same time, it is the foundation of the technological processes of a railway transport service provider. A timetable harmonises the transport demand and the available technical and human resources of the railway transport service provider, which are based on the plans related to the flow of goods and passengers, business decisions of the operators, international agreements, and arrangements for the period of validity.

A clock-face timetable (German: Taktfahrplan) is a timetable based on consistent and regular departures at certain stations, e.g. every 5, 10, 30 minutes past the hour (or more frequent). It was initially introduced as an innovation aimed to make the public transport more appealing, versatile, and easier to remember. Furthermore, clock-face scheduling often ensures higher operationality of operators, since one train turnover can be utilized multiple times up to the end of the working day.

Several public transport lines can pass through a single station, which can create a timetable with regular departures every 5, 10, 15, and then 5 minutes past the hour. If each individual railway line runs at consistent time intervals, the timetable is clock-face.

2.1. Features of Clock-Face Timetables

Train departure and arrival times to their final (clock-face) nodes at consistent time intervals is a clock-face ride time. When trains operate at clock-face ride times, and when the timetable is determined by it, it is referred to as clock-face timetable. Passenger satisfaction is achieved by means of a timetable that is easy to understand, and which can easily be memorised and applied in a simple and practical manner.

At all clock-face, i.e. node stations, passengers are provided with optimal transfer connections, thus ensuring a faster, simpler and better-organised journey. The optimal transfer connection is the shortest time needed to transfer from one train to another. This means that the departing train must not leave the stations before the arriving train arrives and before the passengers have had time to transfer onto it. This train organisation maximally shortens the journey time, simplifies the passenger transfer, and directly leads to an increase of railway transport users while at the same time improving the satisfaction of existing passengers. Shortening journey times also reduces the train turnover time, and thus the operational costs of the railway.

Most European railways are already utilising the clock-face timetable or a similar type thereof. Such feature trains departing always at the minute past the hour, e.g. 7:24, 8:24, 9:24, etc. The clock-face timetable interval is mainly 1 or 2 hours. A clock-face timetable aims to network all the lines into a single node so that not only some but all lines pass through the node approximately every minute. This means that with such a timetable, railways transport should ensure that all the trains arriving from the same directions at approximately similar times actually arrive at clock-face scheduled stations. These stations accept these trains from all directions at regular intervals, thereby providing passengers with several options of continuing their journey. The transfer times are thus shortened to only a few minutes. The objective of a clock-face schedule is, therefore, to increase the journey speed in the railway network by reducing transfer times.

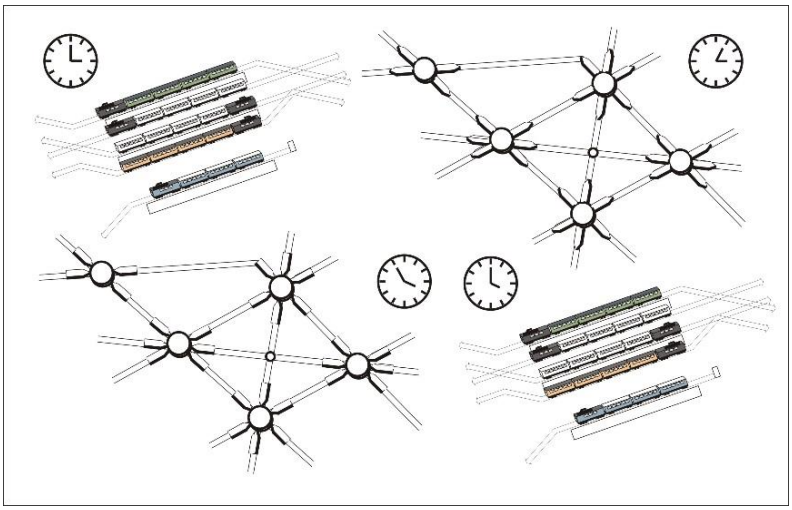


Figure 1 – A schematic of an integrated clock-face timetable
Source: [8]

Figure 1 illustrates the principle of operation of clock-face timetable in the railway network. At a certain clock-face time (15:00), a train halts at clock-face station and provides the possibility of a transfer. Shortly thereafter, each train continues in the direction of its respective destination. At 16:00, trains halt at destination station and ensure additional passenger transfers.

2.2. The Swiss Experiences

Swiss railways have been using clock-face timetables since 1982. It is, therefore, necessary to focus on the changes in transport processes taking place over the last three decades. Figure 2 shows the supply and demand on one side, and the income of SBB from passenger transport on the other. Noticeable is the 63% increase in the supply. Similarly, the demand rose by approximately the same, i.e. 60%.

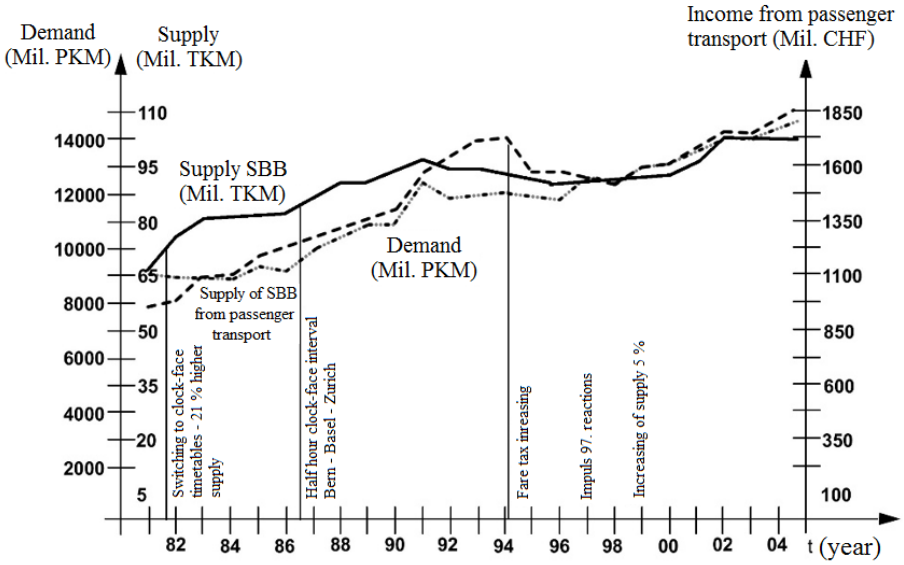


Figure 2 – Supply, demand, and income from passenger transport in 1981 - 2004
Source: [8]

Switzerland switched to clock-face timetables on 23rd May 1982, which ensured an increase of 21% in transport offer, whereas operational costs rose only by 4%. For local transportation, such a railway

organisation brings about a greater potential of rationalisation. In that case, regional trains and buses need to serve a station only at defined intervals - in a clock-face timetable - once an hour.

Since an integrated clock-face timetable leads to an extremely well-organized railway transport, the increased supply only partially represents the increase in expenses. Namely, the income from passenger transport rose in the first 12 years by 76%. It then declined because of the recession and fare tax increase, and at the end of 2005, it began to rise again. This points to the conclusion that passengers accepted the additional offer. The integrated clock-face timetable is adjusted to passenger behaviour (frequent clock-face intervals) which was the basis for infrastructural measures that were taken.

The improvement of the clock-face timetable in Switzerland was carried out in four stages. For that reason, it was essential to reconstruct 90% of the timetables on 12th December 2004. This enabled the Swiss Federal Railway to lower the average waiting time at transfers to less than 3 minutes. In the long run, implementing an integrated timetable was a success. However, it should not go unnoticed that the mere implementation is not the end of the entire project of modernising services and utilising an integrated schedule. It is only a foundation based on which the modernisation of the train fleet (tilting trains and numerous appealing transport fare offers) has led to satisfactory results.

3. PREREQUISITES FOR THE UTILISATION OF A CLOCK-FACE TIMETABLE

3.1. Infrastructural Requirements for a Clock-Face Timetable

The main prerequisite for such a timetable organisation is infrastructure. It is essential to ensure a sufficient number of platforms and tracks at clock-face stations where passengers transfer. At stations where trains overtake and cross each other, there needs to be an infrastructure that ensures train maneuvering, which means fitting the tracks with appropriate switches, signalling, safety, and telecommunications devices.

3.2. Pros and Cons of a Clock-Face Schedule

An integrated timetable has two significant benefits. Firstly, it brings satisfaction to passengers due to an easier understanding of the timetable. Secondly, it is efficient. Timetables that are easy to memorise is what brings satisfaction to service users. A journey then becomes so simplified that a passenger needs only the departure time from their origin in order to move in any direction. At node stations, passengers can choose between optimal transfer connections. Such an organisation ensures a quick and pleasant journey. The comparison between regular timetables and the new concept of clock-face timetable reveals the actual advantage of an integrated timetable. Already in its initial stages, the latter achieves substantial reductions in travel times by utilising only the perfectly harmonised transfer connections. The essential reductions in journey times are achieved by means of reducing the stopping and waiting times, bordering on the legal limit. The efficiency of an integrated clock-face timetable is based on symmetry, which leads to a fully rational engagement of personnel, and rationalisation of the passenger train turnovers.

Drawbacks to such timetables, on the other hand, are found in closely linked sections, where changes are unfeasible as they would affect the entire network. It is, therefore, vital to develop a unified timetable. Total changes to the timetable should be taken into consideration, which means that timetable planning should be done long-term, in stages. Simultaneous arrivals at clock-face stations is based on the presumption the stations are equipped with a sufficient number of platforms and tracks. Considering the fact that trains move at roughly the same time, and that many train engines operate at full capacity and at the same time, this presents an above average load on the electro-energetic supply system of the railway. It is thus essential to take preventive measures to address this infrastructural issue in order to ensure the supply of the additional power. Nevertheless, the

advantages outweigh the drawbacks, as evident from various European studies, and in the successful realisation of such a timetable in the Netherlands and Switzerland.

4. A CASE STUDY OF CLOCK-FACE TIMETABLE AT ZAGREB GK

Zagreb GK is the largest train station on the railway network in the Republic of Croatia. In its essence, it serves as a passenger train station. Every day, 90% of the entire passenger transport trains of Croatia pass through the station. For that reason - the highest traffic load - the operation of a clock-face timetable is exemplified at Zagreb GK, the most dynamic station on the railway network.

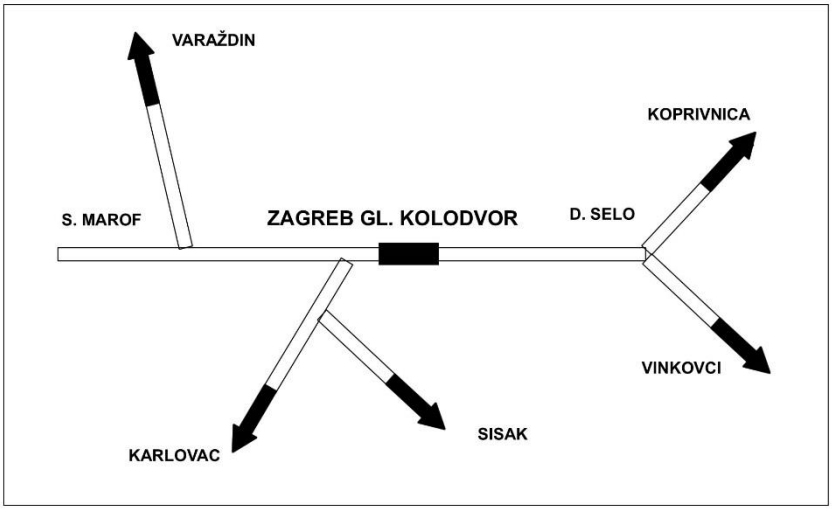


Figure 3 – Railway station node Zagreb
Source: Authors

The currently established practice of developing a timetable had previously not taken into account the clock-face intervals of departures and arrivals, nor the connectivity between certain trains. Consequently, passengers have to wait to transfer onto certain trains for hours. In a modernly organised railway transport system, such an occurrence is uncommon, a thing of the past. In order to provide a quality service to its users (passengers), it should aim to meet their needs, and keep their service offer up-to-date.

Twenty years ago, the number of passengers on the railway network in Croatia was double of what it is today. In order to bring back those numbers, and attract potential passengers to switch to railway again, it is of vital importance to improve the service quality. A simple timetable and a clock-face timetable connectivity of all the major urban centres on the railway network of Croatia is a vision of future that can compete with all modes of transport. The competitiveness of the railway is currently reflected in the travel comfort and ticket price-competitiveness. The addition of a short journey time between all urban centres would, in that case, complete the service which is most desired when opting for a transport service provider.

The railway lines which would need to be connected to the Zagreb GK clock-face network include: Zagreb – Vinkovci, Zagreb – Varaždin, Zagreb – Koprivnica, Zagreb – Karlovac, and Zagreb – Sisak.

4.1. Transfer Times

Although the transfer times could be reduced by additional 5 minutes, the current platform layout of Zagreb GK does not allow for it.

The total walking time between two platforms T_{walk}:

$$T_{walk} = t_w + t_{walk} + t_b[min] \quad (1)$$

whereby:

t_w - the average waiting time to disembark a train (max. 4 minutes)

t_{walk} - the average walking time between two platforms, including the time needed to check departure time and platform (max. 7 minutes)

t_b - the average time needed for the passenger to board the right train (1 minute)

The total time required for a passenger to transfer from one train onto another at the furthest platform is 12 minutes.

4.2. Train Departure and Arrival Intervals

During the daytime when the migration of passengers is at its highest, travel options are determined by the dense timetable. A train arrives at Zagreb GK every hour from all directions and departs the station in all directions. This means that between 6:00-11:00, 13:00-17:00, and 19:00-22:00 the timetable has been designed for a clock-face arrival/departure of trains into and out of Zagreb GK. This ensures an easier transfer with minimal transfer times. Such a layout reduces the journey times as much as possible. The clock-face interval of train arrivals at Zagreb GK is between the eighth (hh:08) and the fifteenth (hh:15) minute past the hour. The clock-face interval for departures is at the twenty-fifth (hh:25) and thirty-second (hh:32) minute past the hour.

The exception to the clock-face interval remain suburban trains in the Zagreb area. Their departure and arrival times are within the clock-face schedule, but due to the frequency of departures and the access to passenger trains on other railway lines, they pass through the station in clock-face timetable. The arrival time for a suburban train on the line Savski Marof - Dugo Selo at Zagreb GK is at the eleventh minute past the hour, with departures at the twenty-third. Apart from these times, suburban trains arrive at the station at several other times in an hour, regardless of the clock-face intervals of other trains, adhering nonetheless to their own clock-face timetable intervals.

4.3. Comparison with the Existing Timetable

Considering that the existing timetable was established in 2005/2006, a comparative analysis was made between the existing design of the timetable, i.e. the train times in the current timetable, and the train times in a clock-face timetable. All travel times were purely hypothetical, obtained from the existing timetable charts. To make the comparison as accurate as possible, a single transfer at the railway node station Zagreb GK was taken into account. For the purposes of this paper, a randomly selected method was used, which clearly compares the two transport methods. The calculation was performed for all the possible connections between the following stations: Sisak, Karlovac, Varaždin, Vinkovci, and Koprivnica. These five stations comprise the heaviest traffic load of the railway network in Croatia.

The table lists the destination stations for all train rides. The train ride times according to the existing timetable in the morning peak hours (T_{AM}/min) are listed in the second column. The third column has the train ride times according to the clock-face timetable in the morning peak hours (t_{AM}/min). The difference between the two is listed in the fourth column ($\Delta t_{AM}/\mathrm{min}$). The fifth column contains the difference in percentages. The train ride times in the current timetable for the afternoon peak hours (T_{PM}/min) are listed in the sixth column. The seventh has the train ride times in the clock-face timetable in the afternoon peak hours (t_{PM}/min) are listed in the sixth column. The eighth column lists the afternoon peak difference ($\Delta t_{PM}/\mathrm{min}$), and the ninth includes the differential percentage ($\Delta t_{PM}/\%$).

The obtained results are listed in Table 1.

Table 1 – Train ride times

	T_{AM}/min	t_{AM}/min	$\Delta t_{AM}/min$	$\Delta t_{AM}/\%$	T_{PM}/min	t_{PM}/min	$\Delta t_{PM}/min$	$\Delta t_{PM}/\%$
Sisak - Karlovac	220	129	-91	41.34	165	105	-50	30.3
Karlovac - Sisak	213	129	-84	39.44	165	132	-33	20
Sisak - Varaždin	293	173	-120	40.96	321	220	-101	31,46
Varaždin - Sisak	249	140	-109	43.77	246	238	-8	3.25
Sisak - Koprivnica	220	170	-50	22.73	261	144	-117	44.82
Koprivnica - Sisak	248	139	-109	43.95	152	150	-2	1.32
Sisak - Vinkovci	339	321	-18	5.3	261	256	-5	1.92
Vinkovci - Sisak	293	263	-30	10.24	360	266	-94	39.17
Karlovac - Varaždin	293	277	-16	5.46	269	209	-60	22.3
Varaždin - Karlovac	206	194	-12	5.83	237	221	-16	6.75
Karlovac - Koprivnica	230	156	-74	32.17	138	133	-5	3.62
Koprivnica - Karlovac	205	125	-80	39	176	122	-54	22.88
Karlovac - Vinkovci	291	305	14	4.81	279	245	-34	12.19
Vinkovci - Karlovac	230	235	5	2.17	257	319	-38	10.64
Varaždin - Koprivnica	206	309	3	1.46	360	325	-35	9.72
Koprivnica - Varaždin	362	287	-75	20.72	320	227	-93	29
Varaždin - Vinkovci	400	316	-84	21	503	287	-216	42.94
Vinkovci - Varaždin	337	350	13	3.86	458	413	-45	9.82
Koprivnica - Vinkovci	329	315	-14	4.26	270	262	-8	2.96
Vinkovci - Koprivnica	305	297	-8	2.62	502	297	-205	40.83

Source: Authors

The average reduction in travel time obtained by implementing the clock-face timetable amounts to 18.8%. The average train ride time is 280 minutes, i.e. 4.67 hours. By reducing it by the average reduction in journey time - 18.8% or 53 minutes - there is a significant reduction in journey time, which is a substantial advantage of such a timetable.

5. CONCLUSION

The aim of this paper was to examine the possibility of reorganising the fundamental business project of the railway in order to strengthen the competitiveness of the railway on the market. Based on the case study of designing a clock-face timetable at Zagreb GK, the railway node with the largest number of passengers of all the railway networks in Croatia, the need to introduce such a timetable has been justified. Clock-face train arrivals have proven to reduce transfer times, and thereby the total journey time as well. A system in which trains wait for other trains so that passengers can transfer onto them, which was thus far an exception, has now become a rule. The train turnover times have been reduced, as have the operational costs of the railway. Train paths have become vacant in the remaining times, and can be used by freight trains to a greater extent than before. The average reduction in journey time by implementing the clock-face timetable amounts to 18.8%.

The benefits of a clock-face timetable include the satisfaction of passengers, who find it much easier to memorise the timetable, efficiency, a timetable that is easy to remember, a reduction of journey times, a rational engagement of personnel, and rationalisation of passenger train turnover times. The drawbacks, however, are that these types of timetables have to be designed and planned in stages, providing that there is a sufficient number of platforms and tracks, and that there is an above average load available for the electro-energetic supply of the railway.

Upon the adjustment of the timetable to the technological process of the operation of Zagreb GK, the next logical step is to introduce the clock-face connectivity in the entire railway network. Such a connection is a requirement for the inclusion into the European railway clock-face network. The first step is to harmonise the bus and tram lines with the clock-face operation of the railway, which ensures an integrated passenger transport.

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AN OUTLINE OF SECTORAL QUALIFICATIONS FRAMEWORK IN AVIATION INDUSTRY

ABSTRACT

Aviation industry is a complex industry in which significant technological progress has been made. Huge demands are placed on experts working in aviation industry and therefore their responsibilities are great. Educational system should be created in a way to serve aviation industry and to predict further developments in the industry, and not only to be in line with the contemporary needs and requirements. This paper gives an outline of general structure and Sectoral Qualifications Framework in aviation industry based on current key competences and qualifications. An overview of aviation market is also presented in relation to future job requirements. Categories of qualifications in the sector are to be further analyzed in terms of required knowledge, skills, and key competences.

KEY WORDS

aviation industry; sectoral qualifications; framework; competences;

1. INTRODUCTION

The relevance of education is of utmost importance for all segments of society. The question is just how important is it? Newcomer et al. [1] found that aviation managers consider education important for hiring new staff, even though they did not share the same opinion regarding their own employment. Such an attitude indicates a potential paradigm shift in aviation industry, from an opinion that education is not preferred, towards an attitude that education is an imperative [1]. Smith et al. [2] found that in the course of pilot training, candidates who completed higher education need less practical training than those who did not. The importance of education in aviation industry recruiting should also be observed in the context of certification and experience that an individual hold. The research carried out on this topic [3] showed that education is a field of constant and considerable importance and is extremely significant for employers. It appears to be the only field with constant positive trends.

However, the greatest importance is placed on individual's experience. It has been shown that, if a particular job is of a more technical nature, employers will require persons who hold certain certificates. If a job is more about management and involves communication and other soft skills, then employers will look for experienced and educated individuals. The current research has shown that experience is the most relevant issue for performing a job and for delivering skill, knowledge and ability (in that order) and is accordingly vital to the aviation industry hiring process [3]. Education is on one hand considered to be important, but on the other hand it solely serves as a foundation upon which the experience is built.

This paper elaborates on the sector called aviation industry. It discusses trends in aviation industry and establishes a link between international sectoral qualifications frameworks and sectors. The key competences of the sector are detected; but still they need to be further developed and elaborated.

2. AVIATION INDUSTRY MARKET

Air traffic is expected to grow in the long-term. New concepts and technologies that have emerged over the last six years enabled implementation of free routes or point-to-point flying using advanced on-board avionics. According to 2016 report on air traffic market [4] airlines globally achieved record profitability in 2015 with operating margins of at all-time high of 8.8%, while average air fares decreased by 5% against a backdrop of fuel prices averaging 44% lower than in 2014. All the above mentioned was in favor of the fact that the number of passengers carried (revenue passenger kilometer – RPK) grew by 6.3% in 2016, in comparison to 2015. This gives a number of 3.7 billion passengers carried by air in 2016. The International Air Transport Association (IATA) expects 7.2 billion passengers to travel in 2035, which means that the number of passengers will be doubled compared to 2016. With the strong and resilient passenger traffic growth, and the fact that air traffic doubles every 15 years, there is a great need for new aircraft. In 2016, there were 19,000 passenger aircraft in service. Airbus predicts a demand for 34,900 new aircraft by 2036 (34,170 passenger and 730 freight aircraft) [5]. Asia pacific region should account for 41% of the demand, with the US and Europe together representing 36%.

As the world fleet grows, grows also the need for pilots and technicians to meet the demands of airlines and passengers. Airbus forecasts that over the next 20 years, more than a million aviation industry professionals will have to be trained to the fullest possible extent [5]. It is predicted that only European companies will need to hire 106,000 pilots and 111,000 technicians between 2017 and 2035 [6]. The prediction of total demands for aviation professionals according to world regions is presented in table 1.

Table 1 – Prediction of total demand for aviation professionals according to world regions

World region	Demand for commercial airline pilots	Demand for airline technicians	Demand for commercial airline cabin crew
Asia Pacific	253,000	256,000	308,000
Europe	117,000	118,000	173,000
North America	106,000	111,000	154,000
Middle East	63,000	66,000	96,000
Latin America	52,000	49,000	52,000
C.I.S./Russia	24,000	25,000	28,000
Africa	22,000	23,000	28,000
TOTAL	637,000	648,000	839,000

Source: [6]

The demand for pilots is influenced by retirement of experienced pilots, by a large number of inexperienced pilots that enter the service and by the fact that army is no longer the primary source of airline pilots.

A shortage of workforce in maintenance technician field was identified by 42% and presents the greatest challenge in aviation [*7*]. It is predicted that a global demand for qualified aviation experts will take place in the next 15 to 20 years.

In the future, a digital transition will cause a re-evolution of traditional MRO practice. Today, new generation aircraft are able to communicate in real time through datalink systems up to 400,000 separate parameters, enabling predictive maintenance to begin to play a key role in aircraft operation and support.

If we want to design educational system or training programs for air transport and aviation experts and other jobs in the sector that encompasses aviation in general (also known as Sectoral Qualifications Framework), firstly we have to understand what qualification is. Secondly, the most important and challenging objective is to predict what aviation industry and air transport will look like 20 years from now.

3. INTERNATIONAL SECTORAL QUALIFICATIONS FRAMEWORKS AND SYSTEMS

International sectoral initiatives are widespread phenomena. The Final Report on Sectoral Qualifications Frameworks (SQF), commissioned to support European Commission in recognition of International Sector Qualifications (ISQ) and related initiatives, identified 254 organizations delivering SQF initiatives, of which several managed more than one. Most were qualifications, suites of qualifications, or standards [8].

The integration of International Sectoral Qualification is a key objective of European Qualification Framework (EQF) which should enable international organizations to relate their qualifications systems to a common European reference point and thus show the relationship between international sectoral qualifications and national qualifications. EQF is also an instrument for the promotion of lifelong learning, so it encompasses all levels of qualifications acquired in general, vocational as well as academic education and training.

Qualification is a formal outcome of an assessment and validation process which is obtained when complement body determines that an individual has achieved learning outcomes to given standards [9]. The EQF's eight reference levels define all levels of qualifications, from basic general knowledge (level 1) to doctorates (level 8). All EQF's levels are described in terms of leaning outcomes, while the levels 3-5 are reserved for vocational education and levels 6-8 for an academic degree.

Learning outcomes are statements used to describe what a learner knows, understands and is able of doing after the completion of a learning process. Learning outcomes are specified in three categories – knowledge, skills and competences [9].

European Member States have been invited to align their national qualifications levels with the EQF. But EQF Recommendation [10] does not include definition of International Sectoral Qualifications Framework and it does not elaborate on how such relationship shall be established. The EQF Recommendation refers to a linkage between EQF and sectoral qualification systems, however there is very little clarity about what is meant by this term. The EQF basically translates qualifications acquired with the different education and training system in Europe more readable and understandable.

The study [8] detected that, so far, there has been little concrete action to clarify the role of EQF in support of IQF. Most ISQ initiatives target at highly skilled professionals. They are top-up qualifications, mainly designed for professionals who already hold an initial qualification. Hence, the most common purpose for the initiatives is to facilitate the movement of professionals across countries and secure and/or raise professional standards. One of important conclusion of the study [8] was that the most commonly mentioned reason for having or wanting to create a link with IQF and EQF is to improve recognition.

3.1 What is Sectoral Qualification Framework?

Hupfer and Spöttl [11] state that a sector related qualification framework, or sectoral framework in short, includes qualifications and competences (learning outcomes) that are relevant in a specific economic sector. Further to that, what is a sector and how to define it? The above mentioned authors define a sector (from the point of view of vocational education) as an area of expertise that relates to comparable or similar work tasks and work processes and has a similar production or service structure. Based on economic nature of a sector, it can be considered as a Single European Market which refers to the EU as one territory without international boundaries or other regulatory obstacles to the free movement of goods and services. In relation to that, EU defined 22 sectors, out of which Aeronautical industry is one.

A distinction between aeronautics industry and aviation industry should be noted. European aeronautics industry develops and manufactures civil and military aircraft, helicopters, drones, aero-engines and other systems and equipment. The industry includes companies that provide support

services, such as maintenance and training. In this concept, term aeronautical is strictly focused on production.

On the other hand, term aviation is more general term which can be more appropriate for definition of specific sectoral framework. Aviation is the activity of flying aircraft, or designing, producing, and keeping them in good condition. It is convenient to use more general term aviation instead of aeronautics together with the term industry to emphasize the importance of economic perspective to be consistent with EU sector definition. Therefore, it is proposed that in that specific sector is called aviation industry and the future framework Sectoral Qualifications Framework for Aviation industry.

3.2 What is the Framework?

In addressing the problem of attempting to explain the nature and meaning of SQF, the understanding of framework can be crucial. There are two groups of frameworks that can be distinguished [11]: frameworks whose descriptors reflect merely market-oriented requirements and employers' perspective, and frameworks whose descriptors include additional claims to education that go beyond a partial market perspective.

The employability model aims at an output oriented or learning outcome-oriented description of qualifications, irrespectively of the pathways, models and systems of qualification for the labour market.

Understanding the model of qualification is essential for generating qualification framework. In vocational education model qualification for the labour market is below the level of higher education and is traditionally input oriented. EQF qualification structure follows the model of market-oriented employability. EQF descriptors are in principle inadequate for representing qualifications that are achieved in the system of dual vocational education and training. This is likely to be an obstacle to the successful implementation of the EQF, especially in those countries that have elaborate system of vocational education. Anglo-Saxon concept of employability became the reference model for the EQF and number of other national frameworks, whose design in terms of the concept of qualification and the descriptors used, follow the EQF [11].

In this sense, a problem of education or practical training of air traffic controllers (ATCOs) can be considered. The question is whether the employer, the Air Navigation Service Provider, needs their ATCOs to be engineers with university bachelor diploma, or is it more appropriate for them – considering job description which is mainly skill oriented - to be high school graduates with intensive specifically designed training? The supporters of the second option argue that 90% of university education program is unnecessary (too much natural sciences, etc.) and therefore needless. So, three-year (bachelor) university program for ATCO is a waste of time, after which ATCO candidates anyway have to complete additional courses to gain their licenses. The supporters of the first stand (ATCOs as engineers), argue that the complex Air Traffic Management system does not only need highly trained professionals, but also such experts who will actively contribute in designing the system and adapting it to the needs of the employer. That includes highly specialized knowledge of the field, problem-solving skills and critical awareness of knowledge. These are the exactly the same knowledge and skills mentioned in descriptors of EQF level 7 which corresponds with European Higher Education Area and framework of Bologna process. The truth is probably somewhere in the middle. Some candidates should be trained as career ATCOs, and others to be experts in the field of ATM with engineering background and practical experience. The same problem arises when education of professional or commercial pilots is discussed.

3.3 What is Competence?

European and international sectoral bodies aim to recognize the diversification and internationalization of qualifications. The emphasis is put on qualifications that are tailored to meet the specific demands of sectors. The European Commission thus addresses the perspective of markets

and enterprises in accordance with the employability model. Given this orientation it is no surprise that sectoral frameworks are developed from market and business perspective that leaves out more general objectives and standards of education like those addressed in the principle of vocationalism highlighted in Copenhagen Declaration of 2002 [11]. The two approaches in designing principles and structure of sectoral frameworks can be detected. The first is a competence framework where the relationship between education and work is considered exclusively from the demand side. One such example is the e-Competence Framework (eCF) where competences are described as the demonstrated ability to apply knowledge, skills and attitudes for achieving observed results. This is a holistic concept directly related to workplace activities and incorporating complex human behaviors expressed as embedded attitudes [12]. The basis for the identification of the sector-relevant competences is work process analysis (identification and exact description of the core work process). The crucial point is organization of work. Therefore, for sectoral framework based on competences, it is necessary to establish the link to the context of work and identify/describe core competences that are developed in schools and training enterprises.

The second is a qualification framework where the starting point for the definition of descriptors is not the work-process analysis or company-specific job titles or workplace descriptions, but the academic degree known as qualification. Here, competence means the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal development. In the context of the EQF, competence is described in terms of responsibility and autonomy [9].

In Evidence-based training (EBT) concept, the ICAO [13] defines competency as a combination of knowledge, skills and attitudes required to perform a task to the prescribed standard. Core competencies are further defined as a group of related behaviors, based on job requirements, which describe how to efficiently perform a job and what proficient performance looks like. They include the name of the competency, a description, and a list of behavioral indicators (an overt action performed or statement that indicates how the crew handles the event).

In European Plan for Aviation Safety [14], EASA identified having the right competencies and adopting training methods for aviation personnel as a key area. Those competencies are [15]:

- Communication
- Aircraft Flightpath management - Automation
- Aircraft Flightpath management – Manual control
- Leadership and Teamwork
- Problem Solving and Decision Making
- Application of procedures
- Work load Management
- Situational Awareness
- Knowledge.

ICAO concept of EBT therefore may be more suitable to be considered in the perspective of competence framework as it emerged from industry-wide consensus to reduce aircraft fatal accident rates (demand side). Thus, the EBT concept was delivered from international working group facilitated by IATA and other industry representatives which comprised of Civil Aviation Authorities, aircraft equipment manufacturers, airlines, training organizations, but also an academic institution.

To further develop sectoral framework in aviation industry based on qualifications, all possible professional occupations should be considered by conducting occupational and qualification analysis. In general, occupations in aviation industry can be sorted in following categories:

- Air Traffic Control
- Aircraft Maintenance
- Aircraft or Aircraft Systems
- Manufacturing and Design

- Airlines/Pilot (Civil/Military)
- Airports Operations
- Aviation Education
- Aviation Logistics
- Aviation Support Services
- Other Aviation Occupations.

Sectoral qualification framework for higher education (based on EQF) in aviation industry should aim at describing knowledge, skills, and competences to be acquired during study courses, and to be enhanced during the subsequent first years of professional experience [16].

4. CONCLUSION

Aviation industry is a complex system in which experts have a significant role to cope with new procedures and emerging complex technologies. It is soon to be expected that the needs for such experts in the labor market will surpass the offer. Institutions providing training and education for these experts need to have a clear vision of the expectations set by the industry. In this context, consideration should be given to the importance of education and the relationship between certification and experience. Educational frameworks should be designed in such a way that emphasis is placed on each segment to bridge the gap between higher education ("without the knowledge, an individual cannot perform specific job adequately") and the industry ("without the experience, an individual cannot do any responsible job"). Aviation industry is an extremely challenging and motivating sector, and students enrolling in a particular education program expect to get the level of education (or the right mixture of knowledge, skills and competences) that will adequately prepare them for work in the industry. The outline of Sectoral Qualification Framework in Aviation Industry is proposed, based on two different approaches (competence and qualifications framework). Required knowledge, skills, and competences as categories of qualifications in sector are to be further analyzed based on close collaboration between the industry and higher education institutions.

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FLIGHT TEST VALIDATION OF PBN CONCEPT OF OPERATION IN TERMINAL AREA IN SIMULATED ENVIRONMENT

ABSTRACT

The Performance-based navigation (PBN) concept defines requirements for navigation specifications on which instrument flight procedures are designed. The results of standard instrument arrival procedure flyability testing based on the RNAV-1 navigation specification at Dubrovnik terminal area are presented. The use of these procedures was demonstrated in a simulated environment. The methodology established can be useful contribution for further development and possible improvements in airspace concept design.

KEY WORDS

performance-based navigation; navigation procedures; flight test;

1. INTRODUCTION

Performance Based Navigation (PBN) is a framework for defining performance requirements in navigation specifications that contain detailed aircraft and operator or pilot requirements [1]. It defines a set of standard airborne and ground functional requirements also for navigation applications, and infrastructure. The new ICAO PBN concept requires a unified airspace classification. This airspace classification is also applied to terminal areas and is a basic prerequisite for the PBN procedure implementation. An additional requirement is the development of a National plan for PBN implementation along with airspace concept clearly defined at a strategic level. The National Plan is an umbrella strategy document, which defines the short, medium and long-term goals for implementation of the selected PBN navigation specifications. These specifications will meet operational requirements of airspace users and other requirements concerning environmental protection, and will increase safety and capacity of airspace. The PBN implementation steps are defined by ICAO and should be accepted by the National authority. As by 2017, the guidelines for the implementation of PBN were not defined through the umbrella strategy document in the Republic of Croatia, Croatia Control Ltd. applied internal expertise and the common practice according to which Eurocontrol member states define the airspace concept for PBN implementation.

In this paper, the research results of future standard instrument arrival route/procedure at Dubrovnik terminal area (TMA) are presented. Ground validation of instrumental flight procedures included obstacle clearance, trajectory calculation, coding and charting. Simulator validation, as next step in procedure validation process according to [2] aimed at high level quantitative assessment of manoeuvring and database validation. The objective of the flight/simulator evaluation was to assess flyability to determine that the procedure can be safely flown, and to evaluate other operational factors. The arrival routes were based on the RNAV-1 navigation specification for aircraft category A and B. An aircraft flight simulator (FNTP Type II) was used as a model to determine the fuel consumption (fuel burned) and flight time of the King Air 200 aircraft. The procedures were designed,

programmed into simulator's guidance computer, and a series of test flights were carried out. The objective of the research was to demonstrate the possibility of manoeuvring an aircraft within the flight envelope according to the proposed scenarios. The scenarios were defined upon the anticipated traffic situation. The flyability of the instrument flight procedures was demonstrated and the obtained results will be used for further development and possible improvements prior to the PBN implementation.

2. AIRSPACE ANALYSIS

In conventional navigation, open loop radar vectors (tactical vectoring) included heading instructions are common used method for merging and handling arrival traffic flows. Moreover, standard instrument arrivals (STARs) based on conventional procedures could be used for handling the traffic where aircraft should follow a route which is described by ground navigational aid [3]. PBN concept capitalize on the enhanced navigation capabilities of aircraft avionics and represents the shift from conventional navigation with Global Navigation Satellite System (GNSS) as primary sensor. For arrivals, it reduces the vectoring of aircraft in terminal areas to the final approach and from the runway to the terminal area boundary for departures. Additionally, voice data analysis results show up to 40% reduction in the amount of two-way communications and up to 50% reduction in the amount of information required [4]. The PBN implementation plan includes the definition of adequate navigation specifications according to airspace concept. Therefore, an airspace analysis of TMA Dubrovnik was carried out. The analysis was based on the comparison of actual and planned traffic. The Communication Navigation Surveillance (CNS) equipment and aircraft capability were analyzed and linked with available CNS functionalities of Air Navigation Service Provider (ANSP). The analysis showed that there is room to improve the level of service by upgrading new and optimizing existing operational procedures. This would improve safety and create preconditions for an increase in airspace capacity and overall flight efficiency. Additionally, the procedure was constructed according to the ICAO Manual PBN for Dubrovnik Terminal Control Area. The use of the Standard Instrument Departure and Standard Arrival Route (SID/STAR), according to the RNAV-1 navigation specification, was also defined. Inadequate coverage of the ground-based Distance Measuring Equipment (DME) station signal in the TMA jurisdiction disables the integration of DME/DME procedures that can be used as back-ups in the event of the GNSS signal loss. The GNSS is a primary sensor for the specified RNAV-1 navigation specification. Therefore, it is necessary to define operational procedures and instrument flight procedures so that an aircraft as a secondary procedure can follow the conventional and available SID/STAR procedures to ensure safe operation during an entire flight. An expert analysis established that the existing operational procedures, related to coordination with other terminal zones, do not adversely affect safety, capacity and flight efficiency. On the contrary, the implementation of the PBN and co-ordination agreements with other providers have a great potential for further improvement.

The trend of air traffic growth at all airports in the Republic of Croatia has been steadily increasing. It is predicted that it could reach up to 5% per annum. The efficient planning of flight operations is limited by the existing instrument flight procedures based on conventional navigational ground-based radio aids (VOR, NDB). In the long run, that might cause operational problems in TMA's because the currently used conventional procedures are specifically designed for non-instrument runways and not flexible for the adaption of future traffic situations. Regardless, during the temporary regulations on air traffic during the peak season have been introduced based on the maximum capacity of the airport rather than those of terminal airspace.

3. CHANGE IN CONCEPT OF OPERATION

The implementation of the PBN concept in TMA includes the design, publication and operational use of an entirely new organizational concept of airspace. This primarily applies to the PBN SID/STAR navigation routes. Furthermore, these routes need to be operatively linked to approach procedures

that are also based on PBN (RNP APCH) concept, for all instrumental runways. This applies also to those runways that are not technically equipped with instrument landing system. Simulation results in advanced arrival management technologies indicates achieved benefits by enabling PBN. Flight path predictability improved, arrivals flew more fuel-efficient descents for longer time and self-reported controller workload was reduced [5]. The change in concept of operation applies to optimization of traffic flows, thus increasing the predictability of flying operations. Predictability reduces air traffic controller workload and operating costs of airline companies along with fewer emissions of the exhaust gases into the atmosphere. To achieve optimization, it is necessary to create, publish and operationally use the PBN concept that will connect the SID/STAR navigation routes and instrument approach procedures. It is therefore necessary to design and publish the RNP APCH procedures that will also provide vertical guidance.

It was shown that an increase in the maximum allowed flight path angle could result in substantial fuel savings [6]. An important element that emerges from the scope of increasing operational capacity in the airspace is the creation, publication and operational use of CDA/CDO/CCO (Continuous Descent Approach/Continuous Descent Operations/Continuous Climb Operations) for all airports/runways in TMA. The operational use of these procedures cannot be implemented without implementing the PBN concept, although they are now to some extent operationally applied at a tactical level. By application of the PBN, arrival and departure procedures would be designed in such a way that aircraft are laterally and vertically separated. This, in addition to reduced fuel consumption and exhaust emissions, has a positive effect on the air traffic controller workload.

4. METHODOLOGY

The impact of introducing PBN instrument navigation procedures on air traffic flow in TMA, has to be tested on the entire Croatian flight information region (fast-time and real-time simulations). It is also necessary to determine the effects of the PBN concept on existing flexible-use-of- airspace (FUA) procedures according to which all safety prerequisites should be taken into consideration and kept at least at the same level as before the PBN implementation.

The purpose of this research was to prove that the present aircraft could safely follow the proposed RNAV-1 arrival procedure in Dubrovnik TMA in various scenarios that may depend on the actual traffic situation. In addition, the possibility to achieve smooth transition from the arrival procedure to the conventional approach (ILS) procedure was considered. Based on this, the scenarios that defined the aircraft's flight path according to the defined waypoints in the RNAV-1 STAR procedure for runway 12 at Dubrovnik Airport (ICAO code LDDU) were elaborated (table 1).

Table 1 – Various traffic-based scenarios for PBN RNAV-1 arrival procedure for runway 12 at Dubrovnik airport

Scenario	Aircraft trajectory according to waypoints
A	TIKSA – NERRA – DU601 – (IAF) PILAP – DU402 – DU400 – RWY12 (landing)
B	TIKSA – NERRA – DU610 – DU607 – DU606 – ERASO – DU402 – DU400 – RWY12 (landing)
C	TIKSA – NERRA – DU610 – DU607 – DU606 – ERASO – DU605 – DU604 – DU601 – PILAP – DU402 – DU400 – RWY12 (landing)
D	TIKSA – NERRA – DU610 – DU607 – DU606 – ERASO – DU605 – PILAP – DU402 – DU400 – RWY12 (landing)
E	TIKSA – NERRA – DU610 – DU604 – DU601 – PILAP – DU402 – DU400 – RWY12 (landing)

The navigation procedure and the corresponding scenarios shown in table 1 were based on the test RNAV-1 STAR for RWY 12 LDDU proposed by Croatia Control according to [7]. Additionally, the design of proposed test procedure was based on actual flight tracks based on conventional STARs in TMA Dubrovnik (figure 1).

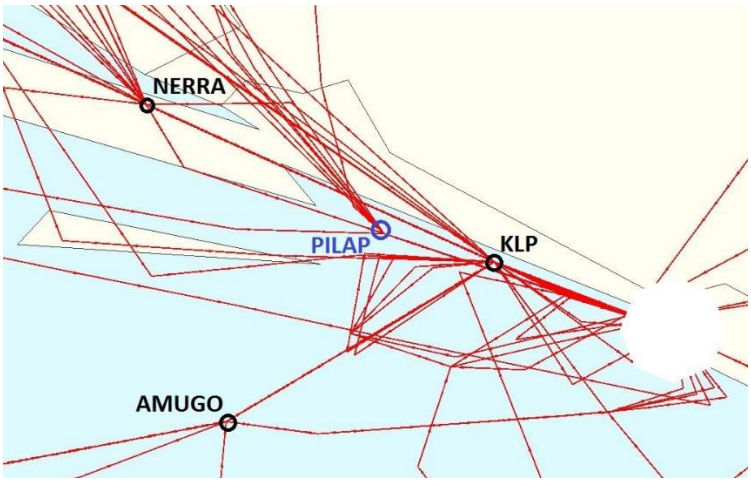


Figure 1 – Usual flight tracks in TMA Dubrovnik based on conventional procedures

In terms of determining flight efficiency provided by the PBN concept, fuel consumption for the aircraft was determined in the specific flight regime under ISA conditions. The basis for the calculation was a King Air 200 airplane with 5620 kg operating mass. The flight speed was 170 kt (at 170 RPM), which was reduced to 140 kt during the approach phase of flight. The navigation procedure RNAV-1 was incorporated into the Garmin 430 GPS flight plan. Each flight plan executed according to a predefined scenario and the aircraft simulator was programmed to follow the defined flight path. During the test flights, the time of overflying of specific waypoints and the fuel condition were recorded. Thus, the total flight time in each scenario and the total fuel consumption of the aircraft were determined from the start of the arrival procedure to the landing.

5. RESULTS

All arrival scenarios were based on same power settings with the same amount of fuel at the initial approach fix (IAF). The IAF was a starting point for arrival procedure. Flight time and fuel consumption were monitored from TIKSA point from initial altitude of 5000 ft. The descent and approach phase of flight started at PILAP waypoint, with recommended rate of descent of 700 fpm. At distance od 3 NM from the runway 12 threshold, speed was reduced to 130 kt and landing gear was extended. Table 2 shows flight times and fuel burned for each of the individual scenarios.

Table 2 – Flight times and fuel burned for different scenarios in TMA Dubrovnik

Scenario	Total flight distance [NM]	Flight time [min]	Fuel burned [kg]
A	49,6	17,31	72,9
B	81,7	26,19	114,3
C	109,7	35,1	162,5
D	95,7	30,5	147
E	76,7	24,54	113,4

Aircraft flight trajectories are recorded in a simulated environment according to individual scenarios describing all possible traffic situations in TMA Dubrovnik (figure 2).

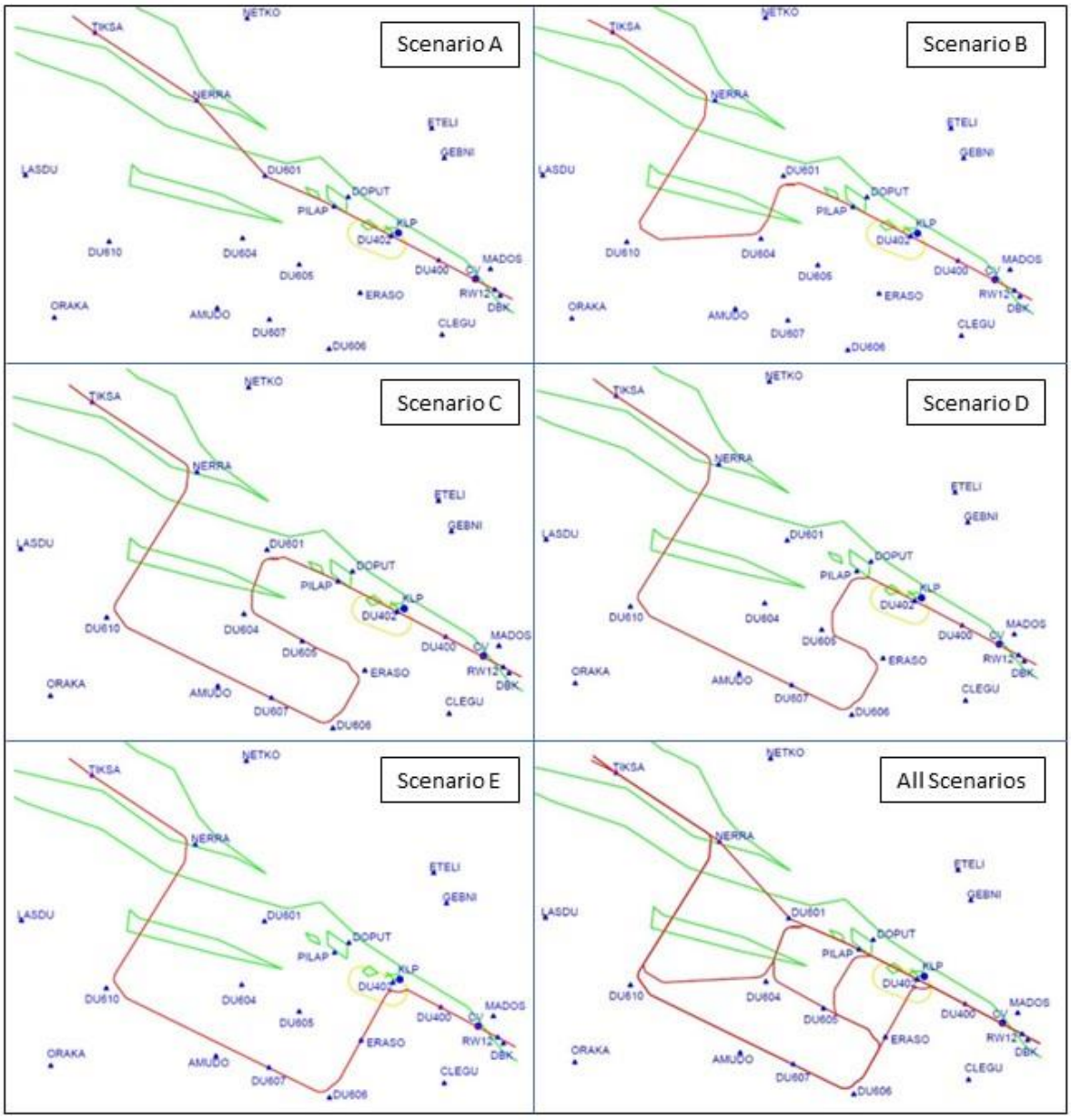


Figure 2 – Aircraft trajectories in different scenarios in TMA Dubrovnik

Data from table 1 and trajectories from figure 1 could be used for operational planning in terms of additional fuel needed if the one of possible detected scenario is in effect in TMA. Thus, data could be useful in defining controller operational procedures in traffic separation. Additionally, controller workload can be tested and compared on those scenarios and possible routing.

4. CONCLUSION

In this paper, the results of instrument arrival flight procedure flyability testing, based on the RNAV-1 navigation specification, at Dubrovnik TMA are presented. It is shown that the aircraft can follow a navigation procedure for aircraft category A and B based on the PBN concept (RNAV-1). The waypoints

based on GNSS rather than conventional radio navigation aids are suitable for defining the aircraft flight path in the terminal area and can be used to create a flight plan in the aircraft navigation system. From an operational point of view, some deviations from a defined arrival procedure are possible. Those deviations are a result of the specific traffic situations which are presented in the paper as five different scenarios. In each of these scenarios, the aircraft following the flightpath defined by the waypoints can perform safe turns with specific radius combined with change of altitude. According to the defined constant flight speed, the safe maneuverability while maintaining safe envelope was achieved. The transition of the arrival procedure to the approach procedure in all five scenarios was accomplished without difficulty and influence on the flight safety. It can be concluded that the procedure design and overall concept correspond to the PBN criteria and application, and are suitable for further development. The results obtained by research can be used to evaluate the application of each scenario on a specific aircraft in terms of flight duration that directly corresponds to airspace capacity of the TMA. Additionally, the difference in fuel burned according to each scenario is an indicator for an airline for forecasting the required fuel for the flight, which, among other things, is calculated according to the operational limits imposed by the ATM. The use of these procedures was demonstrated in a simulation environment. The methodology established can be used for further development and possible improvements of operational concept in terminal area. A further test of concept of PBN operation should be carried out prior to the implementation of approved PBN procedures.

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ANALYSIS OF DRIVERS' EYE MOVEMENTS AHEAD OF INTERSECTIONS: OBSERVATIONS OF HORIZONTAL ROAD MARKINGS

ABSTRACT

Eye movements of young drivers travelling along a two-lane dual carriageway city road were analysed, with particular attention paid to their response to lane-dividing horizontal traffic signalisation, 125-175 m ahead of eight intersections. The visual region was divided into segments containing horizontal road markings or kerbs, central section directly ahead of the driver, and the remainder of the field. Overlay with heat maps, showing stare intensity, clearly demonstrated their importance as guiding paths for drivers, even though only 10% of test participants were recorded to focus on them. On average, 31 gazes on horizontal markings were recorded, as compared to 83 gazes on the centre area and 72 for all other areas, which demonstrates very important indicative role of horizontal road markings. If a fixation occurred, it lasted on average 0.18 s, which was relatively high in comparison with fixations measured at other visual regions (0.24–0.30 s). The results confirm that proper information regarding travel path was provided by horizontal signalisation.

KEY WORDS

eye tracking; city driving; road intersection; horizontal road marking;

1. INTRODUCTION

Driving is a cognitive visual-perceptual process forming a system consisting of the driver, the vehicle, and the road. Majority of traffic accidents were reported to occur due to improper scanning the road [1]. It is completely natural, because more than 90% of stimuli input during driving is visual [2]. Thus, the presence of horizontal road markings, which support the drivers in their task of keeping the vehicle in the centre of the desired travel path, appears obvious [3]. Indeed, statistical analysis has demonstrated that the presence and proper quality of horizontal road markings can bring safety benefits sixtyfold exceeding the financial expenses required to install and maintain them [4]. The benefit is caused mainly by the reduction in collisions, which were reported to drop by about 20% with the markings' installation. Especially at the hazardous areas, installation of horizontal road markings was proven to be a safety-enhancing feature [5]. Hence, horizontal road markings became ubiquitous road safety features and at present there is no know alternative to their installation.

While there is a plethora of research done on perception of horizontal road markings under various conditions, we concentrated on analysing the response of drivers to their presence before intersections. We did not find in literature results of such studies, which would be done in the field, in the environment of a busy multi-lane city roads. Our analysis was done with a stationary eye tracking

device, which recorded drivers' eye movements and focus time. As an important note while analysing results given herein, one must keep in mind that focus does not always correspond to attention [6].

1.1 Eye Tracking as a Research Tool

Eye tracking is a well-established research technique recording eye movements in response to a stimulus. First eye tracking studies of drivers were reported in the early 1970s [7]. Since then, it became a broadly used tool for analysis of drivers' behaviour [8]. There are four main parameters that are recorded: gaze, fixation, fixation duration, and saccade. A gaze is a single eye regard at a specific position, fixation is a group of many gaze points within a certain space. Each fixation has its duration that is usually measured. A saccade is a change of eye focus between fixations [9]. In our work, we concentrated on analysing the fixations and gazes at horizontal road markings delimiting travel path ahead of intersections. Measurements of physiological responses, including pupil diameter was not possible with the utilised equipment.

2. METHODOLOGY AND EXPERIMENTAL

Analysis of eye movements can be done under laboratory conditions or in the field. Each method has advantages and disadvantages and both are very valuable. Laboratory work permits for exact simulation of the environment, inclusion or removal of specific distractions, change of conditions, carefully controlled mental workload, etc. On the other hand, field work is more realistic, with the multitude of natural factors that affect the analysed people and their responses. We have chosen to perform the assessment on drivers exposed to everyday street traffic with all of its distractions.

2.1 Route

The study was done within city limits of Kraków, Poland. The area was designed in the 1960s and comprises mostly quarters filled with high-rise residential blocks of low-end flats, separated by broad multi-lane streets forming barriers for pedestrians who can cross only at very limited places. The route was selected based on the diversity of infrastructure objects. The roadway had usually two lanes of traffic, with increases at most of intersections approaches; there were numerous interchanges, including roundabouts, turnarounds, pedestrian crossings controlled and not controlled by traffic lights, presence and absence of public transport infrastructure, etc. The route is shown in Figure 1.

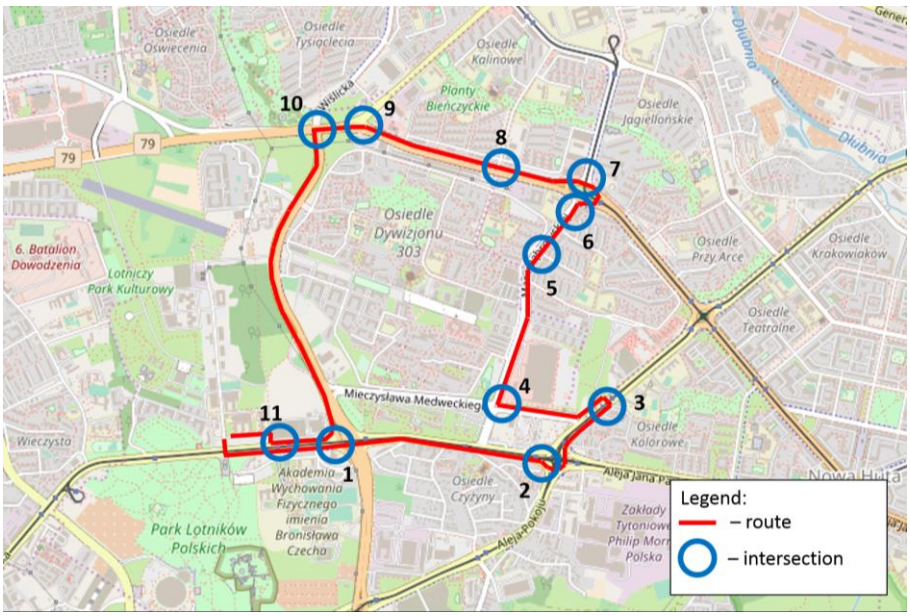


Figure 1 – Map of the test route with the eleven analysed intersections marked
Source: Open Street Maps (2017), route overlay by authors

2.2 Participants

The test participants were recruited amongst final-year Krakow University of Technology students and selected after filling a standard questionnaire regarding their health, vision, driving experience, etc. There were 32 drivers (21 male and 11 female), aged 20-28 (average 24.3 years, standard deviation 1.7). All of them were holding a valid category B driving licence and declared having uncorrected or corrected 6/6 vision. Familiarity with the test route varied amongst the test participants: only 4 declared no knowledge of the area and 28 knew the region. The participants were not compensated for their work. Ethical guidelines related to work with human subjects, set by Krakow University of Technology, were followed at all stages of the experiment.

2.3 Experiment

The eye tracking device FOVIO (Seeing Machines; Canberra, Australia) was mounted on the steering column of a 2014 compact car powered by 1.25 dm^3 petrol engine and equipped with a 5-speed manual transmission. Participants were given a brief time to familiarize themselves with the vehicle, during which time the performance of eyetracker device was verified. Drivers who knew the area were not informed earlier about the planned travel path and all participants were instructed to obey speed limits and rules of the road. Verbal instructions regarding the driving path, with appropriately advance information, were given by the research coordinator present in the passenger seat. Tests were run in late summer, with weather conditions varying from sunny to cloudy. Driving was done during off-peak hours on work days.

3. RESULTS AND DISCUSSION

The collected data was processed by software EyeWorks™ (EyeTracking Inc.; Solana Beach, California, U.S.A.). One has to note a significant deficiency of the utilised method: unlike wearable eye tracking devices, the used stationary equipment was not able to record eye movements with head movements of the driver. Therefore, there were quite significant data voids. Nevertheless, the quantity and quality of the obtained raw data was sufficient for processing. The best way to present and visualise the obtained results was by overlaying the gazes of all recordings to form heat maps [10].

Even though the analysis was done on 11 intersections, for data presented herein were selected eight. In the three discarded cases, road configuration was quite specific: a turnaround through a median with a tram line (intersection 3), tram turn from a median to a median on a side street (intersection 7), and a busy multi-lane left turn (intersection 10). Discarding the three intersections permitted for elimination of additional factors, which would unnecessary obscure the presented results. In all of the cases, the readings from 125-175 m before the intersection were analysed. Such large distance permitted for proper assessment of early visual search path. Analysis of near visual search path is in progress and shall be reported separately.

Exemplary heat maps for four intersections are provided in Figure 2–Figure 5. In all of the cases, clearly visible is high intensity of focus at the centre area, directly ahead of the drivers, which was fully expected. Quite intense search for travel path, delineated by horizontal road markings, is also obvious. In Figure 2 (intersection 1), visible is high focus intensity on directional road sign (quite surprising, because the drivers mostly knew the area and were directed by research coordinator present in the vehicle) and a search for delineation, which on the right side was the kerb. Quite similar visual search was seen in Figure 3 (intersection 2), where overhead directional road sign and traffic lights were the primary objects of focus and horizontal road marking was clearly the secondary. Ahead of intersection 9, intense scanning of pedestrian crossing was dominating (Figure 4). Equally intense search for lines delimiting travel path was seen at intersection 11 (Figure 5), ahead of a marked pedestrian crossing. Similar results were obtained for other four analysed intersections.

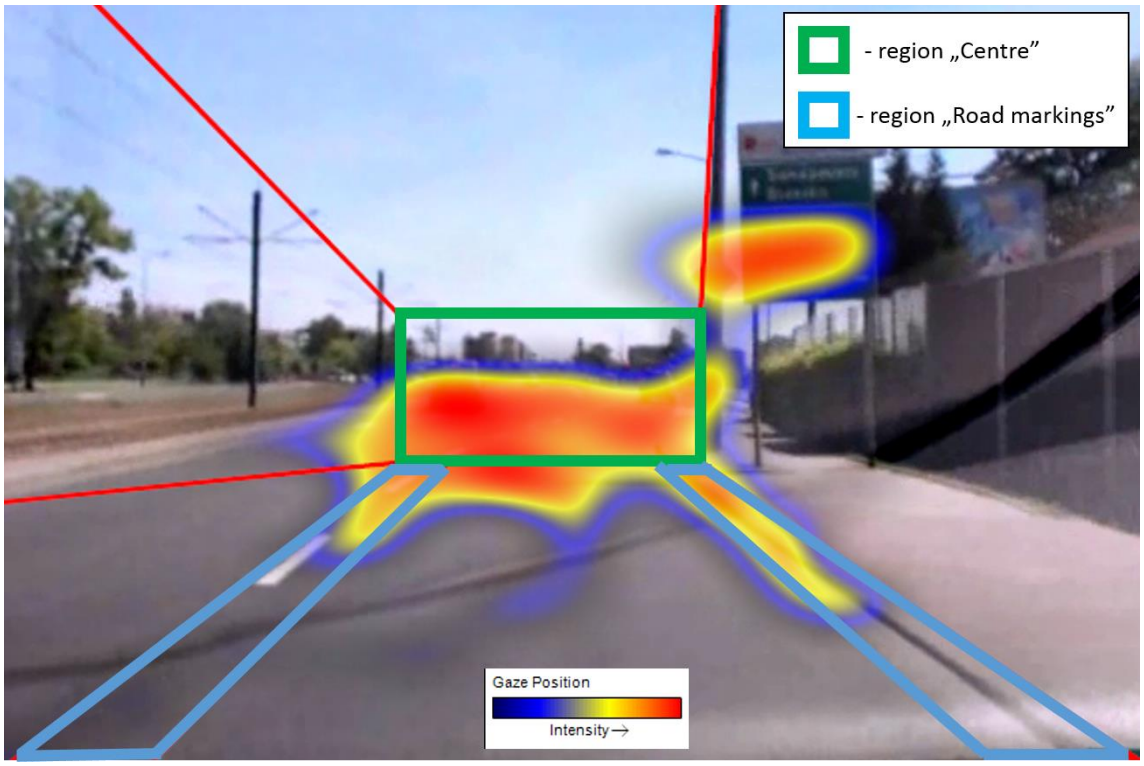


Figure 2 – Heat map of visual search before intersection 1
Source: Authors

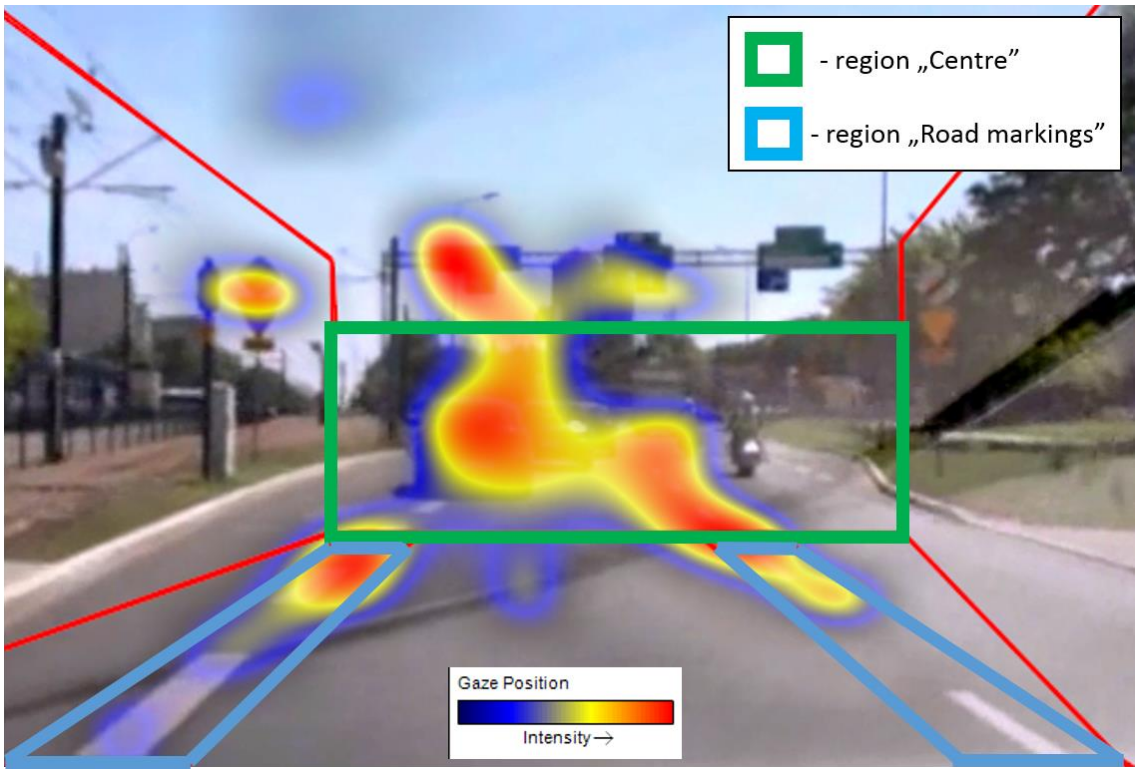


Figure 3 – Heat map of visual search before intersection 2
Source: Authors

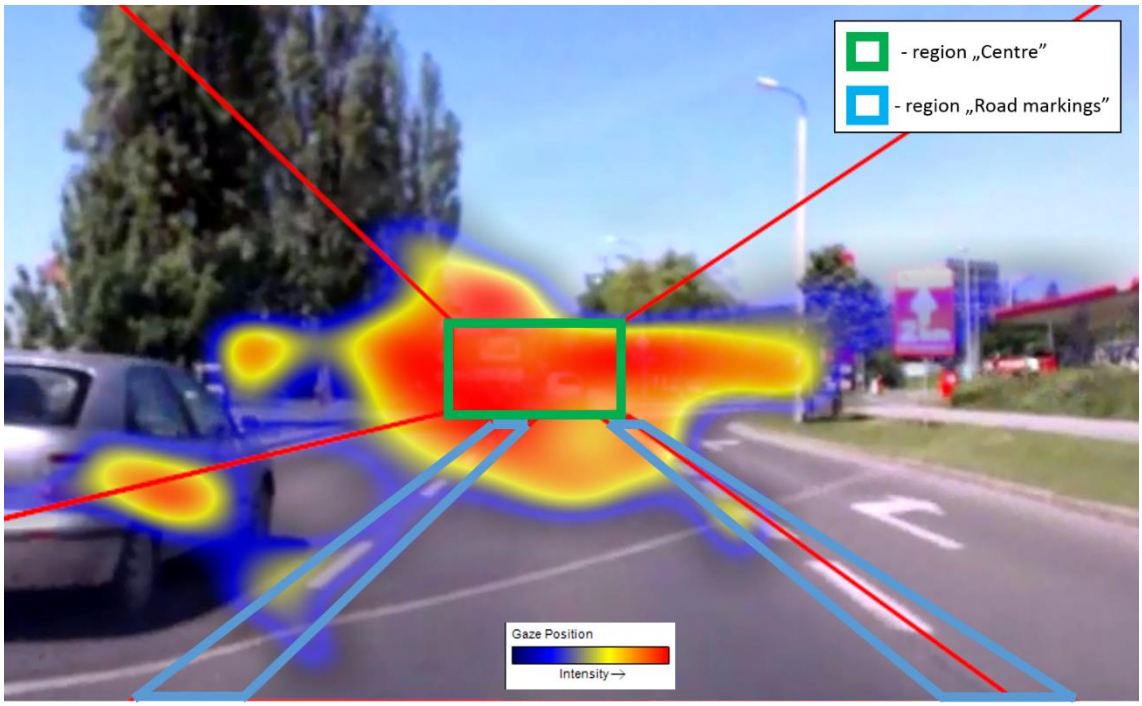


Figure 4 – Heat map of visual search before intersection 9
Source: Authors

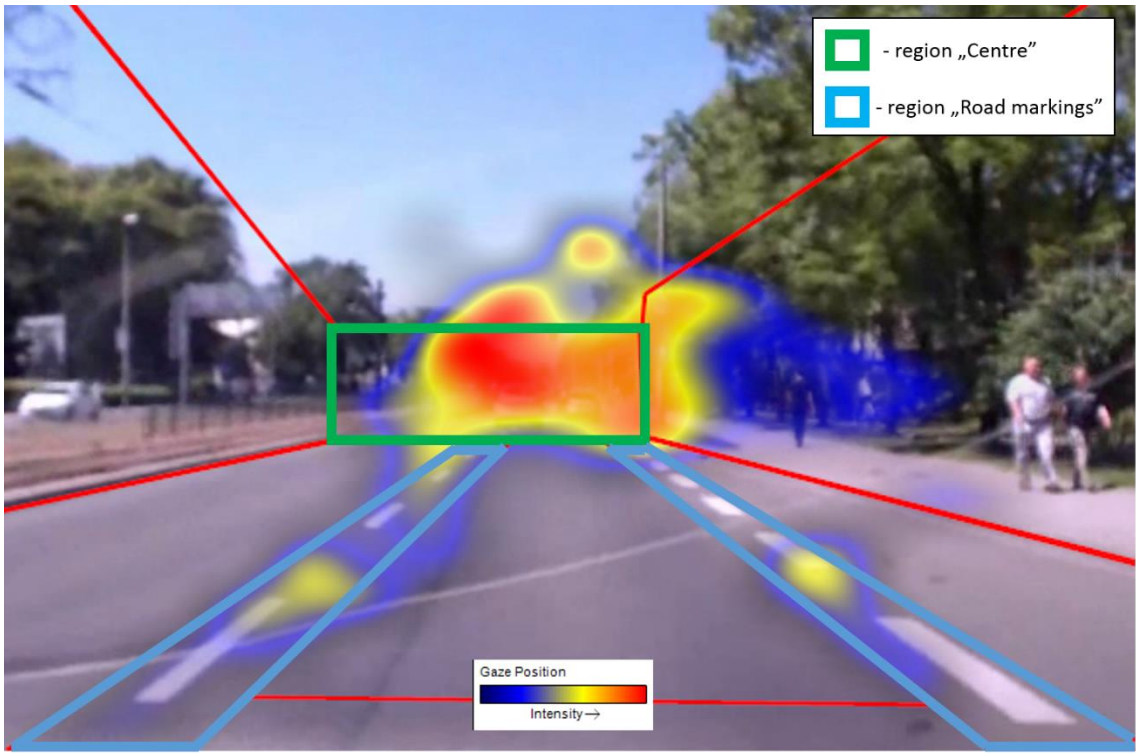


Figure 5 – Heat map of visual search before intersection 11
Source: Authors

Summarised results from the analysed intersections are shown in Table 1. Whereas on average only 10% of participants were recorded to focus on horizontal road markings, the average number of fixations on them was 2.3, which was less than half of that recorded for centre and other areas (4.2 and 4.0, respectively). Mean fixation duration on horizontal markings, 0.18 s, was only 25% lower than fixation duration for the centre area (0.24 s). The average number of gazes at horizontal markings was

31, as compared to 83 for the centre area and 72 for all other areas. It was noted that the average number of fixations per participant varied least at the centre area (4.2, standard deviation 0.92) and most at the horizontal road markings (2.3, standard deviation 1.82). However, comparing average number of gazes at the centre and the road markings, variability between participants is much smaller, correspondingly 83 gazes with standard deviation 19.0 and 31 gazes with standard deviation 17.9. This indicates that road markings are perceived mostly at the level of gazes and eye fixations at them might be unnecessary.

Table 1 – Observations, fixations, and gazes at various regions

Area	Visual region	Observers	Fixations		Average number of gazes per observer
			Average number per observer	Average duration [seconds]	
1	Centre	14 (44%)	4.6	0.22	73
	Road markings	6 (19%)	3.8	0.22	48
	Other regions	13 (41%)	5.0	0.36	83
2	Centre	14 (44%)	3.8	0.28	101
	Road markings	3 (9%)	6.3	0.17	48
	Other	12 (38%)	5.2	0.35	100
4	Centre	17 (53%)	4.9	0.25	84
	Road markings	2 (6%)	1.0	0.12	12
	Other	8 (25%)	3.3	0.42	48
5	Centre	18 (56%)	6.1	0.34	121
	Road markings	2 (6%)	1.5	0.10	31
	Other	5 (16%)	3.0	0.18	49
6	Centre	13 (41%)	4.6	0.25	84
	Road markings	2 (6%)	1.0	0.37	16
	Other	17 (53%)	3.5	0.26	72
8	Centre	13 (41%)	4.0	0.21	84
	Road markings	4 (13%)	3.3	0.24	30
	Other	14 (44%)	4.6	0.39	81
9	Centre	13 (41%)	3.2	0.19	55
	Road markings	2 (6%)	1.5	0.21	25
	Other	16 (50%)	4.4	0.29	74
11	Centre	14 (44%)	3.9	0.25	79
	Road markings	6 (19%)	1.5	0.13	59
	Other	15 (47%)	3.9	0.23	78

Source: Authors

While performing analysis of the presented results, one must remember that the participating drivers were young. Research has shown that older, experienced drivers frequently have different visual search pattern; they avoid unnecessary glances and concentrate at the potential hazard sources [11]. An example of apparent distraction of drivers who focused on a sky instead of road ahead is provided in Figure 3. Whereas it is unknown what caused the distraction, such loss of focus during city driving can have dramatic effects.

3. CONCLUSIONS AND FUTURE RESEARCH

The results obtained with the stationary eyetracker device were according to the expectations and matching previous reports: Drivers' focus concentrated at the centre of the field of view. Even though only 10% of drivers were recorded to focus on horizontal road markings, their fixation times were relatively long, which was quite surprising and we suspect that it might have been caused more by their inexperience than the real need to fixation. Majority of observations of horizontal road markings were at the level of gazes, without proper focus, which can be considered as very beneficial for road safety. Thus, the importance of furnishing roads marked in an unequivocal and clear manner is critical.

Quite recent field assessment of eye movements in response to vertical road signs done in Poland suggested that moving some of the information from vertical to horizontal markings should be beneficial for drivers and could lead to improvement of road safety [12]. It could happen, because it was determined that drivers focus on a certain area for the time required to properly process the provided information, and then move their attention back to the centre area; hence, time spent on analysing a vertical road sign could be treated as a distraction period, taken away from observing the road ahead [13]. Analysis of such modification or road signalisation has not been done so far, even though it would be of particular importance for Poland, plagued with excessive number of vertical road signs.

One of the important recent factors in research regarding horizontal road markings is availability of novel technology for glass beads, which permits for obtaining very high retroreflectivity, exceeding even 1,000 mcd/m²/lx, as compared with only 350 mcd/m²/lx that can be achieved with standard markings [14]. While one might argue that retroreflectivity is important only for driving at night on unlit roads, it has to be remembered that the use of the new technology improves markings durability, which is making them more environmentally-friendly [15]. Additional eyetracker work related to retroreflectivity of the markings, their width and clarity, and perception of additional information that could be placed on the road needs to be done to fully comprehend the role of horizontal markings in city driving, particularly due to the recent reports that people driving at night do see and appreciate high retroreflection [16][17].

Familiarity with the route, age and experience of the driver, and weather influence – during both daytime and night time driving – are yet another unexplored area in this topic. It was demonstrated that drivers familiar with a particular road pay less attention to the road, but do notice features that are meaningful for safety [16][18]. It is not known if these factors would lead to a change in the number of gazes, focus, and focus time on the markings, particularly during field experiments.

The presence and clarity of horizontal road markings is critical not only for human drivers, but also for machine vision technologies and self-driving vehicles that rely on it. It was established that high quality of road marking is absolutely necessary for successful autonomous vehicles and simultaneously for safety of drivers of traditional ones [19]. Assessment of horizontal markings in response to machine vision and their concurrent usefulness for human drivers is still awaiting appropriate research [20].

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AIRPORT SECURITY AND PASSENGER AND BAGGAGE HANDLING TECHNOLOGIES IMPROVEMENTS

ABSTRACT

Airport security as well as passenger and baggage handling process in passenger terminal is conventionally organized with staffed facilities. In international departure there are primary facilities: passenger and baggage check in, security control, passport or identity card control, boarding control. International associations and organizations, airlines, airports and national aviation authorities significantly changed and improved processes using modern technologies to speed up a process and make it cheaper. After attack on US on September 11, 2001 new security measures were adopted. The handling processes on departure are not unified in the world. Paper is reviewing security measures after 2001 and the scope of latest examples of modern technology globally in passenger and baggage handling on international departure.

KEY WORDS

airport security; security measures; passenger and baggage handling; biometrics; facial recognition;

1. INTRODUCTION

Airport passenger and baggage handling process is conventionally organized on staffed facilities on the route of passenger in departure and arrival. On international departure, there are staffed passenger and baggage check-in or self-service check-in, security control, passport or some identity card control and boarding control. At check-in there is a check of travel and passenger documents: airline ticket in the past, the passenger name and surname on passenger list today and passport or identity card check for passenger identification. At the registration, on the base of airline information system passenger list and identity document (passport, identity card …), a boarding pass is mainly issued for passenger and baggage tag for cabin or carry-on baggage as well as baggage tag for hold or checked baggage and sticker for confirmation of checked baggage accept. It takes two to three minutes per passenger in the case of regular procedure. During the peak traffic period at the first facility in departure, the check-in, queues are usually formed in front of the counters, sometimes very long with waiting time of half of an hour or even more.

On the next facility, usually security check, the procedures are becoming more and more demanding tailed and time consuming which increases waiting time (especially in the USA). Further there is passport or identity card control and usually there are less queues in front of passport or other identity card control. On the passport control, the identity of passenger is controlled again. The last control is boarding control. On the most airports, passenger is identified the third time by passport or identity card at the boarding control. In a peak periods all waiting times for services are reaching almost one hour. In spite of the fact that facilities are served by staff, the services were poor

according to the waiting times and expensive. Airlines want to get cheaper and faster service using more efficient technology.

2. THE ROLES OF INTERNATIONAL ORGANIZATIONS AND ASSOCIATIONS IN SECURITY AND PASSENGER AND BAGGAGE HANDLING

The most important international governmental organization, International Civil Aviation Organization (ICAO) established in 1944, and was formalized as a specialized agency of United Nations in 1947. Convention on International Civil Aviation is followed by 19 Annexes as a part of the Convention. It regulates wide scope of matters important for international cooperation and highest possible degree of uniformity in regulations and standards, procedures and organization regarding civil aviation. Adopts standards and recommended practices on security matters and mainly recommendations for quality of service in handling and presents it in two annexes to the Convention on International Civil Aviation [1, 2].

ICAO is prescribing a set of rules, standards and recommendations in Annex 17 Security [1], on preventive security measures at the airport. After 2001, ICAO established new guidance on preventive security measures related to: access control, aircraft, passenger and their cabin baggage, hold baggage, cargo, mail and other goods, special categories of passenger, landside and the cyber threats.

Annex 9 to the Convention on International Civil Aviation, Facilitation [2], regulates total passenger handling duration in departure and arrival. In international departure ICAO is recommending: „Contracting States, in cooperation with aircraft operators and airport management, should establish as a goal a total time of 60 minutes in aggregate for the compilation of required departure formalities for all passengers requiring not more than normal processing, calculated from the time of passengers presenting himself at the first processing point at the airport (i.e. airline check-in, security control point or other required control point depending on arrangements at the individual airport) [2]. In spite of ICAO recommendations on duration of handling processes, airlines in conjunction with airports announce to the passengers to come to the check-in one and a half hour for short and medium range flights and up to two and a half hours before departure of intercontinental flights.

International Air Transport Association (IATA) represents interests of its members – regular airlines. Passenger and baggage handling costs and quality of service are of the great interest of airlines. IATA is an airline association and in its scope there were numerous actions just like paperless ticket which practically eliminated a paper ticket and saved a lot of money to airlines; improvements of passenger and cabin baggage security check, introduction of modern technologies in passenger and baggage handling using a biometrics etc. In 2011, IATA rolled out the idea of the future of airport screening with three lanes: first for known travelers, second for normal and third for enhanced security. Passengers who are preregistered with the appropriate government agency and undergone a background check are known travelers who will be subjected to simple security measures. Enhance security would be for travelers on selectee lists. The ultimate goal is screening process where a passenger walks through corridor where security systems are integrated and hidden within the walls. It is not yet realized. One of the most important editions is Airport Development Reference Manual which consists of very detailed techniques of airport and its facilities planning [3].

There are a numerous airlines which are developing procedures and facilities as well as information technology support. One of them is SITA, Société Internationale de Télécommunications Aéronautiques. SITA is a multinational information technology company providing IT and telecommunication services to the air transport industry. Among other SITA developed Smart Path technology which captures a passenger's biometric details through a facial scan at the first touch point in the journey, usual check-in. Once checked against the passenger's travel documents, a secure single token is created. Then, at every step in the journey – whether it is during self-bag drop,

at border control or boarding control a facial recognition is used. SITA's Smart Path solution can be integrated with existing airport infrastructure and airline systems, as well as government databases, to enable easy immigration and border checks.

3. THE ROLES OF STATES, AIRLINES, AIRPORTS AND OTHER PARTICIPANTS IN SECURITY AND PASSENGER AND BAGGAGE HANDLING

According to ICAO security regulation, standards and recommended practices, member States, respectively national aviation authority is prescribing a security regulation as well as procedures of state's authorities involved in passenger handling (security control, immigration control, customs control …).

Airlines have primary tasks in passenger and baggage handling: lower price and shorter waiting time. This is the reason that today airlines are very important in introduction of improvements in handling process by using modern information technologies and staff less facilities. In these processes they must have support by national civil aviation authorities as well as immigration authorities.

Airports have primary tasks to enable passenger and baggage handling with optimal ratio of quality and capacity. They are usually supporting the activities of airlines and adapted facilities to the needs of airlines.

National aviation authorities have important roles to accept and implement security policies in benefit for airlines, airports and passengers. In practice, an airport, airport operator, airline or airline operator are mainly organizing passenger and baggage handling processes. Airlines, national authorities and IATA or SITA or some other association or manufacturer are preparing improvement of handling procedure.

Airlines intend to have a speedy and cheap passenger and baggage handling. It is possible in collaboration with national aviation administration which have to care on national civil aviation security programme to safeguard civil aviation operations against acts of unlawful interference as well as in simplification of handling procedures.

One of the ways to speed up a handling process is use of biometrics for recognition of passenger on the facilities passenger have to pass in departure. For the years, especially after 2001, a lot of a security equipment producers have promoted biometric trying to assure customers that their solution is the most appropriate for airport security and passenger recognition among next: fingerprint, hand geometry, facial, iris, voice and vascular pattern.

Focus is given to passenger identity which has to be checked at least three times: on check-in, passport/identity card control and boarding control. An immigration control is responsible for passenger recognition and special measures have been given to those agencies to accept modern method of passenger recognition.

4. IMPROVEMENTS OF SECURITY IN AIR TRANSPORT

The terrorist act on September 11, 2001 was the first time that aircraft was unlawfully seizured and used for attack on building with aim to kill as much people as possible. Four airplanes killed, with passengers and crew and hijackers almost 3,000 people, injured approx. 6,000 others and caused at least USD 10 billion in infrastructure and property damage.

ICAO in Annex 17 Security amendment after 2001, the latest Amendment 10 to Annex 17 was adopted by the ICAO Council on 7 December 2001 in order to address challenges posed to civil aviation by the events of 11 September 2001. It became applicable on 1 July 2002 [4]. The amendment includes various definitions and new provisions in relation to the applicability of this

Annex to domestic operations; international cooperation relating to threat information; national quality control; access control; measures related to passengers and their cabin and hold baggage; in-flight security personnel and protection of the cockpit; code-sharing/collaborative arrangements; human factors; management of response to acts of unlawful interference etc.

Next, Eighth Edition of Annex 17 implemented numerous additional measures on the airports (access control, new standards for passenger and their cabin baggage, hold baggage screening, in-flight security personnel, protection of cockpit, standards for airport landside security measures etc.) [5]. According to the needs, ICAO edited new Annex 17, Ninth Edition, in 2011 [6]. Preventive security measures were improved and two recommendations connected with landside and cyber threats were added. Last edition, Tenth [1] enlarged text on measures relating to landside and approved to standard and enlarged text on measures relating to cyber threats.

The European Union adopt regulations in civil aviation security for all members and follow the ICAO regulation prescribing more in detail the preventive measures than ICAO. European Union accepted Regulation (EC) No. 2320/2002 of the European Parliament [7] and the European Civil Aviation Conference (ECAC) in December 2002 which established standards for aviation security at all EU airports. It is based on standards of ICAO Annex 17, Security, the recommendations of ECAC, and proposals of European Commission (EC). Document is more extended than Annex 17 in details of security control, equipment etc. The security controls are prescribed more in detail and procedures which have to be applied to passengers, baggage, cargo, mail, courier, catering stores, supplies, company mail etc.

In next years, according to the changes in Annex 17, EU Regulations has been also changed and adopted in European Union Regulation (EC) No 300/2008 [8] of the European Parliament on March 11, 2008 which put out of power Regulation (EC) No. 2320/2002. In 2015 the new regulation was adopted, Regulation (EC) No 2015/1998 [9] at November 5, 2015. As in previous regulations standards for aviation security regulation are far more detailed than in Annex 17 in prevent security measures, equipment etc. According to the level of development of European Union States, the security requirements presented in EC regulations are more costly than Annex 17 measures.

After terrorist attack U.S. civil aviation authorities started to improve the measures on safeguarding of civil aviation against acts of unlawful interference as well as ICAO. In the USA at the governmental level Department of Homeland Security and Transportation Security Administration (TSA) has been established. Cockpit have been sealed off, the government took responsibility for airport security away from private companies. TSA inspects baggage and screens passengers. Airports have better technology to screen luggage and passengers. TSA sets the rules on what passenger can take through airport security, at first banned and after limited liquids can carry on board and implemented a special procedure for all electronic devices greater than cellular phone. There are more air marshals, from approx. 100 to more than 5,000 today and pilots can carry guns into the aircraft. TSA employees screen passenger for suspicious behaviors etc. All new measures take far longer procedures for passenger and baggage in departure and passengers have to get to the airport a lot earlier. Vast majority of mentioned measures implemented in USA are implemented in developed states.

The EU States followed ICAO standards and EU directives and significantly improved security in civil aviation comparing with a situation before 2001. According to the level of development of the EU States, there are similar rules in European Union as in the USA.

One of the most important improvement in last years is implementation of biometrics in security as well as in passenger handling.

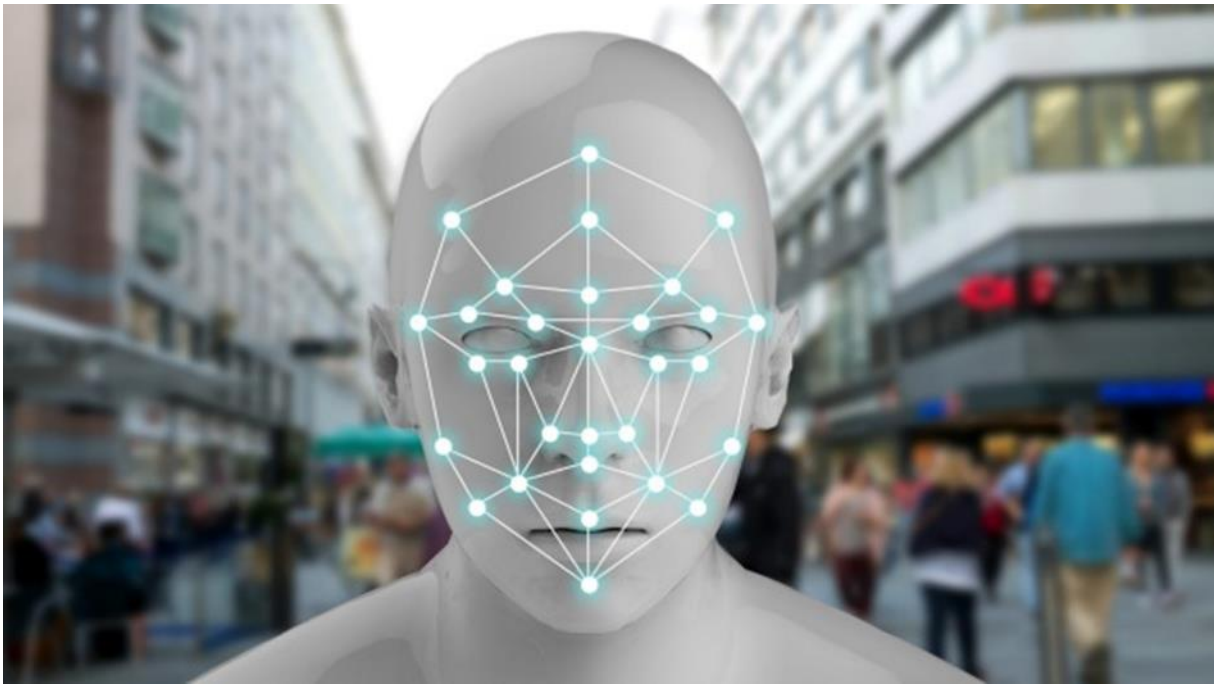


Figure 1 – Facial recognition
Source: [10]

It means that passenger doesn't has to show passport or identity card few times but only one or even non if the system is connected with the State Border protection Database or similar state system and a system gives far higher level of security and speeds up a handling process.

5. IMPROVEMENTS OF PASSENGER AND BAGGAGE HANDLING

The whole period from 2001 showed significant development in passenger and baggage handling. The most important improvement is implementation of information technology in these processes.

Airports, airport operators, airlines and airline operators implemented self-service check-in, at first for passenger only and afterward for passenger and hold or checked baggage. Some airlines forced passenger on web check in.

Passengers have to show only a passport, other ID at the first biometric kiosk they encounter, typically at check-in, baggage drop or security, depending on whether they have baggage and whether they checked in prior to airport arrival. After that, a biometric marker, usually their face, is all they need to get through various airport pass points.

Some airlines and airport are not issuing a boarding pass. In spite of they are introducing a facial recognition at check-in and boarding control. Lufthansa announces a pilot program to test biometric boarding at Los Angeles International Airport. The self-boarding gates use facial recognition cameras to capture passenger's facial images as they approach and then sends the images to the United States Customs and Border Protection database for real-time matching and verification. After the image is matched, the system recognizes the passenger as a boarded and the passenger can board the plane without the use of boarding pass or passport. This is possible according to cooperation of airline, airport and U.S. Border administration.

Some American airlines in conjunction with U.S. Customs and Border Protection (CBP) allow passengers to board their flights hands-free. Passport or identity card control is already automated and connect with governmental agencies responsible for immigration. Security control is mainly staffed facility but, in last years, there are solutions with automated procedure with certain surveillance. At certain airports there are a passport control facility equipped with automated

passport control and facial recognition and only passengers are available to proceed toward departure concourse.

Somewhere it is staffed and in other cases there are automatic door opened when some identity elements just like facial recognition is successfully confirmed as well as fingerprints or iris or even two of identity elements (for example facial recognition and fingerprints). This principle is used for boarding control. Only recognized passenger by facial recognition or some other or in combination are available to enter boarding area or waiting lounge.

The fact that in some states it is obliged that airlines has to give a passenger list in advance, state is available to make a background check of passenger. With facial or any other type of biometric recognition it is possible handling of passenger without passport or any other ID.

Planning of staff less passenger and baggage handling in departure is presented in figure 2.



Figure 2 – A case of Sydney Airport Biometric Trial for Quantas flight in six steps
Source: [10]

With the biometric data that are stored at check-in used to verify identity automatically as passengers pass camera positions at bag check, security and the boarding gate (figure 2). One's face more or less becomes both passenger and ticket.

Yesterday utopian vision of document-free travel is becoming reality.

SITA unveils new robotics check-in kiosks for airports, not fixed, that will autonomously move to busy congested areas in the airport as needed.

6. CONCLUSIONS

Terrorist attack on US in 2001 significantly changed security and had influence on passenger and baggage handling.

ICAO through Annex 17 and its amendments included various definitions and new provisions in relation to the applicability of this Annex to domestic operations; international cooperation relating

to threat information; national quality control; access control; measures related to passengers and their cabin and hold baggage; in- flight security personnel and protection of the cockpit; code-sharing/collaborative arrangements; human factors; management of response to acts of unlawful interference etc.

EU followed ICAO standards and recommended practices in security prescribing more detail the preventive measures than those one in Annex 17.

Passenger and baggage handling in departure included information technology in these processes. Cooperation with Border Protection and with airline passenger list on response to the Border Protection Administration it is possible to organize the passenger handling and facial on some other biometric recognition the process with one control of passenger ID or even without it.

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PROPOSAL OF INTEGRATED PASSENGER TRANSPORT FOR BJELOVAR AREA

ABSTRACT

This paper presents the basic characteristics of the integrated passenger transport accompanied with examples from practice. In addition to this, a brief overview of the European guidelines on the integration of passenger transport will be provided. Throughout the work, the area of Croatian city of Bjelovar will be analysed as it is an example of an inadequate public transport system resulting in an increased use of personal cars. After the analysis of the existing transport system, authors proposed a solution for the organization of the integrated passenger transport system for this example.

KEY WORDS

integrated passenger transport; railway; public transport; case study;

1. INTRODUCTION

Most of the big European cities found the solution for the problem of reduced mobility and traffic jams through the concept of integrated passenger transport. Integrated passenger transport represents the union of more different public transportation modes using only a single ticketing system. Places where change of transportation mode is possible are called integration points.

Focus of the research of this paper is Bjelovar city and its surrounding area. After conducting analysis of the transportation system authors gave a proposal for organizing integrated passenger transport in Bjelovar area. Although observed area is not big regarding population or traffic load, detail analysis will show which segments of the transportation system can be improved in order to improve the quality of life of the population. The aim of this paper is to apply the concept of the integrated passenger transport in practise, defining the role for each transport mode and integration points.

Apart from the introduction and conclusion, in the second chapter authors analyse characteristics of the integrated passenger transport along with the examples of best practice and European guidelines for organizing integrated passenger transport. In the third chapter authors conducted the analysis of the current state for Bjelovar area. In forth chapter authors gave a proposal for organizing integrated passenger transport in Bjelovar area.

2. INTEGRATED PASSENGER TRANSPORT

Integrated passenger transport (IPT) is a system of public transport of passengers where all public transport modes (trains, buses, trams, boats…) are united in a common system of passenger transport in a particular region, [1]. System is applied to a particular region, population needs and

demand for the certain type of service. The probability that the population will start using such system is greater if the supply is diverse. That means that user should be able to choose between more options in order to achieve shorter travel times.

The backbone of the IPT systems are usually a rail based systems due to their environmental, energy and infrastructure advantages in comparison to other transportation modes. The main disadvantage of rail transport is in the restricted and nonflexible travel routes. Other transportation modes included in IPT thus serve to the rail system in order to fill the gap between origin/destination of travel and integration points.

The basic characteristics of IPT can be described through timetable, types of transportation modes that participate in IPT, infrastructure of mentioned modes and common ticketing system. All mentioned will be described in detail bellow.

2.1 Characteristics of the Integrated Passenger Transport

The most important element of this system is coordinated timetable which means that arrival of additional transportation modes must be in synchronization with departure of backbone systems. Apart from coordinated timetable, integration points must enable quick and seamless transfer for all passengers. The IPT systems most commonly use cyclic timetable where the cycle mostly depends on population density and the time of the day. To mitigate negative impact of the delays it is necessary to accompany the reliable timetable with real-time passenger information system.

Utility of ITP is increased if there are more transport options for the end-users on the integration points/terminals. That means that the user can choose transportation mode from the origin to the terminal (walking, bicycle, car, bus) and from the end-terminal to the destination of the travel. The most commonly used vehicles within IPT are trains and buses but other modes of public transportation can be present such as taxies, public bicycle systems, rent-a-car, car sharing systems, trams, boats and funicular. Each city or region has its own characteristics regarding available transportation modes. The most important role of the integration points is to provide seamless transfer of the passengers between the transportation modes, which is especially important for the passengers with disabilities.

Apart from public transport, private vehicles like private cars, motorcycles or bicycles also become a part of the whole transport system as means of getting to the ITP entry points. Some terminals can provide additional infrastructure for the users such as Park&Ride system. That type of terminal should provide sufficient number of parking lots and adequate places for the users to leave their bicycles. Investments in infrastructure to build such system can be significant. Due to that reason it is wise to utilize existing infrastructure as much as possible and if necessary adjust it to the IPT system.

A bad condition of the railway infrastructure due to inadequate investments and maintenance can lead to a greater journey time that is not encouraging for the end user. Travel times with buses should be competitive with the private transportation modes and if there is possibility dedicated lines for buses and vehicles from the car sharing systems should be provided. Generally speaking, for the IPT to work efficiently and attract new users the quality of the transportation service must be satisfactory on each journey segment.

All parts of the IPT should be adjusted to the user needs. A common ticketing system enabling seamless transfer for all passengers while changing transport mode is required, as end users are discouraged if they have to buy a separate ticket for each transport mode and the meaning of integration is lost. The price of that kind of ticketing system should satisfy both users and the operators within IPT and motivate all involved to continue using/providing public transport services.

2.2 Examples of Integrated Passenger Transport

In order to better present practical application of the ITP concept authors decided to describe the good examples of IPT systems.

The Münchner Verkehrs und Tarifverbund (MVV) is the transit authority of the city of Munich, the capital of the German state of Bavaria. Its jurisdiction covers the city and its surrounding area and is responsible for S-bahn, U-bahn, tram and bus transport. It is one of the best organized and arranged public transportation system in the world in which participates around 40 operators, [2].

Timetable with regular departure interval is used on all lines. In dependence of time of the day, transport demand, passengers load on a line and other elements departure interval adjusts to the users' needs. Different lines and different transport modes have different departure intervals, and the most common are:

- For S-bahn 10 - 30 min
- For U-bahn 2 – 20 min
- For bus 5 – 20 min
- For tram 5 – 20 min.

Stations that are located outside of the city centre have P&R systems and good access for bicycles, cars and pedestrians. Ticket purchasing is very easy and possible via internet, automatic ticket purchase kiosks and in the official offices.

Verbund Linie Steiermark is a name of transportation union in Styria, which started operating in the year of 1994, connecting the city of Graz and its surroundings, while by 1997. It connects the whole Styria state.

It contains 7500 stations and 500 lines. Each year 109 million of passengers are transported and 60 operators participates in the transportation process, [1]. Area is divided into several zones. Timetable with regular departure interval of 30 min is used, but in the peak hours departure interval is 15 min. Stations that don't have much passengers have departure interval of 60 min that can be reduced during weekends and holidays.

2.3 European Guidelines for Organizing Integrated Passenger Transport

European commission considers IPT systems to be very important. Due to that reason guidelines are developed to improve planning of such systems and implementation can be co-financed by the EU. In this part of the paper overview of the basic documents that encourage public passenger transport and improve mobility through integration will be given. Mention documents are White Paper, Green Paper, Action Plan on Urban Mobility and Sustainable Urban Mobility Plan.

In White Paper from 2001, published by European commission, the focus was on railway transport and its revitalization to be competitive to road transport, promotion of maritime and inland transport and integration of different transport modes. Few years later, in 2010, European commission published another White Paper in which proposed 60 additional measures, [3].

Green Paper is presented due to the fact that mobility in urban area is one of the most important factors for achieving economic growth and sustainable development in EU. Traffic congestions are common problems in urban areas, and its negative impact can be seen on economic, environmental, social and health level. In order to reduce those negative impacts the following goals are proposed:

- Greater use of bicycles and walking
- Increased use of public transport and reduced use of cars, [4].

Action Plan on Urban Mobility has been published in 2009 as a result of acceptance of strategy for development of integrated passenger and freight transport. Its aim is to promote healthy, cleaner

and sustainable transportation modes. Action Plan on Urban Mobility contains 4 chapters in which the positive influence of integrated transport for passenger and environment is highlighted.

New approaches for the planning of urban mobility are appearing. Local authority is trying to substitute current situation in transport system with new and fresh ideas that would enable clean and sustainable transportation. In that context Sustainable Urban Mobility Plan (SUMP) is created in which participates experts for transport planning from EU. It is also important to mention the CIVITAS initiative that unites cities that want clean environment, better transportation and more comfortable way of life. From the setup it was tested and suggested more than 800 measures with purpose of creating better transportation system in urban area, [5].

3. ANALYSIS OF BJELOVAR AREA TRANSPORTATION SYSTEM

To introduce novelties in the best and most reliable way, to change current transport system, it is necessary to develop a high quality and detailed analysis of the traffic area that we want to improve. In this paper authors analyse the traffic infrastructure, traffic demand and the transport supply of the Bjelovar area.

3.1 Analysis of Transportation Infrastructure

The road infrastructure of the Bjelovarsko- bilogorska county is well developed and maintained. The length of all county roads is slightly less than 507,500 km, while the length of local roads is about 418 km. All the larger cities in the county are linked with state roads and their maintenance depends on the state. Local administrators are in charge for maintaining county and local roads.

The relative vicinity of Croatia's captial Zagreb adds optimism to the development of a series of job activities that would result in increased employment of the population, under condition if good transport connectivity is established. There is also a good connection with the town of Križevci and city of Virovitica. In 2013, Bjelovar took over 286 km of county and local roads from the Bjelovarsko – bilogorska county administration for maintenance, of which 131 km is in a very bad condition. Therefore, during 2016. it is planned to spend 10,000,000.00 kn of the city budget on the road infrastructure reconstruction, [6].

Walkways and cyclist paths are regulated and maintained, therefore, inhabitants do not have difficulty walking around the city, also because car parking grounds do not cover those paths.

In the area of the city, the inhabitants are accustomed to use bicycle, which is favoured by terrain and climate characteristics. In 2010, the city approved the "Strategy of Bicycle Paths in Bjelovar". The reasons for the approval of the strategy were ecological benefits, the positive impact on the health of the population, road relief and the easy overcoming of small distances, [6]. By 2016, 22.77 km of bicycle trails were built, of which 16.17 km are marked and 6.60 km unmarked, [6]. In addition to the mentioned, there are also two bicycle parking zones and an underground garage with 81 parking spaces, [6].

The railway line of local significance L203 Križevci-Bjelovar-Kloštar passes through Bjelovar area. The length of the entire railway line is 61,082 km, of which 11,3 km is passing through City of Bjelovar and 32,77 km of railway line is passing through the observed area. The whole line is non-electrified and single-track with the maximum allowed speed of 80 km / h on the route of Sv. Ivan Žabno-Bjelovar. Line capacity is not great due to the fact that only one train can occupy interstation spacing. Route Križevci – Bjelovar contains 10 stations and route Bjelovar to Kloštar has 8 stations. Figure 1 shows transportation infrastructure for Bjelovarsko – Bilogorska County.

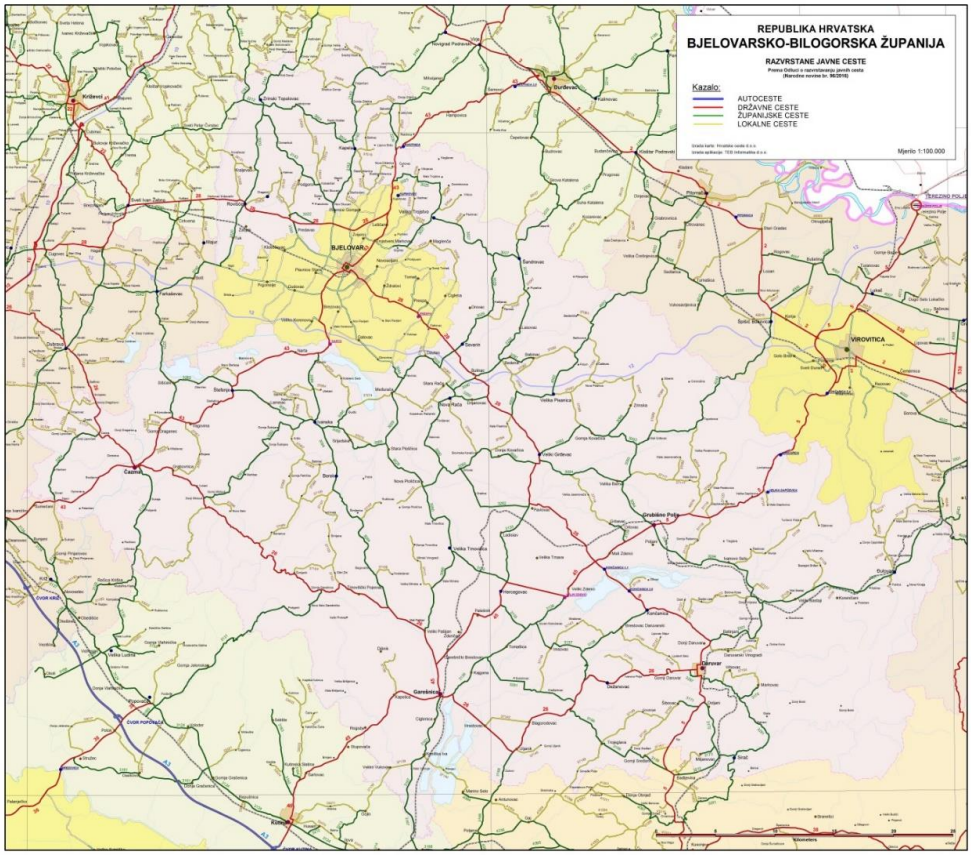


Figure 1 – Transportation infrastructure for Bjelovarsko-Bilogorska County
Source: [7]

3.2 Analysis of Transportation Demand

Transport demand for Bjelovar area will be analysed through several elements such as population demographics, population migration and areas that generate and attract traveling.

According to the demographic structure of the population, the county has 115,536 inhabitants, which makes 45,4 people/km^2, of which 33,36% or 40,276 live in the City of Bjelovar, [6]. By studying the demographic structure of cities in the Republic of Croatia, it can be concluded that the city of Bjelovar has the same marks as other major cities in the Republic of Croatia. The number of inhabitants compared to the previous lists has a negative sign same as in most Croatian cities city of Zagreb being an exception to that rule.

Daily travellers, people who go to work every day in another city or another county are shown in Table 1. Table 2 shows children and students who travel on a daily basis from their home to school or college. Weekly travellers, people working in another city or another county and coming home on weekends are shown in Table 1. Table 2 shows children and students who go to schools or faculties in another city other county, and in weekend they come home.

Table 1 – Daily and weekly travellers of employed people

Name of city or county	Employed-total		Work in the other part of city/coumty		Work in another city of the same county		Work in another county	
	daily	weekly	daily	weekly	daily	weekly	daily	weekly
Bjelovar	4.479	318	2.878	20	576	17	1.025	263
Rovišće	775	71	64	1	567	8	144	60
Veliko Trojstvo	505	36	34	1	420	3	51	31

Source: [8]

Table 2 – Daily and weekly travelers of school children and students

Name of city or county	Students-total		Elementary school students		Highschool students		Faculty students	
	daily	weekly	daily	weekly	daily	weekly	daily	weekly
Bjelovar	1.494	35	891	11	603	24	195	429
Rovišće	554	12	330	3	224	9	31	55
Veliko Trojstvo	201	4	108	2	93	2	10	18

Source: [8]

Generators of transport demand represent all business facilities, educational and health institutions that attract and create the need for traveling. In the area of Bjelovar city there are the following demand generators:

- Preschool Upbringing - Five kindergartens were founded where is 1007 kids and 162 persons were employed. Kindergartens are: Bjelovar, Ciciban, Osmijeh, Pinokio, Bubamara.
- Elementary education - Five elementary schools were founded in Bjelovar, attended by 3,033 students and 350 employees.
- Highschool education is in eight high schools (Economics, Gymnasium, Vatroslav Lisinski Music School, Commercial, Medical, Craft school, Technical) in the school year 2015/2017. there were approximately 2,500 students.
- Faculty education - High technical school in Bjelovar with direction of mechatronics and nursing, and in 2015 there were about 700 students.

Except healthcare institutions (Bjelovar General Hospital, BBŽ Health Center, Emergency Medical Services, BBZ Public Health Institute) and larger business companies (Sirela, Koestlin, Troha dill, Hittner ...) also have a significant contribution to transport demand. The city currently has three business zones employing 630 workers.

The most famous events that are attracting inhabitants are: International Beekeeping Fair, Spring International Bjelovar Fair, BOK Fest, Terezijana (Days of Town), Christmas Gala Concert. Sport compared to culturals event is completely differently accepted, currently there are 75 sports associations and clubs with more than 4000 members in Bjelovar.

3.3 Analysis of Transportation Supply

Railway timetable for the Bjelovar area and the town of Bjelovar is generally inadequate for passengers who travel to work and school, as it is not synchronized with their needs. On the railway route Zagreb-Bjelovar in one day there are 15 departures and 11 departures in the opposite direction, [9]. Bjelovar - Kloštar and Kloštar - Bjelovar are scheduled for 8 trains a day. The arrival times of passenger trains in Zagreb, as well as the arrivals in Bjelovar, are not adjusted to passengers who work in the morning shift.

In Bjelovar-Bilogora county, bus transport is more common than the railway transport. In the area where this railroad is, most people continue to prefer the bus because of comfort, the accuracy of arrivals or better fare. On relation Bjelovar - Zagreb and Zagreb – Bjelovar there are scheduled 24 buses per day, making the frequency of bus departures significantly greater than the departures of trains. Timeing of the bus arrivals at the destinations are better adjusted to passengers and their daily commitments.

Bus routes Bjelovar - Zagreb via Vrbovec lasts on average about 105 min., while with the train takes about 100 min. The price of one-way bus ticket Bjelovar - Zagreb via Vrbovec is 71 kn, while the one-way ticket for the train is 56 kn.

4. PROPOSAL OF INTEGRATED PASSENGER TRANSPORT FOR BJELOVAR AREA

To make a good analysis of the traffic system, it is necessary to found out the inhabitant's opinions and views of the existing system and plans how to improve it. The objectives of the conducted survey were to investigate opinions primarily on railway traffic, the use of bicycles in the daily travel and the introduction of the public bicycle system.

Total of 236 forms were completed and the survey questionnaire analysis showed that 75% of the population would be willing to use the public bicycle system if it existed, 65% would use the bicycle if there were custom bicycling tracks, while 70% would use the parking spaces for their cars and continue their journey with train.

The primary task in this research is to develop measures that would encourage the population to use rail instead of bus transportation, in the areas where it's possible. The secondary task is to reduce the dependence on using the car in carrying out everyday duties, such as going to work, school, college or shopping.

In the integrated passenger transport system, rail transport is the main carrier of mass transit and as such it needs to have timetables adjusted to the needs of users, which is not the case in the current state. Travel time, comfort, frequency of departures and prices must be at a satisfactory level so that residents can recognize the benefits of using the rail.

The speed on the railway line Bjelovar-St.Ivan Žabno is 80 km / h which is acceptable. From St. Ivan Žabno to Križevci speed drops to 50 km / h, mostly because of curved track line. The new St. Ivan Žabno – Gradec railway is being built at the moment, with designed speed of 120 km / h, and the axle bearing of 22.5 t and 8 t / m, which will cause great benefits for the passangers. The railway line should be opened in year of 2018. Currently, the average travel time is about 1 hour and 35 minutes, while with the new connection line time travel will be reduced to about 1 hour. Which will create additional opportunities for employees and students on that route.

Authors have proposed the new timetable which implies the construction of the new railway line St.Ivan Žabno-Gradec and also rescission of some of the current stations. The criterion for suggested rescission of some train stations on the observed route is primarily based on the absence of passengers, what was established during the survey and the counting of passengers within the scope of this research.

Train arrivals at stations need to be adjusted to passenger's needs. If this is not corrected, users and potential users of railway services will have no reason to use it. For employees who work, for example, from 7:00 am in Bjelovar, a minimum 15 minute arrival interval at a destination is needed so that they come to their jobs without hesitation.

The stations the authors propose to cancel are: Žabjak, Stare Plavnice, Markovac, Grginac, Mišulinovac i Paulovac. Stations that remain in function are: Rovišće, Klokočevac, Grginac Novi, Veliko Trojstvo. The installation of bicycle stands and the design of parking spaces for personal cars need to be introduced on all these stations.

In the integrated passenger transport system there is also room for personal cars. P & R systems are also built along with public transport stations. Parking lots should be equipped with a ramps and allow that the public transport document is at the same time a parking ticket. In the scope of this research, P&R systems should be introduced at the station in Bjelovar and in all stations that remain in the function (Figure 2).

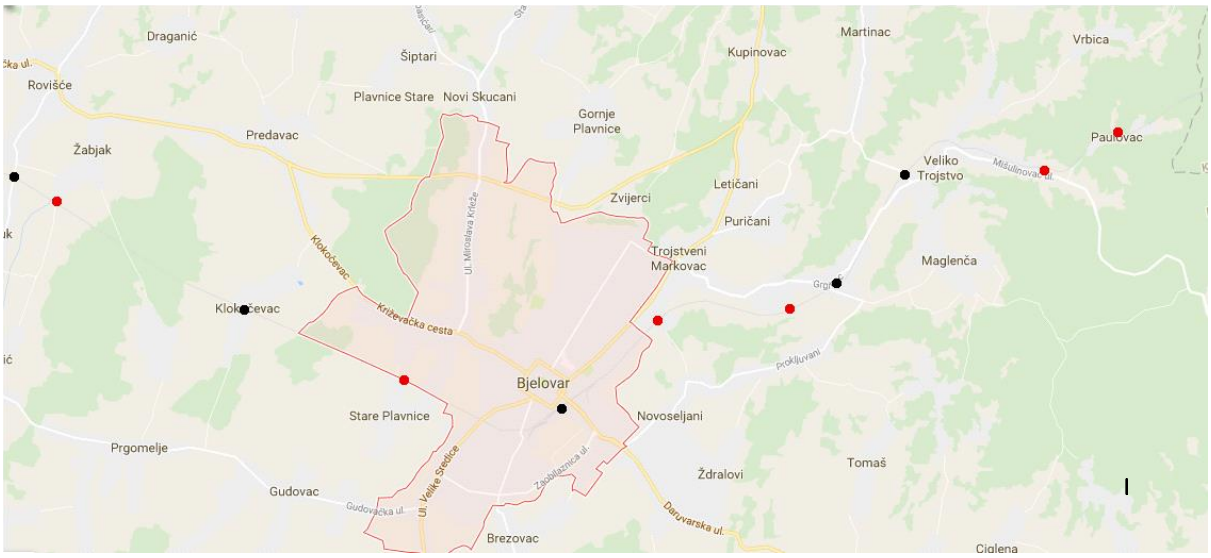


Figure 2 – Overview of Railway Stations in Research Areas

Bus timetables are currently better adjusted to passenger's needs and therefore the bus is preferred over the rail. But in integrated passenger transport, the main carrier should be the railway and other means of transportation need to be adapted to its schedule. Bus transport should be oriented to complementary instead of competitive routes. It is also necessary to add several bus stations in the urban area so that passengers would choose bus over personal car.

The special bus line timetables for the areas of Paulovac and Mišulinovac need to be adjusted to the railway timetable, so that passengers can convey in Veliko Trojstvo using the train. To use integrated transport ticket, we need to bring together all transport modes in that area. On the road towards Čazma and Đurđevac, city buses can be added to existing bus lines so that residents can reach the railway station or city centre by bus.

Taxi transportation is needed to cover the area missing from the rail and bus lines. Taxi service should be used to complement the bus and train routes. Travellers who come by train or bus should be offered to use public bicycles that can shorten their trip to the final destinations a public bicycle system becomes integrated in the passenger transport system. Bicycle subscription can be daily, monthly or annual. In Figure 3 there is an overview of planned cycling paths where red colour marks roads with cycling tracks, a combination of green and red marks the road and the bicycle paths, while the combination of yellow and red indicates pedestrian and bicycle routes along the road.

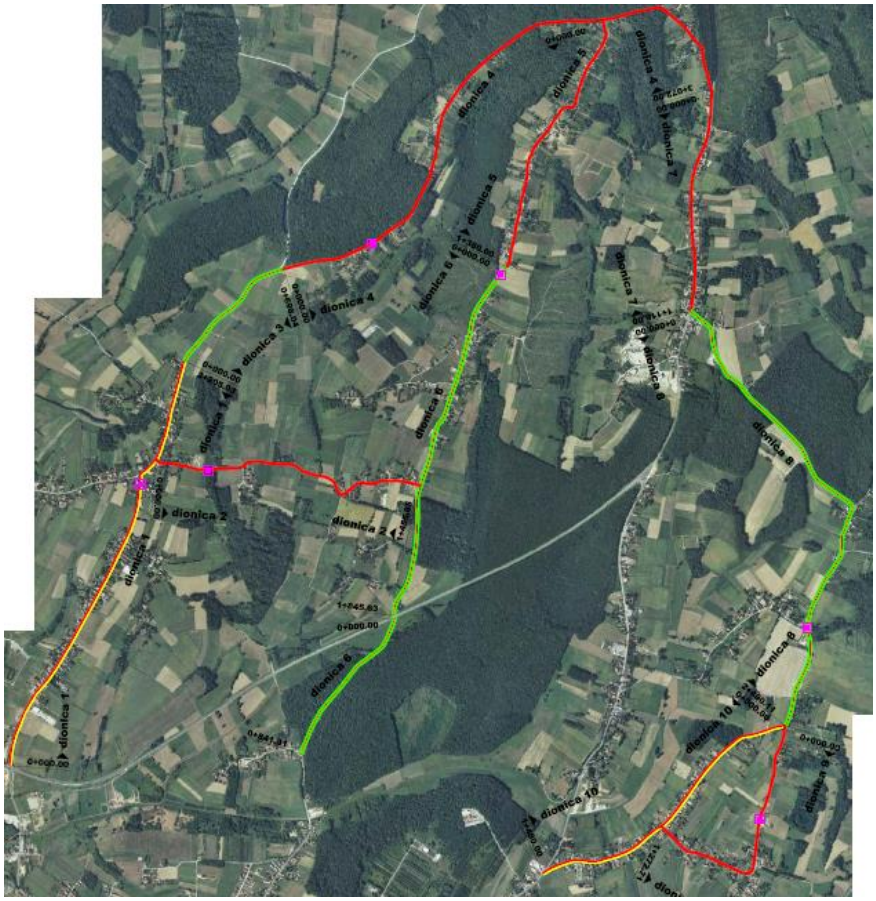


Figure 3 – Display of planned cycling routes
Source: [10]

For a simpler charging, it is necessary to introduce a unique ticket that can be purchased at all stations or over the internet in agreement with the railway and bus operators, Bjelovar, Bjelovarsko - Bilogorska county and other participants in the transportation process. The prices must be acceptable and attractive to potential users as well as the transport operators.

5. CONCLUSION

Through first and second chapter authors wanted to describe all parts of integrated transportation systems in a clear manner emphasizing its advantages in respect to current models of public transport. Furthermore, authors described examples of such systems along with European guidelines for organizing and implementing such systems.

In third chapter detail analysis of the current transport system for Bjelovar area is given. Focus was on transport infrastructure, transport demand and supply. Survey was conducted on railway stations and high schools to better understand behaviour of public transport users.

Based on the detail analysis authors can conclude that great use of cars is due to the inadequate public transport and all said is a reason for low mobility of population. Railway timetable is not adapted to the user's needs which is reducing number of passengers. Bus lines have better timetables, but can't offer shorter journey time with sufficient comfort level. Bus lines and railway lines are currently competitive while they should be complementary. Bicycle routes don't meet required standards which makes them unattractive and dangerous.

Implementing IPT railway should become a backbone of the public transport. A good link with Zagreb is important, and the new railway line from Gradec to Sveti Ivan Žabno might play an

important role in the future. The role of the bus transportation should be mainly in gathering passengers for railway transport but also in connecting places that are not connected with rail.

Bicycle routes should meet required standards and their role should be to connect city centre with the outskirts. Population would greatly benefit from the introduction of public bicycles system.

By introducing stated measures mobility of population would increase while reducing car dependence. Through a better connection with Zagreb additional opportunities would arise regarding employment and schooling of population from Bjelovar area.

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TURBO ROUNDABOUTS: CASE STUDY OF CROATIA

ABSTRACT

The popularity of various roundabout types has driven substantial efforts to optimize their design procedures. Implementing effective roundabouts is a highly demanding task and requires optimizing traffic (operational) efficiency (TE) and traffic safety (TS) while considering various geometry factors and constraints. The turbo roundabout concept has emerged as a viable alternative to conventional multi-lane roundabouts, aiming to improve exclusively TS. In multi-lane roundabouts driver indecision and misunderstanding of the driving rules and traffic situations can lead to weaving conflicts and frequent accidents. To capture a relationship between turbo roundabout design, TS and TE parameters brief overview of the latest guidelines and studies correlating Croatian case studies is presented here.

KEY WORDS

turbo roundabouts; traffic (operational) efficiency; traffic safety; geometry design; Croatia;

1. INTRODUCTION

The popularity of various roundabout types has driven substantial efforts to optimize their planning and design procedures. Implementing various types of roundabouts is a highly demanding task and requires optimizing traffic (operational) efficiency (TE) and traffic safety (TS) while considering various factors. Studies of roundabouts, particularly of single-lane roundabouts in urban areas, have shown that proper design can significantly improve TE and TS parameters [1,2]. Authors have developed models demonstrating the importance of; geometry elements, circulating traffic flow, proportion of heavy vehicles, follow-up time, and critical headway for determining roundabout capacity and delay [3].

Studies of roundabout TE have led to several computational mathematical models that have been integrated into various roundabout software engineering simulation tools. Differences among these models make it difficult to identify the most suitable ones for given conditions [4,5]. In practice, TS is most often measured in terms of the number of traffic accidents observed during a given period or mathematically modelled during a given simulation time frame. Several models have been developed to predict the number and types of accidents based on main roundabout geometry design elements [6–8].

In multi-lane roundabouts driver indecision and misunderstanding of the driving rules and traffic situations can lead to weaving conflicts and frequent accidents. These accidents, although not usually severe, often affect TE and TS parameters. The turbo roundabout concept has emerged as a viable alternative to conventional multi-lane roundabouts, aiming to improve primarily TS. However, recent studies do not allow definitive conclusions about TE [9] parameters. Additional entry and circulatory lanes increase TE parameters but they also increase the TS. These are mainly related to improper driver

behaviour at the entrance, circulatory and exit zones, and to the consequent weaving manoeuvres within the circle. At multi-lane roundabouts, increasing vehicle path curvature creates greater side friction between adjacent traffic streams and can result in more vehicles cutting across lanes and higher potential for sideswipe collisions [9]. Previous studies on multi-lane roundabouts confirmed improper behaviour as being common practice, resulting in conflicts and increased likelihood of crashes [10]. Also, the use of the inner circulatory lane is poor, which will have a negative impact on the capacity [11]. Some countries have avoided these problems by limiting the adoption of multi-lane roundabouts; France, Germany and Switzerland [10].

The focus of the research is to study the impact of turbo roundabouts as a new roundabout concept design with emphasis on Croatian experience. This is done by using the latest relevant literature review considering design guideline and studies on TS and TE parameters.

The remainder of the paper is organized as follows. Section 2 briefly describes the turbo roundabout design concept: latest guidelines, basic geometry design with TE and TS infuences. Section 3 presents Croatian case studies and Section 5 discusses the results and implications for future work.

2. TURBO ROUNDABOUTS DESIGN

2.1 Guidelines

Turbo roundabouts studies were mainly based on evaluation of their TE (capacity and delays), environmental and TS parameters, regarding other roundabout types [12]. First turbo roundabout guidelines were published in the *Netherlands* in 2008 [13]. These guidelines were world widely accepted and used by road designers in practice. Slovenian government released a draft version of *Slovenian* technical specifications on turbo roundabouts in 2011 [14]. In 2015 *German* association FGSV issued an official working document on turbo roundabout use and design [15]. *Croatian* turbo roundabout guidelines [16] were published in 2014 (*Guidelines2014*), when the first turbo roundabout in Croatia was built (*Figure 2*). Nowadays there are few of them located in the city of Osijek and Pula.

Comparative analysis of turbo roundabout design procedures described in *Dutch*, *Slovenian*, *German* and *Guidelines2014* on turbo roundabouts guidelines is in detail given in by Džambas [12], with brief overview here pointing out main design indicators. *Dutch* and *Slovenian* guidelines are chosen for the analysis since these guidelines origin from the countries with a notable experience in turbo roundabout design. According to *Slovenian*, *German*, *Guidelines2014* and *Dutch* guidelines, geometry design of turbo roundabouts can be carried out through the following steps: (1) selecting one of the available roundabout types; (2) defining a relevant design vehicle; (3) creating one of given turbo block templates; (4) designing the remaining turbo roundabout elements; and (5) conducting design vehicle horizontal swept path analysis and fastest path vehicle speed analysis.

Main roundabout forms given in *Dutch* and *Slovenian* guidelines are: four leg variants that could also be planned as three leg variants: Egg, Basic turbo, Knee, Spiral and Rotor roundabout; and three leg variants: Stretched-knee and Star roundabout (*Figure 1*). Egg, Basic turbo, Knee, Spiral and Stretched-knee roundabout are recommended forms when one of the traffic demand flows is predominant. Rotor or Star roundabout forms are recommended in case of equal traffic demand flows on all approaches. Other modified variants can further be designed by varying the number of entry lanes. *Guidelines2014* define roundabout forms: Egg, Basic turbo, Knee and Stretched-Knee roundabout. According to *German* guidelines, there are maximum two traffic lanes at roundabout circulatory roadway, and several possible arrangements of entry and exit lanes on roundabout approaches.

2.2 Basic Geometry Elements

According to observed guidelines, Džambas [12] concluded that turbo roundabout elements must provide unobstructed passage of the relevant design vehicle. Design vehicle and its swept path trajectories have a main influence on the turbo roundabout geometry design. The choice of the relevant design vehicle should be based on the structure of traffic demand flow, which significantly depends on the share of the vehicle in the vehicle fleet of the region where the roundabout is located and local regulations. Swept path trajectories of relevant design vehicle must be checked using one of the CAD program tools, usually AutoCAD with AutoTurn, where all relevant design vehicles can be found defined by various guidelines. *Guidelines2014* provide dimensions for various turbo roundabout templates, but it is unclear to which design vehicle they are associated with. *German* guidelines states that all turbo roundabout elements must be designed regarding design vehicle swept path, but relevant design vehicle for turbo roundabout design is not recommended. *Slovenian* guidelines provide that relevant design vehicle is usually a 16.50 m long truck with a semitrailer. Design vehicle parameters that influence vehicle swept path width are: overall width *w*, length of the front overhang *t*, and length of the wheelbase s_2. Design vehicles have similar lengths of the front overhang and the wheelbase, but different overall widths: *Guidelines2014*, *German* and *Slovenian* design vehicles are 2.50 m wide, and *Dutch* 2.55 m. Because wider vehicles occupy a greater area when driving critical turning movement, it would be advisable that widths of the design vehicles are set to 2.55 m [12].

Turbo roundabout geometry design is mainly defined by defining the turbo block. There can be two groups: guidelines that provide turbo block templates with predetermined dimensions [13,14,16], and guidelines that do not provide turbo block templates [15]. Recommended maximum width of circulatory lane is 5.25 m. Turbo block should be designed in a way that circular arcs at one side of the translation axis overlap with circular arcs at the other side of the translation axis i.e. that inner circular lane at one side of the translation axis continues the outer circular lane at the other side of translation axis [9]. Turbo block templates given in *Dutch* and *Slovenian* guidelines do not entirely fulfil this requirement. In these templates 5 cm shift of circular arcs at translation axis exists. In *Guidelines2014* this shift is eliminated by application of 5 cm wider outer marginal strips i.e. circular arcs are overlapping on translation axis. After designing a turbo block, remaining turbo roundabout elements can be designed: central island, approaches, and raised mountable lane dividers. Detail guideline comparison can be found in [12].

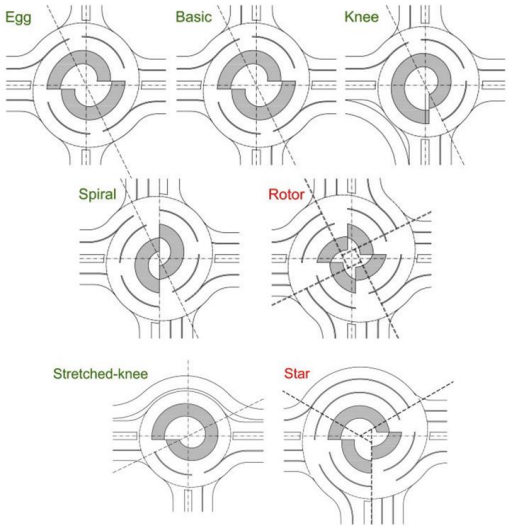


Figure 1 – Turbo roundabout variants with four and three approaches
Source: [12]

2.3 Traffic Efficiency and Safety

Although the TS benefits are recognized there are still doubts about TE parameters. Studies show that researchers have been using methods that not fully describe the complex interactions between the different traffic flows. Fixed lane usage at the entries and the irrelevance of traffic distribution in the circulatory lanes are fully described in a new calculation method [10] based on gap-acceptance theory and on the generalization of Tanner's formula for multiple traffic lanes. For the scope of this paper, detail turbo roundabout capacity formulation can be found in Silva [10]. The application of this method reveals that the rigid allocation of movements to the entry lanes in the turbo roundabout's often leads to higher saturation in the left lane and consequently to a waste of the right lane's capacity (used only for the right turns). Fernandes et al. [10] concluded that turbo roundabouts offer more capacity than two-lane roundabouts of similar size only in specific and rare circumstances of traffic demand, i.e. when the proportion of right turns in the minor direction is very high >60%.

Fernandes et al. [10] also concluded that turbo roundabouts show a 40-50% reduction in the accident rate. In a study based on microsimulation applications, [4] concluded that drivers using the outer lane of a turbo roundabout drive more slowly than in the double-lane roundabout, with reductions from 48 to 38 km/h. There is a reduction from 24 conflict points on the double-lane roundabout to 14 points on the turbo-roundabout, indicating an overall reduction in crash probability. It should be noted, however, that some of these conflicts exhibit higher severity both because of the increased impact angle and because circulating traffic is concentrated in the outer lane. In the absence of historic crash data, a deeper analysis is needed using microsimulation techniques (i.e. PTV VISSIM).

3. CASE STUDY OF CROATIA

Croatia has more than 220 roundabouts, of which more than 60% lie within urban areas. Authors have focused on applying roundabout models from outside Croatia to the Croatian situation. Their results suggest that imported models can work well, as long as they are calibrated for local conditions [18–20]. For example, Ištoka et al. [21] used neural networks to calibrate a traffic microsimulation model for two urban single-lane roundabouts in Osijek. Also working with urban single-lane roundabouts, Šurdonja et al. [22] optimized geometric elements such as inscribed circle radii, entry/exit radii, entry/exit approach width, and vehicle path trajectory, while Pilko et al. [23] examined the relationship between vehicle trajectory design speeds through the roundabout and observed vehicle speeds. Recent studies have focused on geometry, sight-distance and vehicle speed on rural single-lane roundabouts [12,24], and various geometry design principles when designing turbo roundabouts [25]. The most recent national guidelines stipulate where urban and suburban single-lane roundabouts should be built, what geometry they should have, and how capacity should be calculated [16]. However, the guidelines do not indicate what models or simulation software should be used for analyzing common TE and TS parameters [1].

3.1 Guidelines

The procedures of planning and designing the roundabouts in Croatia are based on the current national and applied foreign guidelines, especially Netherland, German, Austrian and Switzerland, positive examples of world practice and empirical practice of designers. One of the first steps in creating national regulations for roundabout designing were the *Guidelines for the Design of Circular Intersection* (*Guidelines2002*) from 2002 [26]. The main objective of these guidelines was the standardization of design and implementation of roundabouts on public roads in the country. Also, insufficient attention has been made to geometry design and the concept of turbo roundabouts [1].

Roundabout Guidelines for State Roads (*Guidelines2014*) from 2014 [16] represent a significant upgrade of *Guidelines2002* in terms of geometry design elements, TE criteria, defining, planning and implementation of turbo roundabouts, and the importance and necessity for swept path trajectory

checking of the relevant design vehicle in the design phase. However, the guidelines do not indicate what models or simulation software should be used for analysing TE.

3.2 Examples

Various proposals for implementing turbo roundabout types at existing intersections in Croatia will be shown in the following.

The first turbo roundabout in Croatia was carried out in the city of Osijek in 2014. (*Figure 2*). Intersection is designed in accordance with the *Guidelines2014*. The most important design elements are: external diameter is 5.15 m (outer space between shifted centres of circular segments); inscribed central diameter is 4.95 m (inner space between shifted centres of circular segments); R1 = 15 m (radius of the inner edge of the road surface); R2 = 20 m (radius of the outer edge of the outer lane); R3 = 20.3 m (radius of the inner edge of the outer lane); R4 = 25.2 m (radius of the outer edge of the road surface). Cycling lanes and tram lines are also designed making this intersection more complex for all road users.



Figure 2 – Turbo roundabout in the City of Osijek, Croatia - in traffic 2014

The first location is a single-lane roundabout that was created in 2006 in the City of Zagreb (*Figure 3*). The single-lane roundabout is surrounded with the Rebro Hospital and the Maksimir Park. The intersection is about 3 km to the east from the City centre. Throughout the day, the existing single-lane roundabout cannot cope the existing traffic demand and TE and TS parameters are highly negative. Author [27] proposed an unsignalized turbo roundabout to cope with this problems (*Figure 4*). Red colour layout shows the existing single-lane roundabout while green colour layout shows proposed multi-lane turbo roundabout. The most important design elements are (*Figure 4*): external diameter is 5.75 m (outer space between shifted centres of circular segments); inscribed central diameter is 5.05 m (inner space between shifted centres of circular segments); R1 = 10.45 m (radius of the inner edge of the road surface); R2 = 15.85 m (radius of the outer edge of the outer lane); R3 = 16.15 m (radius of the inner edge of the outer lane); R4 = 21.2 m (radius of the outer edge of the road surface) [27].



Figure 3 – Disposition of the single-lane roundabout in the City of Zagreb, Croatia



Figure 4 – Proposed unsignalized turbo roundabout layout in the City of Zagreb, Croatia [27]

According to authors [28] two unsignalized multi-lane turbo roundabouts are proposed to cope with the TE and especially TS parameters in the City of Varaždin (*Figure 5*). Existing intersections are signalized level intersection with high traffic demand flow, because they represents eastern entry/exit in the City via state roads. The most important design elements are: outer diameter of 5.15 m (outer space between shifted centers of circular segments); inscribed central diameter is 4.95 m (inner space between shifted centers of circular segments); R1 = 14.95 m (radius of the inner edge of the road surface); R2 = 20.00 m (radius of the outer edge of the outer lane); R3 = 20.30 m (radius of the inner edge of the outer lane); R4 = 25.25 m (radius of the outer edge of the road surface) [28].



Figure 5 – Proposed two unsignalized turbo roundabout in the City of Varaždin, Croatia [28]

Another proposition of the Authors [28] is on the suburban level four-way intersection of state roads ST59 and ST27 near City of Zadar. The intersection is surrounded with an industrial zone with high heavy vehicle traffic demand and poor TS and TE parameters (*Figure 6*). The most important design elements are: outer diameter of 5.75 m (outer space between shifted centers of circular segments); inscribed central diameter is 5.05 m (inner space between shifted centers of circular segments); R1 = 10.45 m (radius of the inner edge of the road surface); R2 = 15.85 m (radius of the outer edge of the outer lane); R3 = 16.15 m (radius of the inner edge of the outer lane); R4 = 21.20 m (radius of the outer edge of the road surface) [28].

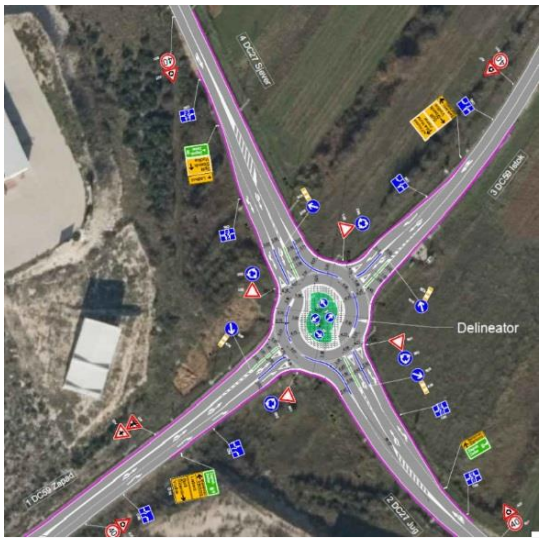


Figure 6 – Proposed unsignalized turbo roundabout of the state roads ST59 and ST27 [28]

4. DISCUSSION AND CONCLUSION

The main purpose of the study was to briefly describe the current state of turbo roundabout concept design features regarding recent studies and design guidelines correlating Croatian case studies.

We can conclude that turbo roundabout design guidelines referred here differ in the following: number of turbo roundabout variants, choice of relevant design vehicle(s), dimensions of certain turbo block elements and definition of specific roundabout elements. Nevertheless, turbo roundabout planning procedures are quite similar. In *Slovenian*, *Dutch* and *Guidelines2014* firstly initial roundabout scheme is designed, and then swept path and fastest path vehicle design speed analyses are carried out. This design approach therefore greatly depends on the quality of performance checks, and gives freedom to the designer on the decision whether the project solution is acceptable or not. Studies performed at the Department for Transportation of the Faculty of Civil Engineering, University of Zagreb [25], have confirmed that this design approach ensures the usage of optimal roundabout element dimensions and an unhindered path for the design vehicle through the intersection.

The turbo roundabout concept solution emerged as a way to solve the TS problems of multi-lane roundabouts and for now it succeded. The geometry design elements of these roundabout types effectively reduce vehicle design speed and conflict points leading to safer driver and traffic flow operations. In terms of TE (capacity), some authors concluded that turbo roundabouts offer better capacity than conventional roundabouts of similar size when the proportion of right turns in the minor direction is very high >60%. The application of a new lane-based method reveals that only in very specific scenarios that are uncommon in real-world networks can a standard turbo roundabout be expected to provide more capacity than the equivalent two-lane roundabout [10].

Results of this paper can be used for dissemination of the knowledge for proper application and implementation of national roundabouts to compare it with international design practice and standards. Also, to conclude which turbo roundabout types and in what locations can perform better in terms of TE and TS parameters and it's signalization [29].

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CHALLENGES AND SOLUTIONS FOR URBAN UAV OPERATIONS

ABSTRACT

Unmanned aerial vehicles are transforming our way of thinking about flight operations and services that can be provided by them. Visions of tomorrow imagine UAVs as ubiquitous platform for many applications in urban setting. Vertical take-off and landing as well as electrical propulsion and short endurance of today's small and micro UAVs make the urban environment the best possible place for adoption of advanced UAV-related services. Adoption, however, is stymied by many challenges which are inherent in urban flight operations. In this paper, we examine the technological challenges faced by future urban UAV designers and operators, and we provide possible solutions to some of those challenges.

KEY WORDS

UAV; urban area; surveillance; navigation; anti-UAV; challenges; solutions;

1. INTRODUCTION

Reduction of production costs of unmanned aerial vehicles (UAVs), sensors and actuators, along with the recent technological improvements, made UAVs easily accessible for industrial and private purposes. UAVs are a product created by the merging of two technological branches - remote controlled aircraft systems and fully autonomous vehicles. Scientists and industry invest significant resources in developing UAVs and evaluating their social and economic influence. However, many aspects of this rapidly evolving technology remain unexplored, including the infrastructure that should enable their operations in urban areas.

The current market share of civilian hobby and commercial UAVs is relatively small compared to military, $3 billion or 11% market share in 2016 [1]. However, the forecasts agree on the rapid growth of civilian use of UAVs and their economic impact on the world market. Goldman Sachs predicts that by 2020, 30% of the total estimated $100 billion of the global UAV market will be in the civilian sector [2]. UAVs already are intensively used in agriculture, aerial photography, geodesy, law enforcement, advertising and, more recently, in building safety and package and food delivery. The industry's largest representatives such as Amazon, DHL and Google have already tested and used UAVs for different civilian purposes, e.g. package delivery. Former London Mayor Boris Johnson called for package delivery solutions with UAVs to help solve the problem of congestion in the city [3].

Increased use of UAVs in urban settings will increase the risks of accidents and incidents which are likely to result in the loss of human life or material damage. It is also inevitable that in the near future UAVs and manned aircraft will share the same airspace. This puts many obstacles and challenges for the UAV design engineer. The problem of collision avoidance in the air could become one of the limiting factors for further development of unmanned aviation systems.

In this paper we systematically searched for challenges and solutions for urban UAV operations. We present the challenges that need to be solved in order to make urban UAV operations possible in a safe and efficient manner. Challenges are identified from the literature, incident reports, and expert interviews. Solutions, where available, are also presented. Challenges are broadly categorized into areas of surveillance, navigation, communication, coordination, air policing and ground services.

2. SURVEILLANCE

Surveillance of air traffic is a basic prerequisite for many functions of air traffic management (ATM) [4]. In the current concept of operations, surveillance is achieved by using primary and secondary radars, and automatic dependent surveillance (ADS). Surveillance gives the air traffic controller the information needed for maintaining the safe and efficient air traffic. This data is displayed on a screen which the air traffic controllers use to decide how to solve conflicts. To avoid work overload, the airspace is divided into sectors and each sector is assigned to a team of two controllers (planning and executive) [5]. Currently, the approximate number of aircraft that are simultaneously monitored in a single sector is around 30 to 40.

This concept of operations translates poorly into the urban UAV environment. Radar-based surveillance methods used in conventional ATM assumes line of sight visibility between one or more radar stations and aircraft. In urban canyons such visibility is not guaranteed, and even if it were, there are other issues that are inherent to UAVs. Firstly, they are small and slow and therefore easily mistaken for birds. Secondly, there are no easy methods for decluttering the display when the radar is aimed at urban environment with many moving objects that need to be filtered out, such as cars, pedestrians etc.

There are specialized systems for UAV detection, such as SharpEye™ X-band radar with electro-optic coupling which can detect typical UAVs at a range of 1 km (Figure 1. a). This system can be used to protect airports, power plants or other critical national infrastructure (CNI), however it cannot be used in urban environment due to line-of-sight requirements [6]. Other approaches rely on detection of radio-frequency (RF) emissions from UAVs such as Aaronia Drone Detection System (Figure 1. b). This system can detect UAVs based on the commonly used frequencies, such as 35 MHz, 430 MHz, 460 MHz, 2.4 GHz or 5.8 GHz, all commonly used for communication with UAVs. Detection range is up to 7 km and angular detection resolution is 2°-3° [7]. Another interesting feature is that the system can also detect the operator. For this system to work one precondition needs to be met and that is that the UAV emits a signal which is not always the case, especially for illegal operators.

The one obvious solution to the problem of UAV surveillance is equipping UAVs with transponders. However, this implies cooperation from the UAV operators. Probably all legally operated UAVs could be equipped with a transponder but the challenge is with surveillance of those non-cooperative operators. One possible solution is a surveillance network consisting of sensors attached to highest buildings and tethered balloons. Police UAVs could also be used to patrol the skies and check for legal transponder operation. This challenge ties in with the challenge of air policing. Namely, what to do when the illegally operated UAV is detected (see section 6. Air Policing)?



a) b)

Figure 1 – SharpEye X-band radar (a) and Aaronia Drone Detection System (b)

3. NAVIGATION

Navigation of small and micro UAVs has many things in common with navigation of conventional aircraft, however, there are many challenges which are specific to the UAV operations. Conventional aircraft, here defined as those operating in general and commercial aviation environment, rely on a layered navigation infrastructure consisting of ground-based systems, satellite-based systems and on-board systems [8]. These systems overlap in function and availability, thus providing redundancy over the whole range of operations. In addition to these navigation systems, all manned aircraft are also able to operate based on the visual navigation which is the main mode of navigation for some aircraft or a backup for others. UAVs have comparatively fewer systems available, whereas those that are available are not suitable to support all types of activities which are expected of UAVs (Table 1) [8].

Table 1 – Comparison of Navigation Systems used in Conventional Aircraft vs. Micro UAVs [8]

Navigation system	Conventional aircraft	Small and micro UAVs
Ground-based radio-navigation systems (NDB[1], VOR[2], DME[3], ILS[4])	Widely used. NDBs are being phased out.	Not used. Receivers have not been miniaturized, accuracy too low for the intended purposes.
Satellite-based systems (GPS, GLONASS, Galileo, ABAS[5])	Widely used. Considered the back-bone of the future air traffic management.	Widely used. In most cases this is the sole provider of navigation information.
On-board systems (INS[6])	Used in commercial aircraft, not as much in general aviation. Highly accurate systems are used to provide autonomous long-range navigation.	Widely used. Low-cost, low-accuracy systems are integrated with GPS to provide high-frequency attitude and position information. INS is not used for autonomous navigation.
Visual navigation	Always available, sometimes used. Commercial air transport relies on visual navigation mostly for take-off and landing or as a backup. General aviation pilots use mostly visual navigation for all phases of flight. Visual navigation is primary source of position information for all low-altitude operations (SAR, law-enforcement, industrial operations such as crop dusting, logging, power-line inspection etc.).	Currently used for experimental purposes. Commercial solutions do not exist yet.

[1]NDB – Non-directional beacon
[2]VOR – VHF omni-directional radio range
[3]DME – Distance measuring equipment
[4]ILS – Instrument landing system
[5]ABAS – Airborne-based augmentation system
[6]INS – Inertial navigation system

As can be seen in Table 1, small and micro UAVs lack the redundancy of navigation systems which is available to conventional aircraft. Radio-navigation receivers could be miniaturized and deployed

on UAVs, however, their accuracy is not good enough for the type of operations which are expected of UAVs. Among other environments, micro UAVs are expected to operate within urban areas, flying safely, accurately, and precisely in close proximity to buildings and people. Flying in GPS-denied environment, such as indoors, will further push the limits of UAV navigation. Interaction with ground objects is also one of the activities which will drive future application of UAVs.

Current situation can be summarized as follows [8]:

- Small and micro UAVs use single source of navigation information (integrated GPS/INS).
- Flying in urban environments requires redundancy.
- Flying in GPS-denied environment requires other sources of navigation information.
- Interaction with ground-based objects requires high accuracy and precision.
- Research is already underway with purpose of enabling autonomous visual navigation for UAVs.

A large body of research has been produced on the topic of visual navigation with application to UAVs. The aim of the visual navigation is primarily to localize the UAV by mapping the surroundings. It can be made by building the local map or by matching the features of the terrain to the pre-existing map. For example, in [9] dense three-dimensional reconstruction from downward looking camera images from UAV is presented, while in [10] a complete UAV setup for autonomous exploration is demonstrated. In [11], a visual algorithm for long term object following was presented. It specifically uses global geometric matching to ensure that the object is followed in global coordinate system.

4. COMMUNICATION

Current ATM systems use voice communication in VHF aeronautical spectrum (118-137 MHz) and controller-pilot data-link communication (CPDLC) also in the VHF aeronautical spectrum. ADS-B uses 978 MHz and 1.09 GHz, airport ground radio uses 460 MHz, and various radar systems operate in L and S bands (e.g. ASR-11 uses 2.7-2.9 GHz, L-STAR uses 1.5 GHz). Commercial UAVs communicate in the several parts of the spectrum which are shared with many other users. These frequencies are [12]:

- 35 MHz: Older RC gear in Europe
- 72 MHz: Older RC gear in the US
- 420-450 MHz: **UAV control links**, amateurs in emergency communications
- 902-928 MHz: **UAV video and telemetry**, Industrial, Scientific and Medical (ISM) equipment, cordless phones, computer networking, walkie-talkies, amateur TV, repeaters
- 1.24-1.3 GHz: **UAV video links**, amateur TV, voice, data, GPS
- 2.39-2.485 GHz: **UAV control links, video and telemetry**, Wi-Fi, Bluetooth, microwave ovens, wireless headphones, cordless phones
- 5.15-5.825 GHz: **UAV video**, Unlicensed National Information Infrastructure (UNII) devices, 5G routers

Each of these frequency bands has its own advantages and disadvantages. Lower frequencies, like 430 MHz and 900 MHz, suffer less multipath distortion, have lower susceptibility to bad weather, have longer range with equal power, but also, they do not support broadcast of quality video, 900 MHz is dedicated for GSM in Europe, and they can experience interference in urban areas due to the wide use of cordless phones.

Higher frequencies, on the other hand, enable broadcast of quality video, have smaller transmission antennas, but they require line-of-sight operations, their range is affected by humidity in the air, they need higher power than the lower frequencies for the same range, and they can experience interference from wide variety of appliances and devices commonly used in urban areas (e.g. microwaves, wi-fi, cordless phones, etc.).

One advantage of urban operations is good availability of 4G mobile networks which can enable transfer speeds of up to 50 Mbit/s. Using the existing infrastructure, such as mobile networks, for video link in use cases where a small delay is tolerable, can be a solution when it is difficult to maintain longer range line-of-sight high-frequency communications link. Control links could also be established through the existing mobile networks but only for UAVs with higher degree of autonomy, since small delays could make direct control difficult.

Another solution for interference problems is local pre-flight interference analysis [12]. Operator can use special equipment to test for other signals on the frequencies which are required for UAV operations. This test can then show if the test site can be characterized as "positive transmitting environment". If not, mitigation measures can be made, such as switching to other frequencies [12].

5. COORDINATION

Coordination in the context of this paper is used as both coordination among UAVs and coordination between UAVs and ground services. In civil aviation, aircraft rarely coordinate among themselves directly. Usually, the coordination is mediated by air traffic controllers (ATCOs). ATCOs detect possible conflicts and solve them by making changes to the heading, airspeed or altitude of one or more aircraft. Coordination in terminal and ground operations is similar, with only difference of another constraint in terms of ground infrastructure capacity. Conventional aircraft coordinate among themselves in visual flight rules (VFR) operations or as a final safety measure during the traffic collision avoidance system (TCAS) resolution advisories.

Visions of future urban UAV operations include large numbers of UAVs operating in a very complex environment with many obstacles. To ensure collision detection and avoidance there should be multiple safety nets. First, possible conflicts could be detected and resolved in the planning stage of a flight; this is called strategic conflict resolution. To enable strategic conflict resolution, UAV trajectories must be known and executed with great accuracy. Also, obstacles must be identified in advance and taken into account during the planning phase. This concept of operations is slowly being implemented in European air traffic under the name of trajectory-based operations (TBO). However, there must be a way to maintain safety when capability to maintain TBO fails, e.g. when an aircraft suffers degradation in navigation capabilities. In the case of civil air traffic, there will be an ATCO with all necessary surveillance tools to help maintain safety, in coordination with pilots, when such degradation occurs. For UAVs there is a need for similar backup system which can maintain safety once TBO plans become impossible to realize.

Possible solution to this challenge is to increase capacity of the UAVs to sense their environment and to develop algorithms for conflict resolution and obstacle avoidance. However, most of the currently used commercial UAVs have very limited knowledge of their surroundings. Almost all UAVs today come equipped with the ultrasonic or LIDAR-based height sensor. Increasingly, higher-end and special purpose professional UAVs are equipped with obstacle sensors and avoidance algorithms for multiple directions. These are based on:

- Stereo Vision – uses two cameras to take two images at slightly different viewpoints which are then processed to identify same points in both images. The distance to those points can then be established by triangulation. One example of such system, developed for UAV purposes, is Centeye RockCreek™ vision chips (Figure 2. a).
- Ultrasonic (Sonar) – sends a high-frequency pulse and then measures time it takes for the signal to reflect off the obstacle and return to the microphone. Ultrasonic sensors have relatively short ranges (e.g. HC-SR04 has range up to 5 m, Figure 2. b), wide detection angles and low spatial resolution. They cannot detect size or shape of the obstacle.
- Time-of-Flight camera – it is made of an integrated light source and a camera. It can measure distance information for every pixel in the image by emitting a light pulse (flash) and calculating the time needed for the light to reflect back towards the camera. Small ToF

cameras have shorter ranges, e.g. ELISA 3DRanger™ by Heptagon works at distances up to 5 m (Figure 2. c).

- LIDAR - calculates distances and detects objects by timing how long it takes for a laser pulse to travel from the sensor to an object and back, calculating the distance from the speed of light. LIDAR can be made in single point, single plane or multiplane versions (full matrix). They are used for mapping, however, in obstacle detection role they have been only recently introduced to the UAV market. One example of small LIDAR that is light enough to be used for UAV obstacle detection is Velodyne Puck LITE™, which weighs only 590 g and scans up to 600,000 points per second (Figure 2. d).
- Monocular vision - most UAVs are equipped with a monocular camera. However, almost none of them use the monocular cameras for detecting and avoiding obstacles; they are mostly used for station keeping by employing optical flow algorithms. Monocular vision systems use advanced algorithms to match sequential images taken by the same camera to determine distance to objects in the image. These algorithms, however, cannot sense moving objects.

All of the technologies mentioned above can be used to detect large obstacles, but only some of them can be used to detect other UAVs or small obstacles. These are ToF cameras, some LIDARs, and stereoscopic systems. ToF cameras, at least those small enough to be mounted on UAVs have relatively shorter ranges which makes them useful for detection of obstacles when the UAV is moving slowly enough. Stereoscopic systems work only during the day. Therefore, the best, and most expensive, choice for collision detection are LIDARs. For detection of conflicts among UAVs, transponder-provided locations could be the easiest way of coordinating conflict resolution.

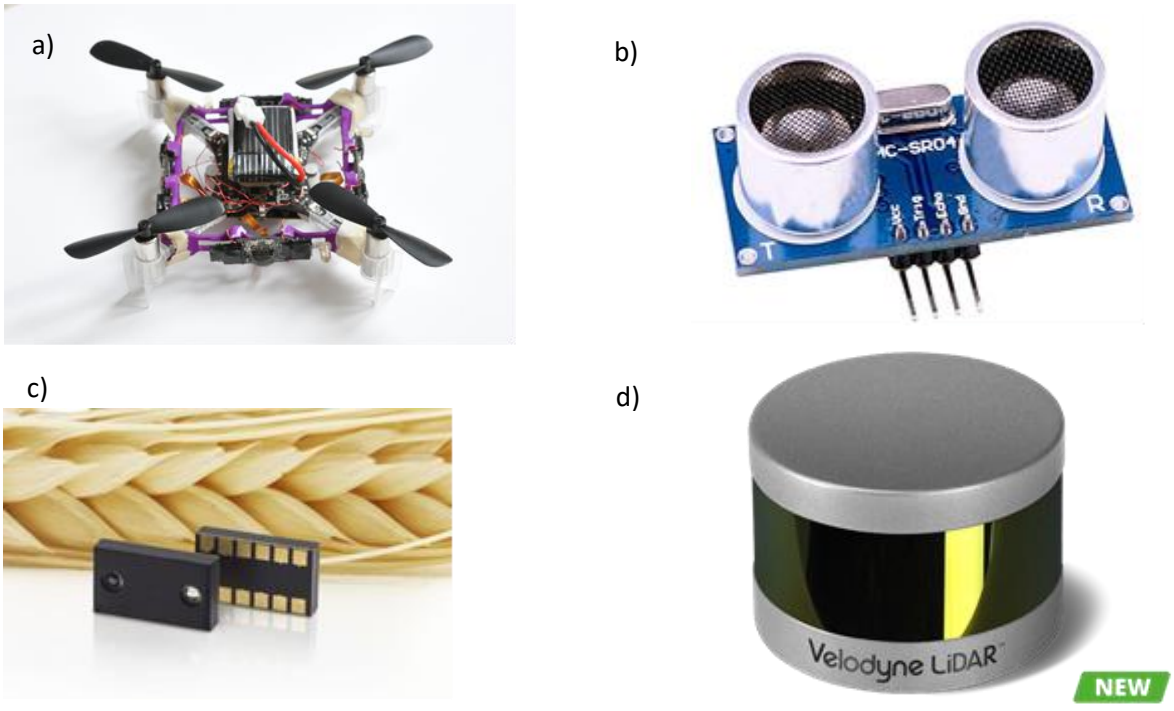


Figure 2 – Centeye RockCreek (a), HC-SR04 ultrasonic sensor (b), ELISA 3DRanger ToF sensor (c), Velodyne Puck LITE (d)

6. AIR POLICING

In conventional operations, a system exists to prevent unlawful operations. Once the intruding aircraft is identified fighter jets are scrambled to escort that aircraft and force it to land. Obviously,

there is little sense in employing such solutions for policing of UAVs in the urban environment. Incidents with UAVs have become so common in recent years that the new methods of law enforcement are being actively developed. Examples of such incidents are injuries to the bystanders (e.g. a toddler lost an eye in the UK [13], a woman knocked unconscious by a falling UAV [14], etc.), damage to other aircraft (e.g. UAV collision with a Black Hawk helicopter [15]), invasion of privacy (e.g. looking into people's homes [16]), and possible acts of espionage (e.g. flying near chemical plants [17] and nuclear power plants [18]).

Anti-UAV technology can be divided into several categories:

- Projectile guns – along with conventional guns there are guns which fire nets or even nets with built-in signal jammers (e.g. OpenWorks Engineering SkyWall 100, Figure 3. a). Net throwers are effective up to 100 m.
- Signal jamming – there are multiple signal jamming solutions which work by jamming navigation and control signals. They operate on usual frequencies used by UAVs and some of them even have the capability to spoof the control signal of common UAV types in order to force them to land (e.g. Battelle DroneDefender, Figure 3. b). Signal jamming guns are effective at distances up to 2,000 m (e.g. DroneShield DroneGun Mk2, Figure 3. c). Researchers have demonstrated the ability to control and capture the UAVs by spoofing the GPS signal [19].
- Lasers – so far only one prototype of this technology has been built by Boeing. It is called High Energy Laser Mobile Demonstrator (HELMD) and it can detect and destroy UAVs up to at least 5 km. Its large size precludes it from being routinely used as a police tool (Figure 3. d).
- Trained animals – French, Dutch, and Swiss authorities trained eagles to intercept and catch UAVs (Figure 3. e). While proved effective in the training environment, the eagles would not always do what they were trained to do and their training proved to be more expensive and complicated than anticipated. Because of this police in the Netherlands has stopped using the birds for UAV interception [20].

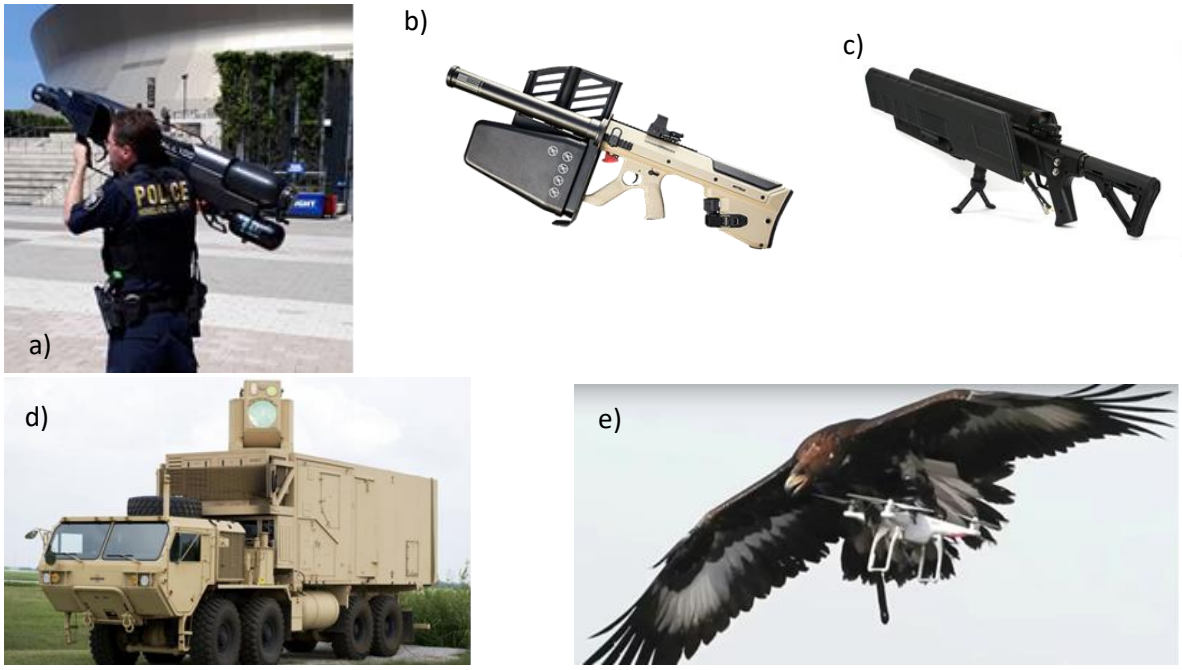


Figure 3 – OpenWorks Engineering SkyWall 100 (a), Battelle DroneDefender (b), DroneShield DroneGun Mk2 (c), HELMD (d), trained eagle (e)

Overall, these systems do provide a level of protection from unlawful UAV operations, but tying them into surveillance systems and training the police in using them is still a major hurdle. Unlike

conventional guns, anti-UAV technology is not deployed routinely and is not at hand to all police officers at all time. Also, discerning unlawful operators from legal operators is made difficult because there are no surveillance systems in place. Also, anti-UAV guns rely on visual detection and identification of illegal UAVs by police officers which is not possible during night or with UAVs flying through clouds or fog.

7. GROUND SERVICES

Airports, airfields and helidromes are areas reserved for operation of conventional aircraft. The utility of these areas for urban UAV operations is minimal. In urban setting, especially if the visions of future ubiquitous UAV operations are to come true, there are not enough areas reserved for landings and take-offs. Most major urban centres have some helidromes, usually attached to hospitals or large office buildings, but this is not nearly enough to support the expected rise in number of aircraft once UAVs enter the market. Also, using the existing helidromes for UAV operations means that all UAV services need to be centralized at several points in the city which reduces the advantages of UAVs. Reserving areas for UAVs closer to users of their services (businesses and consumers) would keep the UAVs away from helicopters, thus avoiding mixed operations, and use the full potential of UAVs. Such areas could be on rooftops or attached to the sides of the buildings. Besides providing landing areas, they could also provide:

- Navigation services – as mentioned in previous sections, visual navigation is possibly one of the main solutions for accurate navigation in complex urban environments. Coded visual markings and coded lights could be attached at the landing site for aiding in visual navigation. Also, in terms of other navigation options, real-time kinematics (RTK) GPS corrections could be broadcast to increase accuracy of GPS navigation on the local level.
- Surveillance services – built-in cameras and video processing algorithms can detect local obstacles and traffic to ensure safe sequencing for landing. In some cases, where longer range is needed and terrain configuration allows (top of building, away from obstacles and people), it is possible to add the radar as well.
- Communication services – dedicated datalinks for control and high-bandwidth data transfer.
- Charging services – current battery technology limits the flight time of the electric UAVs to around 30 minutes. Automatic battery charging or swapping services could increase the fraction of the time the UAV remains operational. Further challenge here is the lack of standardized charging or swapping interface.
- Storage – since the UAVs will spend most of the time on the ground, it will be necessary to ensure that they are protected from strong winds, rain and snow. These parking spaces will have to be built in the numbers greater than the number of operational UAVs due to clustering of UAVs in parts of the city during certain times of day. Storage can be provided by protective covers and/or automatic housing for one or multiple UAVs, possibly combined with charging service.
- Other services – such dedicated space could also provide other specific services such as conveyor belts for packages or maintenance services.

Overall, a lot of the solutions to the challenges mentioned in the previous chapters could be implemented at such dedicated landing areas.

8. REVIEW OF CHALLENGES AND PROPOSED SOLUTIONS

In previous chapters we have identified most-glaring challenges and presented existing or proposed novel solutions. Here we review the lessons learned (Table 2).

Table 2 – Review of Challenges and Solutions to Large-scale Introduction of UAVs in Urban Environment

Challenge	Solution
Surveillance in urban canyons is difficult because radars and optical sensors need line-of-sight visibility, acoustic detectors have very short range, and RF detectors have low spatial resolution.	UAVs equipped with transponders combined with surveillance network to detect unlawful operators (possible use of police UAVs to patrol the lower areas). Surveillance of non-cooperating UAVs is still unsolved.
Navigation in urban setting using GPS can be highly inaccurate due to multipath errors (especially non-line-of-sight multipath). There needs to be a backup navigation capability.	Visual navigation can be used to bridge the gaps in GPS reception and, when more developed, even to be a backup for GPS. Night-time visual navigation is still not solved.
UAV control, telemetry, and video links work on frequencies shared with many other users.	Use existing 4G mobile networks (5G in near future). Perform interference analysis prior to flight. Establish more flexible procedures for dealing with link failure.
In-flight conflict detection and resolution does not exist. Limited obstacle avoidance capabilities.	Implement conflict detection and resolution algorithm based on locations obtained via transponder. Further miniaturization and lower costs of LIDAR sensors will enable easier obstacle avoidance, even during night.
Anti-UAV technology is limited by visual detection of UAVs by police officers (impossible during night or in clouds or fog). It is not clear how will law enforcement officers decide on whether an UAV is operated legally or not without working surveillance and alerting system.	No solution available currently. Surveillance and alerting system is needed to facilitate identification of unlawful operators.
No ground infrastructure and services. No battery charging or swapping standards.	Landing pads can be developed to provide necessary reserved landing space. Additional navigation, surveillance, and communication services could be integrated as well.

9. CONCLUSION

In this paper we tried to identify technological challenges to large-scale introduction of UAVs in urban environment. Other challenges, which we did not tackle, exist as well, such as regulatory, architectural, societal, and cultural.

Some of the challenges we examined are purely technological and they will probably be solved in near future. One example of challenges in this group is the challenge of visual navigation. Great strides towards better and more capable algorithms are being made yearly. Another example is collision detection and avoidance which can be solved with LIDARs even today if not for their relatively large size and weight. Further miniaturization of LIDARs will surely ensue and collision detection will not be an issue anymore.

Other type of challenges are those which are constrained by fundamental physical limits. Such are the challenges in surveillance of UAVs. Their small size, small acoustic and thermal footprint, combined with complex urban environment, make for very difficult detection. Solutions for surveillance problems mainly involve cooperation from the UAV operators (e.g. installing transponders). Detection and surveillance of unlawful uncooperative UAVs and their operators remains unsolved.

Final type of challenges are those related to organisation and standardization of services. For example, battery charging or swapping is not a difficult technological issue, however, there are no standards which enable universal autonomous charging of UAVs made by different manufacturers. Agreement on issues like these will be needed in order to implement many of the proposed solutions.

Overall, we find these challenges both interesting and worthy of future research. In our future work we will take a closer look at possible technological solutions to the surveillance and navigation challenges. Most importantly, surveillance of non-cooperating UAVs is one of the most important issues which have no clear solution as of today.

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APPLYING SIMULATION METHODS IN OPTIMIZING LOGISTIC PROCESSES

ABSTRACT

This paper outlines the possibilities of applying simulation methods in optimizing logistic processes in the warehouse. Based on analysis and comparison of the simulation experiments results, elements of optimizing logistics processes are formulated. Implementation of the optimization elements enables improvements in the warehouse system performance, which is evaluated by varying parameters of the simulation model and comparing results of respective simulation experiments.

KEY WORDS

simulation methods; logistic process; optimization;

1. INTRODUCTION

Design and optimization of logistics processes, as fundamental part of logistics system organization, gain importance for researchers and practitioners. Processes are generic factors in all organizations, in terms of defining what is done and how it is done. Understanding a process can be very difficult, as processes are often considered generally, without detailed analysis. Analyzing each process separately is less demanding than considering them as parts of a system, with interactions, priorities and resource sharing. Therefore, a large number of factors need to be approximated in order to obtain a complete insight into the system of business activities [1].

Simulation is an experimental method that enables study of the actual process using its computer model, which is useful for analysis and preventing problems before they occur. Advanced software tools for simulating logistic processes have been developed, that facilitate modeling and analysing results of simulation experiments. By using such tools, it is possible to outline processes in logistics systems and to visualize the entire system in 2D or 3D format. Simulation of logistics processes in the factory warehouse was performed and analysis of the results was carried out, in order to select parameters that affect productivity of the system. By changing allocation of the workforce resources and testing process workload respectively, the warehouse system performance was improved. The results of the simulation experiments were analyzed and compared, prior and after implementing changes, in order to quantify the elements of optimization.

The main objective of the paper is to outline the possibilities of applying simulation modeling in optimizing logistic processes, in terms of logistic system productivity. It also refers to allocation of resources and testing maximal process workload.

2. ADVANTAGES AND DISADVANTAGES OF THE SIMULATION METHODS

The term simulation is often used as a synonym for any model. Simulation is an attempt of presenting features and design of the real system. Simulations are used to describe and analyze system behaviors, assist in designing real systems, and answer *What if* questions.

The simulation is also defined as a computer model that replicates real life situations, allowing user to evaluate the potential effects of the actions taken. Simulation is a powerful tool in the hands of a manager that helps evaluating effects of the business decisions, on the company performance in the given environment.

In some cases, the future event can be analitically modeled, but in many situations it is not possible, so simulation methods are applyed. Computer simulation is than the easyest way of testing various business actions and identifying the most effective decisions [2].

Simulation methods have advantages and disadvantages in scientific research and in commercial use, such as the following [3].

Main advantages of simulation methods:

- Ability to describe and solve complex dynamic problems with random variables that are too difficult for analytical mathematical modelling.
- Possibility of solving various problems (design, performance analysis, forecasting etc.).
- The experimentation conditions are fully controled, unlike experiments in real system, where it is not possible to adjust certain parameters.
- Evaluation and analysis of the logic and dynamics of system operations are greatly facilitated by modeling animation.

Main disadvantages of simulation methods:

- The model development is time consuming and expensive (although can be facilitated by automaticaly generating program code, when available).
- Because of the stohastic character of simulation it is necessary to perform sufficient number of simulation experiments, in order to obtain appropriate sample of simulation results, which requires significant computing resources.
- Relationships between input and output variables are not expressed analiticaly.
- For the correct use of simulation modeling, it is necessary to know several different methods and tools (although the development of expert systems linked to simulation models promises to compensate for at least some of these knowledge).
- Evaluation of the model is quite complex and requires additional experiments.

Simulation models have proved to be useful for examining the performance of different system configurations and/or alternative operating procedures for complex logistic and manufacturing systems. It should be noted that while most industrial operational procedures are based on the extension of current and past operating practices, development of sumultion model could support defining new operational procedures at a fundmental level. [4]

3. ANALYSIS OF THE FACTORY WAREHOUSE LOGISTIC PROCESSES

The logistic processes in the warehouse of the home appliances factory are analysed. All process activities are measured or assessed by the person in charge. The factory warehouse is divided in two departments. The first department (Department 1) is located next to the factory, while the second department (Department 2) is the extent of the first department. The products are produced in two production plants at different locations (Location A and Location B), but all products are shipped to the buyers from Location A.

Products from the production plant at Location A arrive to the factory warehouse directly from the production line. The arrival pattern is measured on sight and approximated by normal distribution with parameters N (10, 1). That is to say, the products from the production line appear most likely every 10 minutes, with deviation of one minute (the greater the deviation is, the less likely it occurs). Two products arrive at the same time. Often the products comming from production line are not ready to be shipped, but need to be additionaliy processed by the workers in the warehouse.

At entry to the factory warehouse, one worker (controller) inspects the products and decides where the product is to be despatched. It takes 40 seconds for the controller to decide where to send the product. There are three possible choices (options):

- In 70% of cases it is necessary to install a metal plate, attach it to the needles, secure with plastic protection, affix the declarations;
- In 20% of cases it is only necessary to place the plastic protection on the product and paste the declarations;
- In 10% of cases the product is completely correct and has a proper declaration.

The products are finished by the respective warehouse worker. All activities on each product have to be made by the same warehouse worker. Time required for finishing the products is given in Table 1, which shows the time needed for a particular activity.

Table 1 – Time needed for one worker to do a particular finishing activity, measured on site

Number of measured activity	Place a metal plate (h:min:sec)	Attach the screws (h:min:sec)	Secure with the plastic cover (h:min:sec)	Paste the declaration (h:min:sec)
1	0:09:05	0:03:57	0:01:37	0:00:15
2	0:08:21	0:03:47	0:01:18	0:00:12
3	0:07:36	0:03:40	0:01:18	0:00:11
4	0:06:05	0:03:34	0:01:02	0:00:10
5	0:06:03	0:03:33	0:00:59	0:00:10
6	0:05:25	0:03:33	0:02:02	0:00:11
7	0:05:17	0:03:30	0:02:00	0:00:12
8	0:05:15	0:03:24	0:01:16	0:00:15
9	0:05:05	0:03:23	0:01:43	0:00:12
10	0:05:00	0:03:22	0:02:10	0:00:13
11	0:04:59	0:03:24	0:01:01	0:00:10
12	0:04:57	0:03:23	0:03:00	0:00:10
13	0:04:53	0:03:23	0:03:00	0:00:11
14	0:04:51	0:03:22	0:02:00	0:00:14
15	0:04:50	0:03:15	0:01:50	0:00:14
16	0:08:21	0:03:10	0:01:40	0:00:13
17	0:07:36	0:03:10	0:01:30	0:00:16
18	0:06:05	0:03:04	0:01:20	0:00:12
19	0:04:30	0:03:04	0:01:19	0:00:11
20	0:04:27	0:03:04	0:01:15	0:00:12
21	0:09:05	0:03:03	0:01:14	0:00:12
22	0:07:36	0:03:03	0:02:14	0:00:13
23	0:06:05	0:03:03	0:01:58	0:00:15
24	0:05:25	0:03:02	0:01:44	0:00:10
25	0:05:17	0:03:00	0:01:14	0:00:12
26	0:05:15	0:03:00	0:01:38	0:00:10
27	0:05:05	0:02:50	0:01:29	0:00:15
28	0:07:36	0:02:50	0:01:28	0:00:14
29	0:06:05	0:02:48	0:00:53	0:00:14
30	0:06:03	0:04:08	0:02:51	0:00:12
31	0:05:25	0:03:57	0:03:00	0:00:11

The data in the Table 1 are obtained chronographically, by measuring on-site. Measuring was repeated 31 times, within the period of three working days, randomly.

Once the product is processed, a re-checking is performed by the controller, and it takes from 100 up to 150 seconds. After re-checking, one out of 200 products is marked as incorrect and separated aside while the others are placed on pallets and moved to second warehouse department (Department 2). It is very important that the finished products are moveded to the second department as soon as possible, as the worker must return back to the first department. This activity takes between one and three minutes, but most likely one minute and 45 seconds. There are two controllers and four warehouse workers in the first department. At the second department, only two warehouse workers are employed.

In the second warehouse department, where cross-docking operations are performed, the products are wrapped by stretch foil and fastened to the pallet, to prevent moving during transportation. Wrapping is done by machine, but controlled by a warehouse worker from the second department. The time required for wrapping ranges from 45 to 55 seconds, and for the product stabilization, it takes two minutes. When the pallet is ready for transportation, the warehouse worker deposits it in the shipping zone.

Besides the pallets comming from the first department, four trucks arrive at the second department every day, with finished goods from dislocated production site (Location B). Each truck arrives with exactly 12 pallets of products. Products from that production site are also wrapped and fixed on pallets. Only one of 48 pallets need re-wrapping and stabilization. Other pallets are properly assembled, so they are directly dispatched to the shipping area.

The time needed to move the pallets from production site on Location B to the shipping zone varies from 40 to 60 seconds for pallets that need to be wrapped and fastened, and 30 seconds for pallets that are in correct condition. Since the shipments arrive at the beginning of the working day and there are no shipments until the next day, pallets arriving from the first department (which require wrapping and stabilization) are given higher priority then the pallets coming by trucks.

Figure 1 outlines the factory warehouse simulation model (concept) created by the ARENA software, which is described as follows.

The simulation model consists of two sections. The first section represents arrivals of the products from the factory, and the second section represents arrivals of the products by trucks and from the first department of the warehouse (Department 1).

Create module *Products from the factory* is located at the beginning of the first department. It represents arrivals of the products by production lane. Two products appear simoultaneously, with normal distribution N(10,1), which means every 10 minutes, with one minute delay.

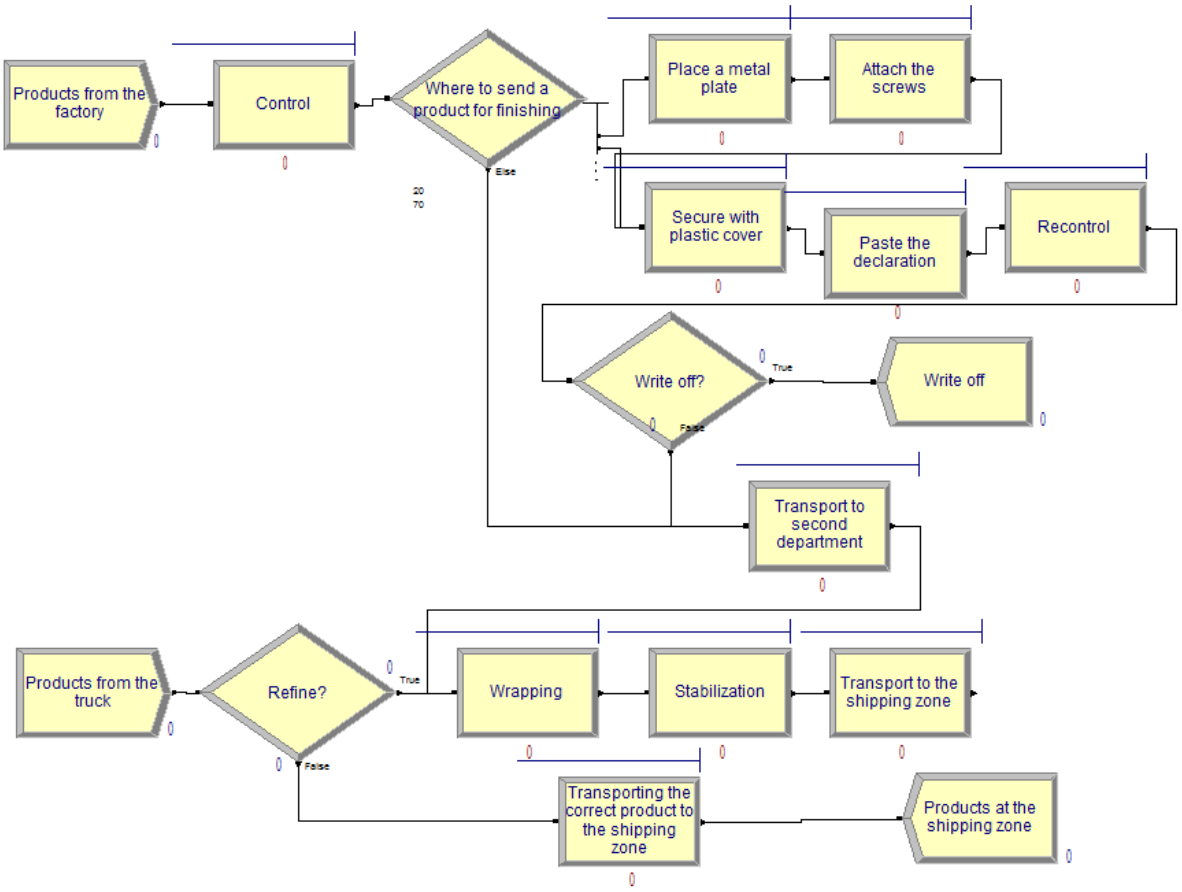


Figure 1 – Concept of the factory warehouse simulation by Arena Rockwell

The following module is process module *Control*, which refers to the product control, performed by the controller. The product control takes exactly 40 seconds. After checking, the controller decides where to send the product to be finished.

Decide module *Where to send a product for finishing?*, which follows the *Control*, represents the controller's decision between three options where to send the product for finishing. The options are:

- Option 1, with probability of 70%, it is needed to place a metal plate, attach the screws, secure with the plastic cover and paste the declaration.
- Option 2, with probability 20%, it is only needed to set the plastic protection on the product and paste the declaration.
- Option 3, with probability of 10%, the product is fully correct and have a proper declaration.

There are four activities that the warehouse worker performs to ensure that the product is completely and properly finished. Each of these four activities is carried out by a single worker.

Theoretical distributions are determined by the input data analysis. The theoretical distribution hypothesis is verified by statistical testing (χ^2 test). Figure 2 shows the distribution of time needed for placing a metal plate, based on the measuring on-site (data in table 1).

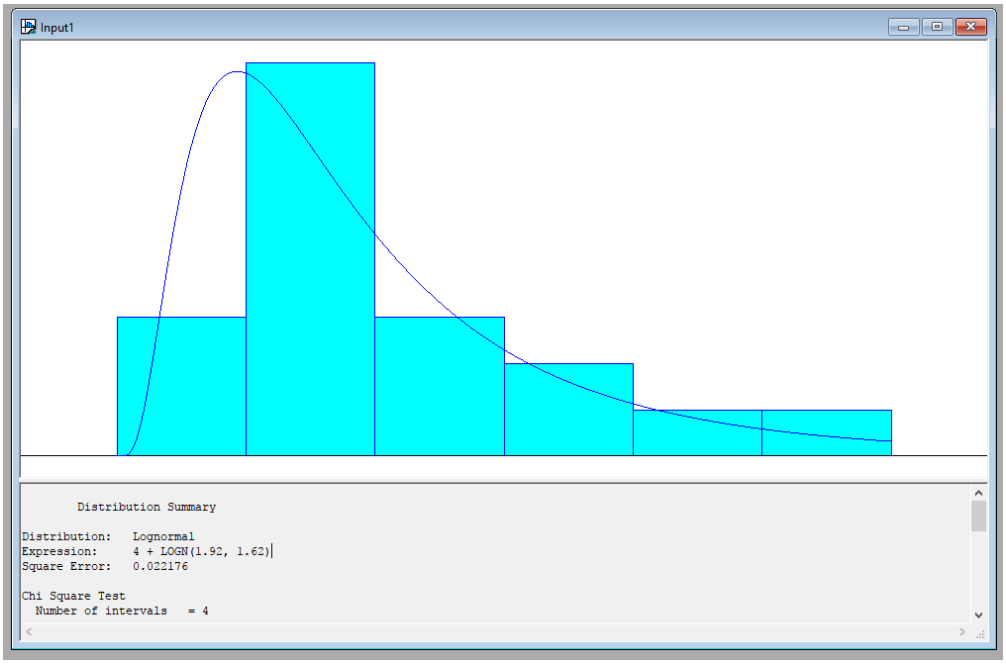


Figure 2 – Distribution of time needed for placing a metal plate

Process modules with their parameters, which are used for parametrization of the simulation model shown in Figure 1, are given in Table 2.

Table 2 – Process modules and settings

Name of the activity	Action	Priority	Delay type	Units	Minimum	Value	Maximum	Expression
Control	Seize Delay Release	Medium(2)	Constant	Seconds	/	40	/	/
Place a metal plate	Seize Delay Release	Medium(2)	Expression	Minutes	/	/	/	4 + LOGN(1.92, 1.62)
Attach the screws	Seize Delay Release	Medium(2)	Expression	Minutes	/	/	/	2.66 + 1.61 * BETA(2.08, 2.69)
Paste the declaration	Seize Delay Release	Medium(2)	Expression	Seconds	/	/	/	0.15 + 0.13 * BETA(1.9, 2.68)
Secure with the plastic cover	Seize Delay Release	Medium(2)	Expression	Minutes	/	/	/	0.61 + LOGN(1.15, 0.721)
Recontrol	Seize Delay Release	Medium(2)	Uniform	Seconds	100	/	150	/
Transport to second department	Seize Delay Release	Medium(2)	Triangular	Minutes	1	1,75	3	/
Wrapping	Seize Delay Release	Medium(2)	Uniform	Seconds	45	/	55	/
Stabilization	Seize Delay Release	Medium(2)	Constant	Minutes	/	2	/	/
Transport to the shipping zone	Seize Delay Release	Medium(2)	Uniform	Seconds	40	/	60	/
Transporting the correct product to the shipping zone	Seize Delay Release	Medium(2)	Constant	Seconds	/	30	/	/

The names of the process modules of the ARENA simulation model are given in the column *Name of the activity*, while the column *Type* represents the type of the activity. Standard processing means that the entity is simply processed within the module, based on the specified action logic, such as *Delay, Sieze Delay,* Seize *Delay Release* or *Delay Release*.

Action logic *Seize* means the module consumes a resource, while *Release* means the resource is made available. Action logic *Delay* affects both, such as *Seize Delay* (waiting to start using a resource) and *Delay Release* (waiting to release a resource). In this model, the action logic *Seize Delay Release* is used, which means when a worker is assigned to the certain activity, he remains dedicated to that activity until the activity is completed.

The *Priority* column shows which priority is asigned to a certain activity, and it is possible to choose three types of priorities, namely: Low, Medium and High. The *Delay Type* column represents the type of distribution or method of specifying the delay parameters (constant, uniform, triangular ...) [5]. This parameter shows duration of the activity.

4. RESULTS OF THE SIMULATION

After validation of the simulation model, the initial run of the simulation experiment is performed in the period of 30 days, with eight hours working time.

Parameters that affect the productivity of the processes are:

- the number of entities at output (how many products are successfully sent to the shipping zone),
- resource utilization,
- waiting time in queue (as additional parameter).

In the first simulation run, the number of entities at output were 4312 on average. This number shows how many products have been successfully delivered to the shipping zone. This data is very important because it represents productivity (the ratio of the products produced against the resources consumed).

As shown in Figure 3, working hours of the *Warehouse worker 1* are 49,46% utilised, *Warehouse worker 2* are 39,21% utilized, while the *Controller* working hours are only 27,48% utilised. Also, the 98,10% of entites that entered the process have been succesfully shipped.

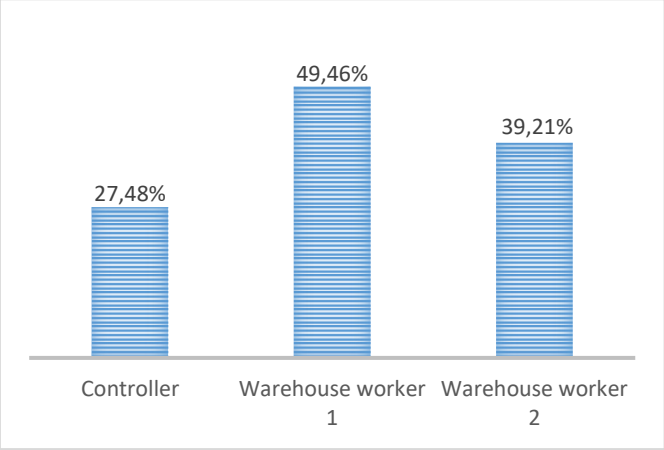


Figure 3 – Resource utilization

According to that data, the workers are not utilized enough, that is the resources are not sufficiently exploited. Waiting times of each activity in the process are given in Table 3.

Table 3 – Waiting times in queue

Name of the Activity	Resource	Waiting time (seconds)
Control	Controller	5,326
Place a metal plate	Warehouse worker 1	0,2598
Attach the screws	Warehouse worker 1	0,02246
Secure with the plastic cover	Warehouse worker 1	0,2152
Paste the declaration	Warehouse worker 1	0,2989
Recontrol	Controller	7,4672
Transport to second department	Warehouse worker 1	0,0687
Wrapping	Warehouse worker 2	15,084
Stabilization	Warehouse worker 2	13,5
Transport to the shipping zone	Warehouse worker 2	11,7178
Transporting the correct product to the shipping zone	Warehouse worker 2	376,53

The highest waiting time is incurred by the activity *Transporting the correct product to the shipping zone*, for an average of 376,53 seconds, or approximately 6,27 minutes. This point is a bottle neck in the system, so it should be resolved in order to optimize the system and increase its productivity.

5. PERFORMING SIMULATION EXPERIMENTS

In order to evaluate process optimization possibilities, two simulation experiments are performed. In the first experiment, work force resources are reallocated. In the second experiment, maximum workload of the process is tested.

The analysis of the first simulation run results, points out the necessity of increasig resource utilization, in order to increase the company's productivity. The simulation experiment with reallocated work force resources is also performed in the period of 30 days, with eight hours working time. It ensures the comparability with the results of the initial (first) simulation run. The activities of the product finishing are assigned to the controller, in order to increase his utilisation. Also, the warehouse workers from the second department move pallets that arrived by trucks to the second department, where subsequent activities are performed. Reorganization of the system is represented by the simulation model shown in Table 4.

Table 4 – Parameters of activities after reorganization

Name of the Activity	Resource	Priority
Control	Controller	high
Place a metal plate	Warehouse worker 1	
Attach the screws	Warehouse worker 1	
Secure with the plastic cover	Warehouse worker 1, Controller	
Paste the declaration	Warehouse worker 1, Controller	
Recontrol	Controller	high
Transport to second department	Warehouse worker 2	
Wrapping	Warehouse worker 2	
Stabilization	Warehouse worker 2	
Transport to the shipping zone	Warehouse worker 2	
Transporting the correct product to the shipping zone	Warehouse worker 2	high

The additional change in the model is setting a higher priority to the activities *Controll* and *Recontrol* to avoid bottle neck in the process and also to the activity *Transporting the correct product to the shipping zone* due to the long waiting time in this activity, which also acts as a bottle neck. The priority is changed from Medium (2) to High (1). This change enables workers to be allocated to this activity with higher priority, so the waiting time of products in this activity can be reduced.

The utilisation of the work force resources is increased, especially the utility of Controllers (Figure 4), which means they are more productive and evenly employed, thus enabling the system performance to be improved. Therefore, the 98,78% of entites that entered the process has been succesfully shipped. As shown in Figure 4, utilization of the Warehouse worker 1 decreased by 8,72%, while the Controller utiliziation increased by 14,04%.

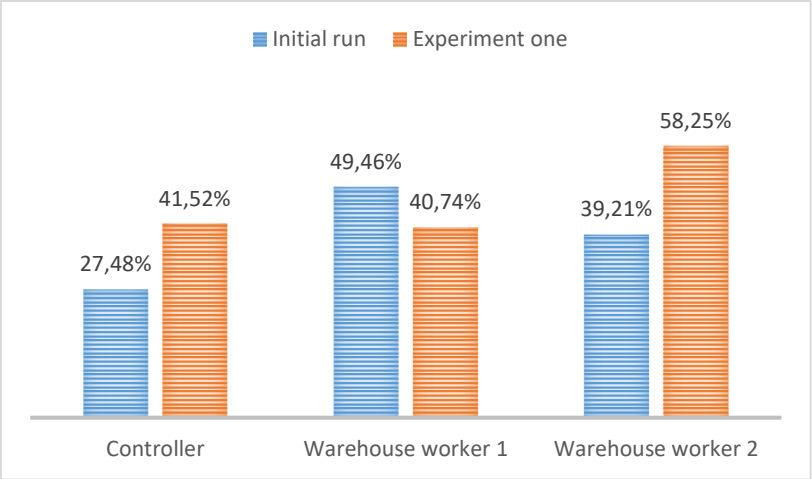


Figure 4 – Resource utilization

Table 5 shows the queues after the resource reallocation is implemented. It didn't have significant impact on reduction of the waiting time, even the queues of the products have increased to a certain extent. However, taking into account other improvements, such waiting times can be considered acceptable.

Table 5 – Wait time in queue after the reorganization

Name of the Activity	Waiting time (seconds)
Control	16,85
Place a metal plate	0,016
Attach the screws	0
Secure with the plastic cover	9,67
Paste the declaration	12,25
Recontrol	5,61
Transport to second department	21,18
Wrapping	17,9
Stabilization	22,6
Transport to the shipping zone	19,03
Transporting the correct product to the shipping zone	180,01

Work force reallocation enables increasing intensity of the products arrivals to the extent that resources are optimaly utilized. Therefore, new simulation experiment is set. Changes are introduced only in create module that simulated entities arriving from the factory (product line), while the entities coming by trucks are not changed.

Frequency of incoming products is increased up to the resource maximum workload. Maximum workload (more than 80%) is reached when entities from the factory start to show up every 6 minutes (two products, N(6,1)). Therefore, the 99, 88% of entites that entered the process has been succesfully shipped.

Figure 5 shows utilization of the workers in the initial system (Initial run), after implementing the work force reallocation (Experiment one) and after implementing the maximum workload (Experiment two).

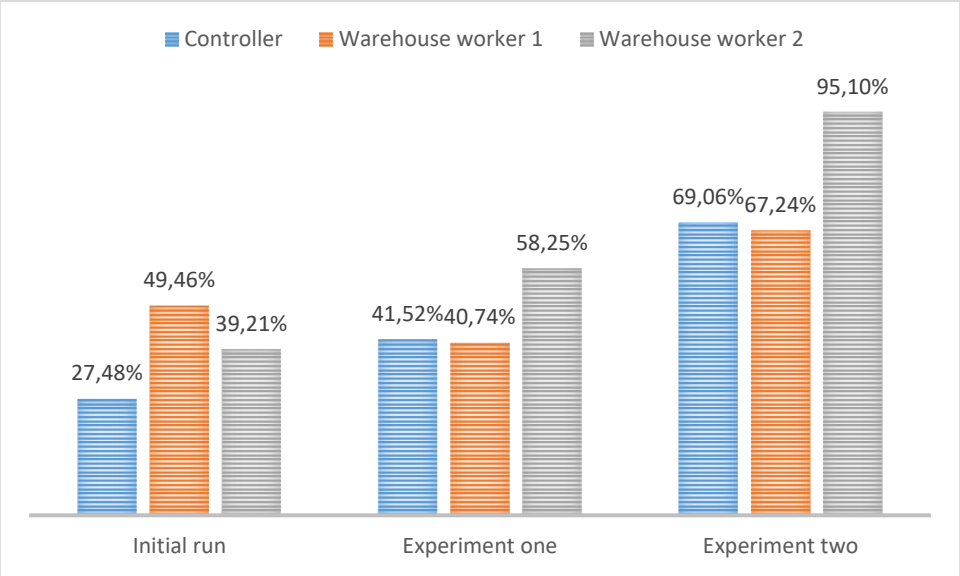


Figure 5 – Work force resources utilization

As shown in table 6, waiting times in activities are changed. Negative values represent decrease of the waiting time, while positive values represent increase of the waiting time, comparing to the initial run.

Table 6 – Changes of the waiting time

Waiting time in activity (seconds)	First run	Experiment One	**Difference**	Experiment Two	**Difference**
Control	5,3260	16,85	**11,52**	32,05	**26,72**
Place a metal plate	0,2598	0,016	**-0,24**	6,355	**6,10**
Attach the screws	0,02246	0	**-0,02**	5,83	**5,81**
Secure with the plastic cover	0,2152	9,67	**9,45**	33,72	**33,50**
Paste the declaration	0,2989	12,25	**11,95**	39,18	**38,88**
Recontrol	7,4672	5,61	**-1,86**	10,13	**2,66**
Transport to second department	0,0687	21,18	**21,11**	166,37	**166,30**
Wrapping	15,084	17,9	**2,82**	168,02	**152,94**
Stabilization	13,5	22,6	**9,10**	164,25	**150,75**
Transport to the shipping zone	11,7178	19,03	**7,31**	172,78	**161,06**
Transporting the correct product to the shipping zone	376,53	180,01	**-196,52**	250,57	**-125,96**

The highest increase of the waiting time occurred in the activity *Transport to second department*, in both experiments (21,11 seconds in the Experiment One and 166,30 seconds in the Experiment Two). The highest decrease of the waiting time occurred in the activity *Transporting the correct product to the shipping zone*, in both experiments (-196,52 seconds in the Experiment One and -125,96 seconds in the Experiment Two).

6. CONCLUSION

Simulation modeling is one of the contemporary methods of modeling facilitated by computer. This method allows to describe, understand and perform a quantitative analysis of complex dinamic systems in production, transport, economics, services, computing etc. In recent years, simulation

modeling has been greatly developped, due to enhanced processor capabilities, computer graphics, methods of artificial intelligence and by using object-oriented programming.

The possibilities of applying simulation modeling to optimize logistic processes in order to increase the productivity of a logistic system are outlined by the example of the factory warehouse. The results of the simulaton experiments are analyzed and the parameters affecting productivity of the system are identified. Initial simulation model is then successively redesigned, to adopt the elements of optimization. The improvements achieved are quantified by comparing results of the subsequential simulation experiment to the initial results.

Besides testing the resource utilization and maximal process workload, productivity of the entire warehouse system is successively increased, due to implementing the elements of optimization, which were formulated and tested in the simulation experiments.

In this particular case, results of the simulation experiments facilitated optimizing logistic processes in the factory warehouse in terms of productivity. The initial number of succesfully processed entities increased from 98,10% to 98,78% by realocation of the resources and finaly to 99,88% by setting the maximum process workload. A similar approach can be applied in optimizing different logistic processes, which could be a topic of the future research.

One of the main advantages of the simulation modeling methods, in terms of examining new solutions and changes, is that simulation methods enable testing in the virtual system (model) prior to implementation in the real system.

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DATA CONVERTER FROM OPENTRACK INTO KRONECKER

ABSTRACT

Within the project GoSAFE RAIL, funded by the H2020 Shift2Rail programme with focus on achieving Single European Railway Area (SERA), one work package is dedicated to the development of an integrated rail network model that will incorporate both infrastructure asset (e.g. crossings, tracks, bridges, tunnels) and traffic (e.g. vehicle, freight and passenger movement) data. Furthermore, the existing OpenTrack model of Zagreb – Rijeka line is used as an input for optimization algorithm based on Kronecker Algebra. Therefore, infrastructure topology is exported in IVT format to cover infrastructure attributes like speed limit, gradients and main signals (home, exit, block). Additionally, the annual timetable is exported in OpenTrack format to create for each train the Kronecker operations. Finally, the simulated output from OpenTrack is compared to results from Kronecker algorithm. Main indicator is the graphical timetable as well as delays of trains in their final destination.

KEY WORDS

rail traffic flow optimization; scheduling; Kronecker algebra; data converter;

1. INTRODUCTION

Rail infrastructure managers are responsible for safety measures and planning within the infrastructure network. Although the railway transport mode is considered one of the safest modes of transport [1] with 0.16 fatalities per billion passenger km's there is a number of infrastructure failures that have happened in recent years. Unfortunately, the number is expected to rise in the future, mainly due to ageing railway network and stronger climate changes.

Consequently, the objective of the Shift2Rail project Global SAFEty Management Framework for RAIL Operations [2] is development of an evolutionary Decision Support Tool that self-learns (evolves) based on machine learning algorithms and artificial intelligence with the main goal of offering safer, reliable and efficient rail infrastructure. As already mentioned above, there is a low number in failures on the infrastructure network, which consequently leads to a lack of data crucial for machine learning. This will be solved by implementation of Near-Miss Concept; in other words, low-consequence events will be also included in the model and enable use of statistically significant data for model training. Furthermore, a new train mounted multiple sensor system for Object Detection will be developed.

Moreover, with OpenTrack micro-simulation modelling tool, traffic model will be developed that will use multi-criteria optimization algorithms to address complex requirements, for both passenger and freight transport. Using Kronecker algebra [3], which showed good results in dealing with optimization scenarios in railway traffic flow, especially avoidance of bottlenecks and conflicts, simulation of actual network performance on the line between Zagreb and Rijeka in Croatia will be performed.

2. OPENTRACK RAILWAY SIMULATION SOFTWARE

OpenTrack was developed at the Swiss Federal Institute of Technology's Institute for Transportation Planning and Systems (ETH IVT). The project's goal was development of a user-friendly railroad simulation program that could run on different computer platforms and could answer many different questions about railway operations [4]. Figure 2 illustrates the three main elements of OpenTrack: data input, simulation, and output.

OpenTrack is a microscopic synchronous railroad simulation model. As such it simulates the behaviour of all railway elements (infrastructure network, rolling stock, and timetable), as well as all processes between them. It can be easily used for many different types of projects, including testing the stability of a new timetable, evaluating the benefits of different long-term infrastructure improvement programs, and analysing the impacts of different rolling stock.

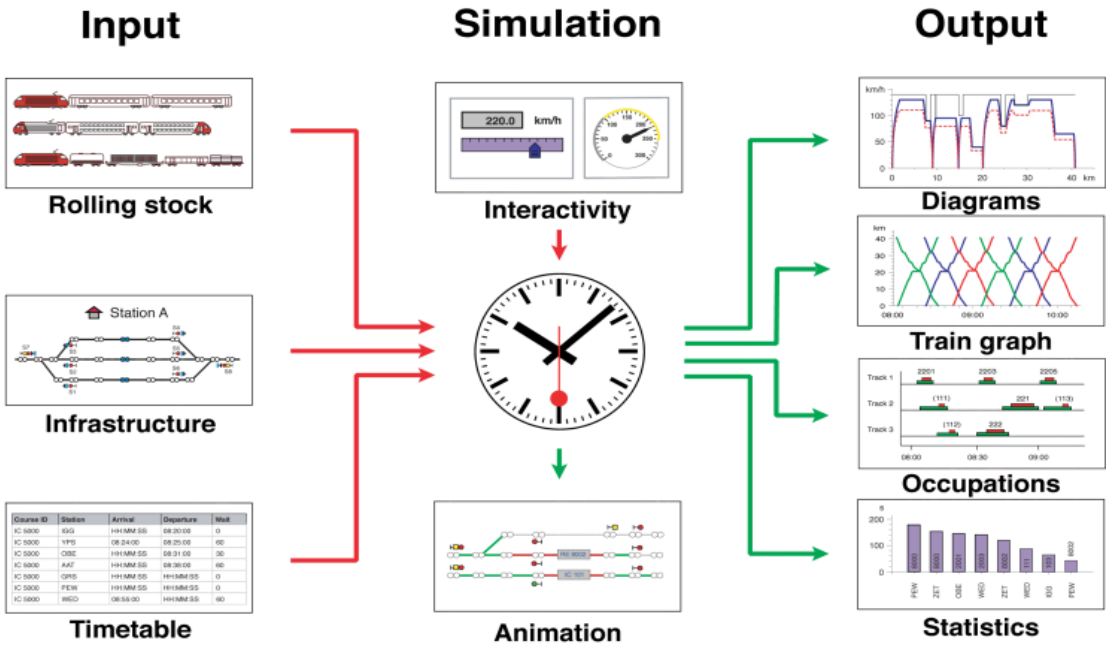


Figure 1 – Data flow in simulation of railway operation
Source: [5]

Input Data

OpenTrack manages input data in three modules: rolling stock (trains), infrastructure, and timetable. Users enter input information into these modules and OpenTrack stores it in a database structure. Once data has been entered into the program, it can be used in many different simulation projects. For example, once a certain locomotive type has been entered into the database, that locomotive can be used in any simulation performed with OpenTrack. Similarly, different segments of the infrastructure network can be entered separately into the database and then used individually to model operations on the particular segment or together to model larger networks.

Train data (locomotive and wagons) is entered into the OpenTrack database with easy to use forms displayed using pull down menus. Infrastructure data (e.g. track layout, signal type/location) is entered with a user-friendly graphical interface; quantitative infrastructure data (e.g. elevation) is added using input forms linked to the graphical elements. Following completion of the railML [6] data structure for rolling stock and infrastructure, OpenTrack is modified to enable train and infrastructure data to be directly imported from railML data files.

Timetable data is entered into the OpenTrack database using forms. These forms include shortcuts that enable data input to be completed efficiently. For example, users can designate hourly trains that

follow the same station stopping pattern an hour later. Since OpenTrack uses the railML [6] structure for timetable data, timetable data can also be entered directly from various different program output files as well as database files. Furthermore, Figure 4 shows a short overview of different software programmes using railML interface.

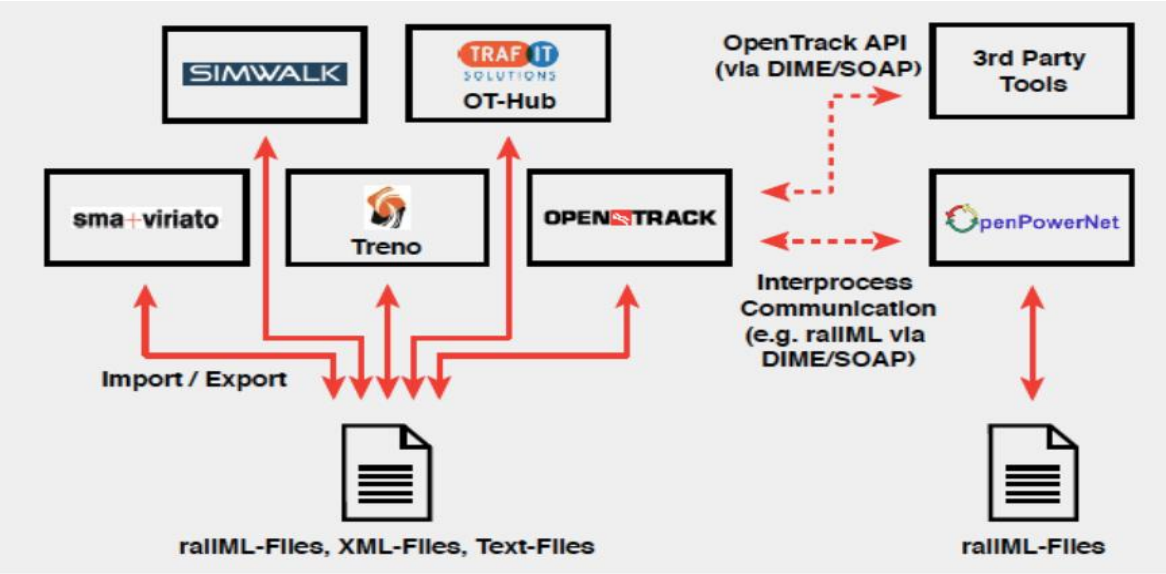


Figure 2 – Programes already using railML
Source: [5]

One advantage of OpenTrack is that it enables users to adjust many variables that impact railroad operations. For example, users can simulate the impact of weather on traction by specifying the adhesion scenario (good, normal, bad). OpenTrack then estimates locomotive traction power using a percentage (also user-defined) of that calculated using the Curtius and Kniffler formula [4]. While OpenTrack provides standard default values for all variables, having the ability to adjust variables makes the program very useful.

Simulation

In order to run a simulation using OpenTrack the user specifies the trains, infrastructure and timetable to be modelled along with a series of simulation parameters (e.g. animation formats) on a preferences window. During the simulation, OpenTrack attempts to meet the user-defined timetable on the specified infrastructure network based on the train characteristics. OpenTrack uses a mixed continuous/discrete simulation process that allows a time driven running of all the continuous and discrete processes (of both the vehicles and the safety systems) under the conditions of the integrated dispatching rules.

The continuous simulation is dynamic calculation of train movements based on Newton's motion formulas. For each time step, the maximum force between the locomotive's wheels and the tracks is calculated and then used to calculate acceleration. Next, the acceleration function is integrated to provide the train's speed function and is integrated a second time to provide the train's position function.

The discrete simulation process models operation of the safety systems; in other words, train movements are governed by the track network's signals. Therefore, parameters including occupied track sections, signal switching times, and restrictive signal states all influence the train performance. OpenTrack supports traditional multi-aspect signalling systems as well as new moving block train control systems (e.g. European Train Control System – ETCS signalling).

OpenTrack is a dynamic rail simulation program. As such, the simulated operation of trains depends on the state of the system at each step in the process as well as the original user-defined objective data (e.g. desired schedule).

A simple way of describing dynamic rail simulation is that the program decides what routes trains use while the program is running. For example, when building the network, users identify various different routes that trains can use between two points; OpenTrack decides, during the simulation, which route the train will use by assigning the train the highest priority route available. If the first priority is not available, OpenTrack will assign the train the second highest priority route and so on.

OpenTrack's dynamic nature allows users to assign certain attributes to specified times in the simulation. Thus, users can assign a delay to a particular train at a given station and time, rather than being limited to assigning a delay at the start and using it through the entire simulation. Similarly, users can define other types of incidents (e.g. infrastructure failures, rolling stock breakdowns) for particular times and places.

Finally, dynamic simulation enables users to run OpenTrack in a step-by-step process and monitor results at each step. Users can also specify exactly what results are displayed on the screen. Running OpenTrack in a step-by-step mode with real time data presented on screen helps users to identify problems and develop alternative solutions.

Output

One of the major benefits of using an object-oriented language is the great variety of data types, presentation formats, and specifications that are available to the user. During the OpenTrack simulation each train feeds a virtual tachograph (output database), which stores data such as acceleration, speed, and distance covered. Storing the data in this way allows users to perform various different evaluations after the simulation has been completed.

OpenTrack allows users to present output data in many different formats including various forms of graphs (e.g. time-space diagrams), tables, and images. Similarly, users can choose to model the entire network or selected parts, depending on their needs. Output can be used either to document a particular simulation scenario or as an interim product designed to help users identify input modifications for another model run.

3. Case study Zagreb – Rijeka Line

As already mentioned, line Zagreb – Rijeka was chosen for the case in collaboration with Croatian Railways. First reason is its importance within domestic traffic network; second and more important reason, it being part of TEN-T corridor.

Starting with the OpenTrack model of a railway line, two files are generated and exported using existing filters. Based on the itinerary covering the main track from first to last station of an OpenTrack model, a text file in IVT format is generated. The structure of an IVT file is always the same and contains the information listed in Tab. 1. The four speed limits have their origin in the Swiss regulation for track speed limits for passenger, cargo (two braking settings) and tilting trains. This file in IVT format is used to create the so called tracks.csv file for Kronecker Algebra. The content of tracks.csv is described in Tab. 2. Here, the macroscopic structure of a railway line is defined. In addition, there is a micro tracks file for the description of the microscopic structure, including gradients and speed limits. This input is required for the calculation of running times later on. The timetable is exported as a text file in OpenTrack format (Tab. 3). Based on this information about the timetable of all trains running in a project, for each train a text file trainID.csv is generated as input for Kronecker (Tab. 4). Additionally, train movements are calculated in accordance with their tractive-effort and braking characteristics (Tab. 5).

Table 1 – OpenTrack IVT file format

Position	Content
1	Position
2	Vertex Name Up
3	Vertex Name Down
4	Vertex km Up
5	Vertex km Down
6	Speed Up 1
7	Speed Up 2
8	Speed Up 3
9	Speed Up 4
10	Speed Down 1
11	Speed Down 2
12	Gradient
13	Radius
14	Tunnel Type
15	Signal Up
16	Signal Down
17	Station Name

Source: [7]

Table 2 – Structure of tracks.csv for Kronecker Algebra

Position	Content
1	Edge ID
2	Initial Condition for Semaphore
3	Maximum Value of Semaphore
4	Start
5	End
6	Sight Position for Start
7	Release Position for End
8	Sight Position for End
9	Release Position for Start

Source: [2]

Table 3 – OpenTrack timetable format

Position	Content
1	Course ID
2	Interval Course ID
3	Time to Interval Reference

4	Station Index
5	Station Sign
6	Track Name
7	Arrival Time Day Offset
8	Arrival Time
9	Departure Time Day Offset
10	Departure Time
11	Use Departure Time
12	Dwell
13	Stop at Station
14	Mean Delay
15	Distribution
16	Delta Mass

Source: [7]

Table 4 – Structure of trainID.csv

Position	**Content**
1	Start Node ID
2	End Node ID
3	Direction
4	Arrival Day
5	Arrival Month
6	Arrival Year
7	Arrival Hour
8	Arrival Minute
9	Arrival Second
10	Departure Day
11	Departure Month
12	Departure Year
13	Departure Hour
14	Departure Minute
15	Departure Second
16	Stopping Point
17	Time Integer
18	Virtual Stop
19	Kronecker operation (block “p” or release “v”)

Source: [2]

Table 5 – Structure of trains.csv

Position	Content
1	Train ID
2	Kronecker Train ID
3	Mass Engine
4	Mass Trailer
5	Train Length
6	Number of Trailers
7	Train Type
8	Maximum Speed of Train
9	Factor for Recuperation
10	Minimum Position of Train
11	Maximum Position of Train

Source: [2]

Figure 3 shows planned timetable (black lines) and simulated timetable (pink for fast trains and green for regional trains) for all passenger trains on Zagreb – Rijeka line.

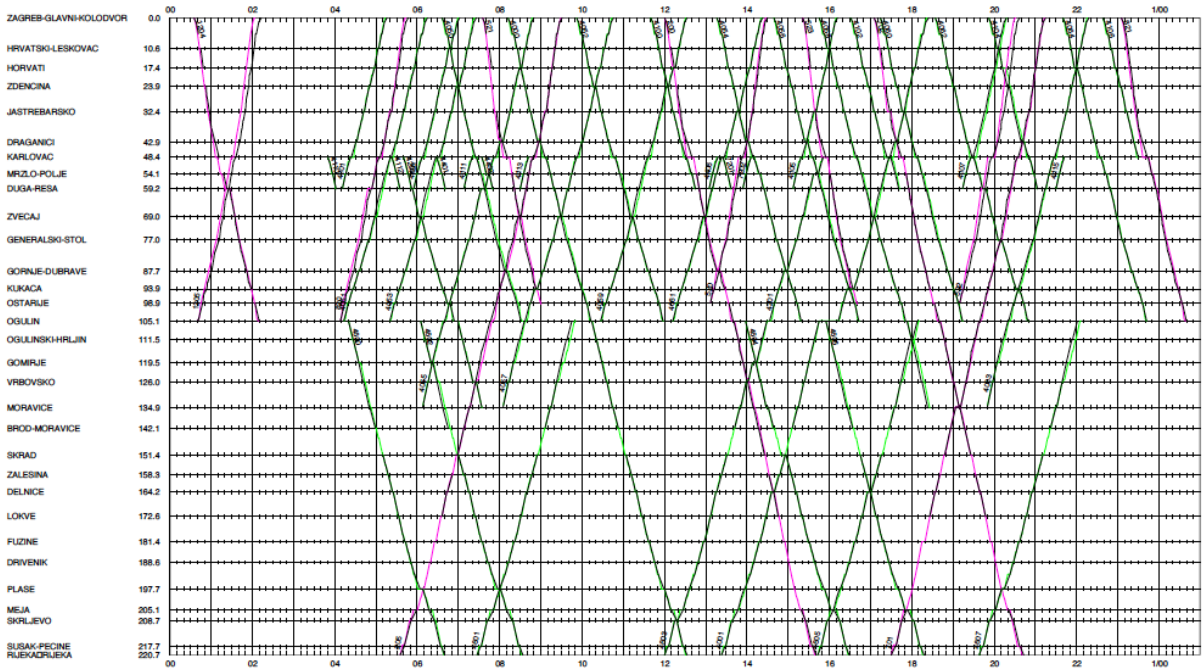


Figure 3 – Train graph of all passenger trains on Zagreb – Rijeka line
Source: [2]

As a benchmark for the Kronecker algorithm delays of all passenger trains are used according to figure 4. Delays are indicated by train ID and station ID in seconds. Obviously, majority of trains has a lot of reserve in running times and therefore arrive earlier at their final station. Of course, crossings with cargo trains are excluded in this simulation which require additional time. On the other hand, maximum delays are below 5 minutes.

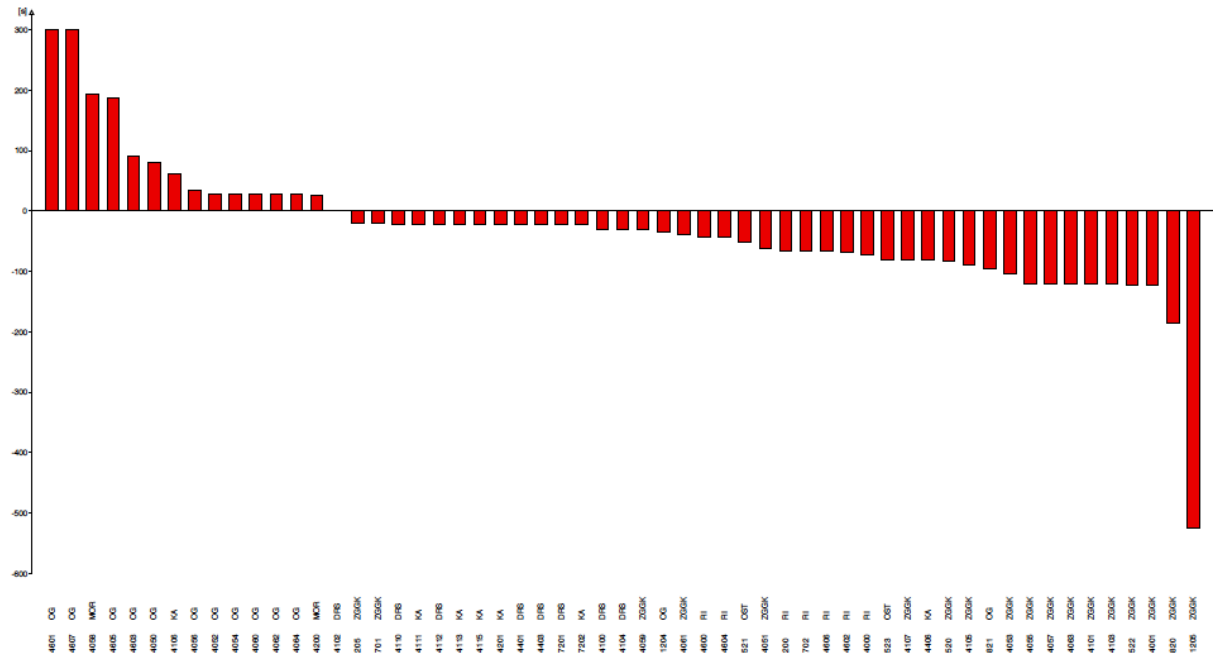


Figure 4 – Delays of all passenger trains on Zagreb – Rijeka line at their final destination
Source: [2]

5. CONCLUSION

OpenTrack, being a sophisticated micro-simulation model allows the determination of impact of safety decisions on network capacity. Thus, by incorporating both infrastructure asset (e.g. crossings, tracks, bridges, tunnels) and traffic (e.g. vehicle, freight and passenger movement), effective delivery of maintenance or new works while maximising the connectivity and adaptability of the overall surface system will be enabled. As a performance indicator for Kronecker Algebra the delays of trains at their final station are used as a benchmark criteria.

ACKNOWLEGMENT

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THE VEHICLE ROUTING PROBLEM WITH PLATOON FORMATION

ABSTRACT

The road-traffic increases continuously but the road infrastructure becomes more and more scarce and less efficient. In addition, emissions related to the consumption of fossil fuels grow up continuously. One idea to address both challenges of limited infrastructure as well as high emissions seems to be truck platooning. Due to technological progress in the field of vehicle-to-vehicle communication it is today possible to electronically dock a sequence of trucks so that they travel safely at high speed and low vehicle-to-vehicle distance. The reduced distance between immediately following vehicles contributes to reduce aerodynamical drag. Significant fuel savings are possible. In this paper, we start the discussion of vehicle routing with integrated platoon formation for the less-than-truckload (LTL) market segment. We present a decision model for the integrated truck route compilation and truck platoon formation with the intention to minimize the consumed fuel of the complete fleet.

KEY WORDS

less-than-truckload trucking; platooning; fuel saving; vehicle routing; optimization;

1. INTRODUCTION

Platooning of vehicles describes the formation of technically but not mechanically connected sequences of vehicles for a certain time and on selected road segments. Due to the incorporation of technological features like car-to-car communication as well as synchronized braking systems it is possible to reduce the distance between consecutively travelling vehicles without any safety impairment even if they travel at high speed. The major benefit of the reduction of the space between adjacent trucks is the reduction of aerodynamic drag which results in reduced fuel consumption. In addition, the reduced length of the technically coupled convoy lowers the needed space on crowded roads since a higher level of traffic coordination is achieved.

We can distinguish two perspectives of platoon formation. From the micro-perspective (or local perspective) it is necessary to take care that vehicles travelling on the same road segment at the same time can perform the automatic docking so that they form a platoon. Here, travel speed coordination among the platoon candidates is the major challenge [1]. However, in order to prepare a rendezvous of two or even more vehicles in a region of a network it is necessary to provide coupling opportunities. They can be realized if vehicle routes deviate from individually optimal vehicle paths during the planning of the vehicle routes for the overall fleet through the road network. We call this the macro-perspective (or network view) of platooning. Here, the well-known but quite complex vehicle routing problem [2] must be merged with platoon building opportunities [3].

Research on platoon formation in the context of vehicle routing is still quite limited. The explicit compilation of routes together with the setup of platoons as objects in one single planning model is not yet discussed. This paper contributes a concept for integrating platoon formation and vehicle routing in the macro-perspective context. We present a mixed-integer linear model in which platoons are contained as explicitly considered disposition objects. Section **Error! Reference source not found.** describes the resulting vehicle routing problem with platoon formation (VRP-PF). Section 0 introduces

and analyses sequences of activities that contain both platoons as well as single nodes executing so-called combined vehicle routes. Section 0 derives the aforementioned integrated routing and platooning model for the VRP-PF.

2. DECISION SCENARIO OUTLINE

This section introduces the extension of a classical vehicle route compilation task by truck platooning opportunities with the goal to reduce the network-wide fuel consumption of a fleet. Subsection 0 consolidates the relevant literature. An informal problem statement forms Subsection 0. Subsection 0 introduces an idea how the platoon forming task will be integrated into a vehicle routing model.

2.1 Literature

Sokolov et al. [4], Larsson et al. [5] as well as Zhang et al. [6] agree that the fleet-& network-wide fuel minimization is the primary goal of truck platoon formation. Equivalent or similar objectives like the maximization of the time vehicles spent in a platoon are also mentioned.

The scientific investigation on road-haulage exploiting platooning-related fuel-savings is limited to full truckload (FTL) scenarios. Trucks originating from individual loading locations have to travel through a given road network to individual destinations for unloading their payload. The vehicle platooning problem aims at coordinating the origin-to-destination paths of these trucks by grouping vehicles to form platoons.

Larsson et al. [5] distinguishes two general problem scenarios w.r.t. temporal aspects of vehicle platooning. In the unlimited platooning scenario it is possible that vehicles wait at the entry of a commonly traversed arc until all potential platoon members have arrived. However, finite deadlines at the unloading locations may compromise this platooning strategy. Zhang et al. [6] investigate platooning challenges in case that travel times are stochastic.

Vehicle platooning requires to solve several decision tasks that all contribute to realize platooning-related fuel consumption reductions. Sokolov et al. [4] as well as Zhang et al. [6] mention that the path determination of trucks as well as the coordination of vehicle departure times at the freight origins are necessary to realize vehicle platoon. In addition, Larsson et al. [5] argue that the selection of an appropriate vehicle speed is also necessary and beneficial for the formation of vehicle platoons.

For the FTL-platooning Sokolov et al. [4] use integer linear programming techniques to derive best decisions. Larsson et al. [5] propose and evaluate problem-specific heuristics. Zhang et al. [6] apply general analytical approaches. Van Doremalen et al. (2014) [7] apply a generalized framework for the integration of platooning and vehicle routing. They describe a hierarchical approach. First, travel paths are individually determined for the vehicles. In a second step these routes are matched so that shared arcs (included in several routes) are identified which form the backbone of platoons.

A recent comprehensive literature survey about the planning of truck platoons w.r.t. to prerequisites, challenges, obstacles and scenarios is provided by Bhoopalam et al. [3]. They conclude that the combination of vehicle route coordination with the goal to form platoons with the customer request consolidation (vehicle route compilation) as a central dispatching task in the less-than-truckload (LTL) segment, is not yet investigated, i.e. that there is a research gap.

In this paper, we provide a first step towards the partial filling of this gap. We present a mathematical optimization model that integrates the platoon formation (vehicle schedule coordination) with the routing of vehicles from the network-view (macro-perspective).

2.2 Informal Problem Statement

We consider a variant of the capacitated vehicle routing problem discussed in detail for example in [2]. All available vehicles form the fleet $\mathcal{F}$. For each vehicle $f \in \mathcal{F}$ d_f^+ represents the start position (start depot) but d_f^- refers to the terminating location (terminal depot). Let $\mathcal{V}^D$ be the set of depot nodes.

The vehicles should be deployed in a network that is not necessarily complete. This network is represented by a weighted mathematical graph $\mathcal{G} = (\mathcal{V}; \mathcal{A}; f)$. The vehicle deployment is necessary to fulfill LTL-requests for quantities commonly picked up at the vehicle's start depot and delivered to several spatially distributed customer locations. Each individual request comprises the delivery location as well as a deadline for the unloading at the associated customer location.

For each vehicle f in the fleet it is necessary to define a route through $\mathcal{G}$ that starts at d_f^+ and terminates at d_f^-. Between the start and the end of its trip a vehicle may visit customer locations. The trip duration is limited but no capacity constraint is imposed on routes since we assume that the moved commodities have only a very small volume.

A customer node is associated with exactly one customer request. Such a node has to be visited by exactly one vehicle exactly once. An infrastructure node is relevant for the formation and/or decomposition of a platoon of trucks. So we specify an infrastructure node for each location where it is possible that vehicles join a platoon or leave it (crossings, junctions, motorway exits, motorways entries, parking lots, service areas). Let $\mathcal{V}^C$ contain all customer nodes and let $\mathcal{V}^I$ form the set of infrastructure nodes. We define the node set $\mathcal{V} \coloneqq \mathcal{V}^D \cup \mathcal{V}^C \cup \mathcal{V}^I$ of graph $\mathcal{G}$.

Nodes are connected by arcs. If both the origin as well as the terminal node associated with an arc belongs to $\mathcal{V}^I$ then this arc is called an **infrastructure arc**. An arc connecting an infrastructure node with a non-infrastructure node (or vice versa) is called a **service arc**. Finally, there are arcs connecting two customer locations, they are called **direct arcs**. We collect all infrastructure arcs in the set $\mathcal{A}^I$. The service arcs are put into the set $\mathcal{A}^S$ but the direct arcs compile the set $\mathcal{A}^D$. These three arc sets form the arc set $\mathcal{A} \coloneqq A^I \cup A^S \cup A^D$.

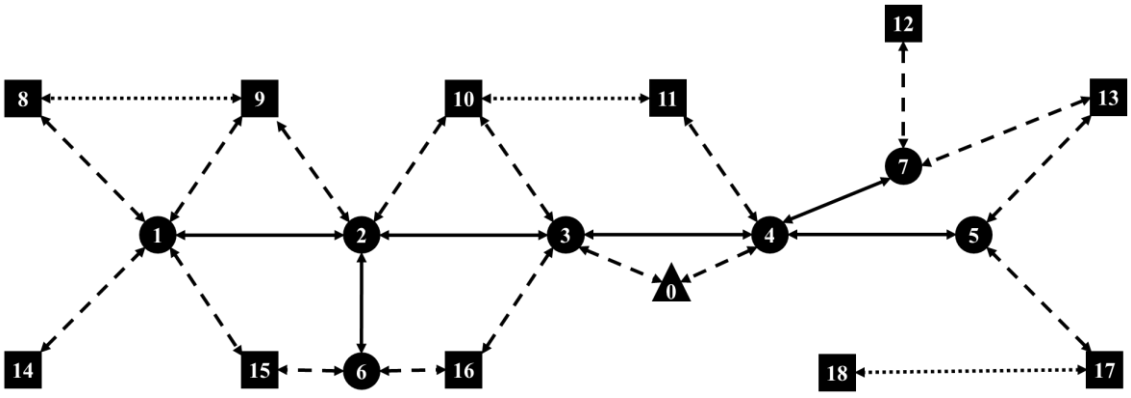


Figure 1 – An example network with three types of nodes as well as three kinds of arcs

Figure 1 shows an example network with one common depot (0) and 7 infrastructure nodes (1-7). The solid arcs are the infrastructure arcs. They could represent a motorway that bridges longer distances and on which high travel speeds are realized. The infrastructure nodes might represent exits or entry points to the motorway or even motorway intersections. In addition, we have the eleven customer nodes (8-18). Dashed arcs are service arcs but dotted arcs are direct arcs.

Two arc related evaluation functions c as well as t define the arc evaluation function $f(i;j) \coloneqq (c(i;j); t(i;j))$. The travel distance to bridge arc $(i;j)$ is stored in $c_{ij} \coloneqq c(i;j)$ and the required travel time is $t_{ij} \coloneqq t(i;j)$.

2.3 Modelling of a Vehicle Platoon

Every infrastructure node can be included into several vehicle paths or at multiple positions within the route of a certain vehicle. As a consequence, it becomes necessary to attach a list to such a node with a priori unknown length to store scheduling decisions. To avoid this, we introduce a platoon that compiles common scheduling information associated with multiple visits of infrastructure nodes. We formally define a platoon P as the triple $P = (path, start_time, vehicles)$. With $path$ we refer to the path in the underlying network $\mathcal{G}$ along which all vehicles from the set $vehicles$ travel together commonly leaving from the first node in $path$ at time $start_time$.

We define the maximal number of possible platoons N_P^{max} as an input parameter of the considered decision task. The consideration of this convention enables the declaration of the set $\mathcal{B} = \{P_1, \dots, P_{N_P^{max}}\}$ of available platoons. This is a similar approach known from most of the vehicle routing problem models that are defined exploiting the existence of a finite but "sufficiently large" set of vehicles to be routed or to be left undeployed.

A platoon is interpreted as a commodity (the group of all vehicles that have joined this platoon before), which "flows" through the network $\mathcal{G}$. In contrast to network commodity flow problems [8] it is necessary to decide, beside the commodity path, also the origin as well as the destination node of this commodity. In order to simplify the description as well as the integration of the platoons into the routing decision model we make some settings:

- the path-component of a platoon contains only infrastructure nodes
- whenever a vehicle joins (or leaves) a platoon then the platoon path starts (terminates) and vice versa
- infrastructure nodes cannot be contained in a vehicle route but a platoon comprising only a single infrastructure node can be defined
- during a platoon execution, the group of vehicles does not wait and so the duration of a platoon is the sum of travel times through the arcs forming the $path$
- The fuel consumption $FC(P)$ of a platoon P depends on the distance of $dist(P)$ of the path-component as well as on the number of vehicles m contained in the set $vehicles$. We have $FC(P) = fuel(dist(P); m)$ for an appropriate fuel calculation function $fuel$

The major reason for the desire to operate vehicle platoons is that significant fuel savings can be realized if a formation of trucks travels at the same speed with short intermediate distances among subsequently driving trucks. A platoon should be set up if and only if the additional fuel quantity needed for detours to join this platoon is overcompensated by the fuel savings from the platoon affiliation.

$$fuel(dist(P); m) = m \cdot dist(P) - (2m - 1) \cdot 0.08 \cdot dist(P) = (0.84m + 0.08) \cdot dist(P) \quad (1)$$

Different fuel saving potentials are discussed in the literature. In this paper we use the fuel saving scheme discussed in [9]. If two or more trucks form a platoon then the first truck saves 266pprox.. 8% fuel compared to riding alone and each following truck consumes 16% fuel less in comparison with riding alone outside a platoon. This leads to (simplified) fuel consumption functions $CF_m \cdot dist(P)$ where m refers to the number of vehicles that commonly processes through platoon P. The application of the fuel calculation function (1) leads to the multipliers $CF_m = 0.84m + 0.08$ $(m > 0)$ and $CF_0 = 0$.

3. COMBINED VEHICLE ROUTES

Figure 2 shows an example of a vehicle route (thick arcs) including two depot stops, three customer nodes (8, 9 and 10) as well as four platoons. The first platoon P_1 contains the path $4 \rightarrow 3 \rightarrow 2$ and two other vehicles join P_1 (thin arcs). The second platoon P_2 contains the path $2 \rightarrow 1$ and is shared with

another vehicle. The third platoon P_3 comprises only node 2 but the forth platoon P_4 hosts the path $3 \rightarrow 4$ and platoon P_4 is shared with another vehicle as well. For the infrastructure node 2 contained in the three platoons P_1, P_2 as well as P_3 it is possible to determine and store the required each three routing as well as scheduling information associated with this node using the different platoons P_1-P_3 as containers.

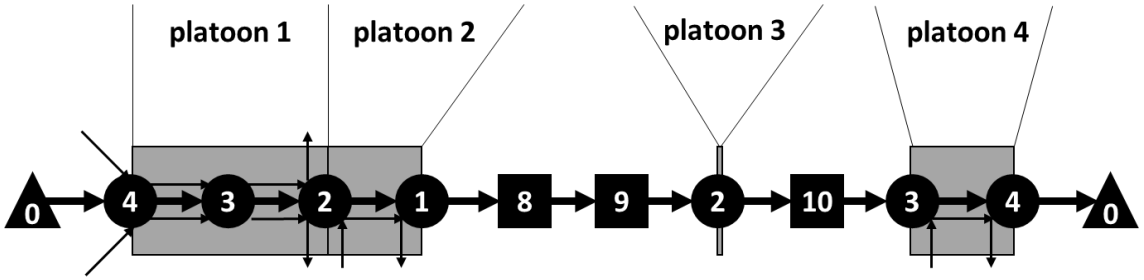


Figure 2 – A combined vehicle route

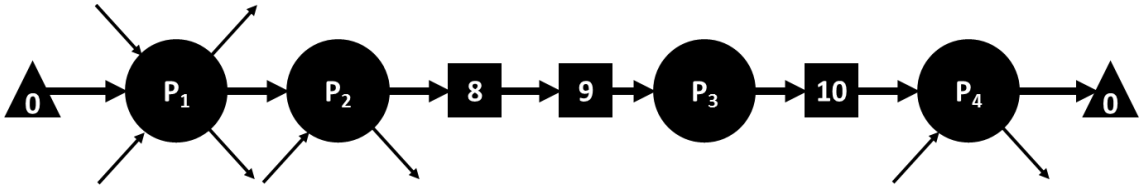


Figure 3 – A combined vehicle route with artificial platoon nodes

We may interpret each platoon path as an artificial node ("platoon node") as seen in Figure 3. Doing so, we achieve a reduced node sequence. However, we need to consider that the "entry" as well as the "leaving" node of a platoon node are not fixed parameters. Platoon nodes might have more than one entry as well as several outbound arcs (thin arcs). In addition, the travel length required to pass through a platoon node is variable since it depends on the decided platoon path. The same observation is true for the time to ride through a platoon node. We call such a route that may contain platoon nodes beside customer and depot nodes a **combined vehicle route**.

Table 1 – Characterization of different node connections

		destination node type	
		node (N)	platoon (P)
origin node type	node (N)	**NN-connection ("Node-2-Node")** • defined on $\mathcal{V} \times \mathcal{V}$ • allowed: depot-to-customer, customer-to-customer, customer-to-depot • evaluation: distance as fixed parameter, travel time as fixed parameter • constraints: arcs connecting two nodes must be part of the network	**NP-connection ("Node-2-Platoon")** • defined on $\mathcal{V} \times \mathcal{B}$ • allowed: depot-to-platoon, customer-to-platoon • evaluation: distance as variable, travel time as variable • constraints: platoon must be used and vehicle must be part of it
	platoon (P)	**PN-connection ("Platoon-2-Node")** • defined on $\mathcal{B} \times \mathcal{V}$ • allowed: platoon-to-customer, platoon-to-depot • evaluation: distance as variable, travel time as variable • constraints: platoon must be used and vehicle must be part of it	**PP-connection ("Platoon-2-Platoon")** • defined on $\mathcal{B} \times \mathcal{B}$ • allowed: platoon-to-platoon • evaluation: distance is 0, travel time is 0 • constraints: both platoons must be used and vehicle must be part of both platoons, last node in path of first platoon must coincide with first node in path of the following platoon

In order to manage the challenges associated with the variable platoon entry as well as exit nodes it is necessary to analyze possible node sequences in a combined vehicle route. Table 1 consolidates all four possible types of connections in a combined vehicle route. Furthermore, the table provides a rough characterization of the different connection types.

4. INTEGRATED ROUTING AND PLATOONING DECISION MODEL

This section presents a mixed-integer linear program (MILP) for the formal representation of the VRP-PF. This MILP is based on the construction of both platoons as well as combined vehicle routes in one model so that an integrated routing and coordination (platooning) decision task is defined. Table 2 summarizes all considered problem parameters.

Table 2 – Parameters

sets	$\mathcal{F}$	set of available vehicles to be routed
	$\mathcal{V}$	set of nodes in the network graph
	$\mathcal{V}^D$	set of depot nodes
	$\mathcal{V}^C$	set of customer nodes
	$\mathcal{V}^I$	set of infrastructure nodes
	$\mathcal{A}$	set of arcs in the network graph
	$\mathcal{A}^D$	set of direct arcs in the network graph
	$\mathcal{A}^S$	set of service arcs in the network graph
	$\mathcal{A}^I$	set of infrastructure arcs in the network graph
values	c_{ij}	costs (fuel consumption) for travelling with one vehicle along arc (i;j)
	t_{ij}	time for travelling with one vehicle along arc (i;j)
	N_p^{max}	number of available platoons
	CF_m	fuel consumption factor if platoon is formed by m vehicles
	$\mathcal{M}$	a large number
	DD_i	due date associated with customer node i
	T^{max}	maximal allowed trip duration
others	d_f^+	start depot of the trip of vehicle f
	d_f^-	termination depot of the trip of vehicle f
	$\mathcal{G}$	graph representing the road network
	$f(i;j)$	arc evaluation function of the graph representing the network
	$c(i;j)$	costs (fuel consumption) for travelling with one vehicle along arc (i;j)
	$t(i;j)$	time for travelling with one vehicle along arc (i;j)
	$FC(p)$	fuel consumption function applied to platoon p
	$dist(p)$	length of path of platoon p
	$fuel(w;m)$	function to determine the fuel consumption of m vehicles that travel together along the path w

Beside the decision variables to code vehicle routes in the graph as well as vehicle-specific schedule information we need to incorporate decision variables for the construction of platoons and for the scheduling of platoon starts. Furthermore, we need decision variables to couple platoons with the remaining vehicle routing and scheduling decisions. Table 3 lists all used decision variables.

Subsection 0 discusses the constraints needed to setup feasible vehicle platoons. Next, Subsection 0 presents all constraints required to guarantee that feasible combined vehicle routes are achieved. Route compilation constraints are subject of the statements in Subsection 0. Subsection 0 reports the objective function definition.

4.1 Platoon Formation Constraints

A platoon path contains only infrastructure arcs (2). Each platoon has at most one start node (3) and each platoon has at most one last node (4). A used platoon is used must have both a start as well as a terminal node but an unused platoon must neither have a start nor a terminal node (5). A node cannot be a terminal node and providing outbound-flow at the same time (6). Similarly, a node cannot be a start node and having inbound-flow (7). The path flow conservation for a platoon is ensured by

(8). Self-loops in a platoon path are not allowed (9). The travel distance associated with a platoon is calculated (10) as well as the duration to travel along the platoon's path (11). If and only if a start node is selected for a platoon then the "used"-indicator is activated (12).

Table 3 – Decision Variables

platoon formation	p_{ik}^{START}	binary	indicates if node i is the starting node of (the path in) platoon k
	p_{ik}^{STOP}	binary	indicates if node i is the final node of (the path in) platoon k
	p_{ijk}	binary	indicates if the arc (i;j) is included in the path of platoon k
	p_k^{used}	binary	Indicates if platoon k is used by at least one vehicle
	p_{fk}^{join}	binary	Indicates if vehicle f joins platoon k
	p_k^{dist}	cont., ≥ 0	travel distance within platoon k
	p_k^{travel}	cont., ≥ 0	time to travel through path of platoon k
	p_k^{ready}	cont., ≥ 0	start time of the platoon k
	$p_k^{complete}$	cont., ≥ 0	completion time of the platoon k
	p_k^{cost}	cont., ≥ 0	costs associated with the usage of platoon k
	λ_{kl}	binary	indicates is platoon k is used by exactly l vehicles
vehicle path construction	x_{ijf}^{NN}	binary	indicates if the vehicle f uses NN-connection between node i and node j
	x_{ipf}^{NP}	binary	indicates if vehicle f uses the NP-connection from node i to of platoon p
	x_{pjf}^{PN}	binary	indicates if vehicle f uses the PN-connection from the platoon p to node j
	x_{pqf}^{PP}	binary	indicates if the vehicle f follows platoon p immediately before platoon q
	CON_{pq}^{v}	binary	indicates if platoon p is coupled by platoon q so that node v is the terminating node of the path in p as well as the starting node in the path of the immediate successor platoon q
path evaluation	$cost_{ijf}^{NN}$	cont., ≥ 0	costs for travelling from node i to node j with vehicle f
	$cost_{ipf}^{NP}$	cont., ≥ 0	costs for travelling from node i to start node of platoon p with vehicle f
	$cost_{pif}^{PN}$	cont., ≥ 0	travel costs from terminal node of platoon p to the node i with vehicle f
scheduling decisions	$at_{kf}^{PLATOON}$	cont., ≥ 0	arrival time of vehicle f at platoon k
	$lt_{kf}^{PLATOON}$	cont., ≥ 0	leaving time of vehicle f from platoon k
	at_{if}^{NODE}	cont., ≥ 0	arrival time of vehicle f at node i
	lt_{if}^{NODE}	cont., ≥ 0	leaving time of vehicle f from node i

$$p_{ijk} = 0 \; \forall k \in \mathcal{B}, (i;j) \notin \mathcal{A}^l \tag{2}$$

$$\sum_{v \in \mathcal{V}} p_{vk}^{START} \leq 1 \; \forall \; k \in \mathcal{B} \tag{3}$$

$$\sum_{v \in \mathcal{V}} p_{vk}^{STOP} \leq 1 \; \forall \; k \in \mathcal{B} \tag{4}$$

$$\sum_{v \in \mathcal{V}} p_{vk}^{START} = \sum_{v \in \mathcal{V}} p_{vk}^{STOP} \; \forall \; k \in \mathcal{B} \tag{5}$$

$$p_{vk}^{STOP} + \sum_{i \in \mathcal{V}} p_{vik} \leq 1 \; \forall \; k \in \mathcal{B}, v \in \mathcal{V} \tag{6}$$

$$p_{vk}^{START} + \sum_{i \in \mathcal{V}} p_{ivk} \leq 1 \; \forall \; k \in \mathcal{B}, v \in \mathcal{V} \tag{7}$$

$$p_{vk}^{START} + \sum_{i \in \mathcal{V}} p_{ivk} = p_{vk}^{STOP} + \sum_{i \in \mathcal{V}} p_{vik} \; \forall \; k \in \mathcal{B}, v \in \mathcal{V} \tag{8}$$

$$p_{iik} = 0 \; \forall \; k \in \mathcal{B}, i \in \mathcal{V} \tag{9}$$

$$p_k^{dist} = \sum_{i \in \mathcal{V}} \sum_{i \in \mathcal{V}} p_{ijk} d_{ij} \; \forall \; k \in \mathcal{B} \tag{10}$$

$$p_k^{travel} = \sum_{i \in \mathcal{V}} \sum_{i \in \mathcal{V}} p_{ijk} t_{ij} \; \forall \; k \in \mathcal{B} \tag{11}$$

$$p_k^{used} = \sum_{v \in \mathcal{V}} p_{vk}^{START} \; \forall \; k \in \mathcal{B} \tag{12}$$

4.2 Construction of Combined Vehicle Routes

According to the characterization given in Table 1 we have the following set $\mathcal{C}^{NN}$ of node-2-node-connections at our disposal: $\mathcal{C}^{NN} \coloneqq \{(i,j) | (i,j) \in \mathcal{V}^D \times \mathcal{V}^D \vee (i,j) \in \mathcal{V}^D \times \mathcal{V}^C \vee (i,j) \in \mathcal{V}^C \times \mathcal{V}^D \vee (i,j) \in \mathcal{V}^C \times \mathcal{V}^C\}$. A vehicle originating from a depot or a customer node can enter a platoon P leading to the following NP-connection set $\mathcal{C}^{NP} \coloneqq \{(i;p) | i \in \mathcal{V}^D \cup \mathcal{V}^C \wedge p \in B\}$. A connection itself is not necessarily an arc in $\mathcal{G}$ but it can be represented by the arc connecting the corresponding two two nodes (here: I and the selected start node of a platoon).

A vehicle leaving a platoon P can go to a customer node or to its depot leading to the following PN-connection set $\mathcal{C}^{PN} \coloneqq \{(p;i) | p \in B \wedge i \in \mathcal{V}^D \cup \mathcal{V}^C\}$. Finally, a vehicle can use a connection between two platoons: $\mathcal{C}^{PP} \coloneqq \{(p;q) | p,q \in B\}$. Since the platoon formation is part of the decision task, the sets $\mathcal{C}^{PN}$ as well as $\mathcal{C}^{NP}$ and $\mathcal{C}^{PP}$ are not static and cannot be used for the formulation of constraints.

$$x_{iif}^{NN} = 0 \; \forall i \in \mathcal{V}^C, f \in \mathcal{F} \tag{13}$$

$$x_{qqf}^{PP} = 0 \; \forall q \in \mathcal{B}, f \in \mathcal{F} \tag{14}$$

We use the binary decision variable families x_{ijf}^{NN}, x_{ipf}^{NP}, x_{pjf}^{PN}, x_{pqf}^{PP} for the representation of the connection decisions. Self-loops on customer nodes are not allowed (13). Furthermore, self-loops originating from and terminating in the same platoon are also forbidden (14).

4.2.1 Blocking of NN-connections

$$x_{ijf}^{NN} = 0 \; \forall (i;j) \in \mathcal{A} \backslash \mathcal{C}^{NN}, f \in \mathcal{F} \tag{15}$$

All those arcs in the underlying network $\mathcal{G}$ that are not contained in $\mathcal{C}^{NN}$ cannot be deployed to connect two nodes (15).

4.2.2 Control of NP-connections

$$x_{ipf}^{NP} = 0 \; \forall i \in \mathcal{V}^I, p \in \mathcal{B}, f \in \mathcal{F} \tag{16}$$

$$x_{ikf}^{NP} \leq p_k^{used} \; \forall i \in \mathcal{V}^D \cup \mathcal{V}^C, k \in \mathcal{B}, f \in \mathcal{F} \tag{17}$$

$$\sum_{l \in \mathcal{B}} x_{lkf}^{PP} + \sum_{i \in \mathcal{V}^D \cup \mathcal{V}^C} x_{ikf}^{NP} = p_{fk}^{join} \; \forall \; k \in \mathcal{B}, f \in \mathcal{F} \tag{18}$$

Connections originating from an infrastructure node and terminating in a platoon are not-allowed (16). A connection starting at a depot or a customer node directing for a platoon can be used only if this platoon is used (17). If and only if a vehicle arrives from any node or other platoon to platoon k then this vehicle joins platoon k (18).

4.2.3 Blocking of non-compatible PN-connections

$$x_{pif}^{PN} = 0 \; \forall i \in \mathcal{V}^I, p \in \mathcal{B} \tag{19}$$

$$x_{kif}^{PN} \leq p_k^{used} \; \forall i \in \mathcal{V}^D \cup \mathcal{V}^C, k \in \mathcal{B}, f \in \mathcal{F} \tag{20}$$

PN-connections terminating in an infrastructure node are not allowed (19). A PN-connection can only be incorporated into a combined route if the platoon is used (20).

4.2.4 Blocking of non-compatible PP-connections

$$CON_{kl}^{v} \leq \frac{1}{2}\left(p_{vk}^{STOP} + p_{vl}^{START}\right) \forall k, l \in \mathcal{B}, v \in \mathcal{V} \tag{21}$$

$$x_{klf}^{PP} \leq \sum_{v \in \mathcal{V}} CON_{kl}^{v} \, \forall k, l \in \mathcal{B}, f \in \mathcal{F} \tag{22}$$

The two constraints (21)-(22) are used to avoid the concatenation of two platoons if the last node in the path of the earlier visited platoon is different from the start node of the path of the later visited platoon. Constraint (21) decides for each individual node if the two platoons can be connected via this node but (22) indicates if there is any node that allows two put the two platoons one after another in a combined vehicle route.

4.2.5 Route Building

$$\sum_{j \in \mathcal{V}} x_{d_f^+ jf}^{NN} + \sum_{p \in \mathcal{B}} x_{d_f^+ pf}^{NP} = 1 \forall \, f \in \mathcal{F} \tag{23}$$

$$\sum_{j \in \mathcal{V}} x_{jd_f^- f}^{NN} + \sum_{p \in \mathcal{B}} x_{pd_f^- f}^{PN} = 1 \forall \, f \in \mathcal{F} \tag{24}$$

$$\sum_{j \in \mathcal{V}} x_{jd_f^+ f}^{NN} + \sum_{p \in \mathcal{B}} x_{pd_f^+ f}^{PN} = 0 \forall \, f \in \mathcal{F} \tag{25}$$

$$\sum_{j \in \mathcal{V}} x_{d_f^- jf}^{NN} + \sum_{p \in \mathcal{B}} x_{d_f^- pf}^{PN} = 0 \forall \, f \in \mathcal{F} \tag{26}$$

Each vehicle has to go from its start depot either to another node or to a platoon (23). Furthermore, each vehicle has to end its combined route in its designated depot coming from another node or leaving from a platoon (24). No vehicle is allowed to travel towards a start depot node (25) and no vehicle can leave a terminating depot node (26).

$$\sum_{v \in \mathcal{V}} x_{vkf}^{NN} + \sum_{p \in \mathcal{B}} x_{pkf}^{PN} = \sum_{v \in \mathcal{V}} x_{kvf}^{NN} + \sum_{p \in \mathcal{B}} x_{kpf}^{NP} \; \forall \, k \in \mathcal{V} \setminus \mathcal{V}^{D}, f \in \mathcal{F} \tag{27}$$

$$\sum_{v \in \mathcal{V}} x_{vpf}^{NP} + \sum_{q \in \mathcal{B}} x_{qpf}^{PP} = \sum_{v \in \mathcal{V}} x_{pvf}^{PN} + \sum_{q \in \mathcal{B}} x_{pqf}^{PP} \; \forall \, p \in \mathcal{B}, f \in \mathcal{F} \tag{28}$$

If and only if a vehicle arrives at a non-depot node either from another node or from a platoon then this vehicle has to leave this node and must go either to another node or to a platoon (27). Similarly, each vehicle that visits a platoon either from another platoon or from a node has to leave this platoon by continuing its trip towards a node or another platoon (28).

$$\sum_{v \in \mathcal{V}} x_{vkf}^{NP} + \sum_{p \in \mathcal{B}} x_{pkf}^{PP} \leq 1 \; \forall \, k \in \mathcal{B}, f \in \mathcal{F} \tag{29}$$

$$\sum_{f \in \mathcal{F}} \sum_{v \in \mathcal{V}} x_{vif}^{NN} + \sum_{f \in \mathcal{F}} \sum_{p \in \mathcal{B}} x_{pif}^{PN} = 1 \; \forall \, i \in \mathcal{V}^{C} \tag{30}$$

A vehicle can participate in a platoon at most once (29). Every customer node has to be served once by exactly one vehicle (30).

4.3 Evaluation of Combined Vehicle Routes

Since the platoons specification is variable the determination of performance indicators like length, processing duration as well as fuel consumption requires the evaluation of the determined platoon

paths as well as the number of vehicles that joins a platoon. Additional constraints are needed to achieve this implicit platoon evaluation.

4.3.1 Determination of Platoon Fuel Consumption

$$\sum_{f \in \mathcal{F}} p_{fk}^{join} = \sum_{l=0}^{|\mathcal{F}|} l\lambda_{kl} \ \forall k \in \mathcal{B} \tag{31}$$

$$1 = \sum_{l=0}^{|\mathcal{F}|} \lambda_{kl} \ \forall k \in \mathcal{B} \tag{32}$$

$$CF_l \cdot p_k^{dist} \leq p_k^{cost} + (1 - \lambda_{kl}) \cdot \mathcal{M} \ \forall l = 0, \dots, |\mathcal{F}|, k \in \mathcal{B} \tag{33}$$

In order to determine the fuel consumption of a platoon we first determine the number of incorporated vehicles and set an indicator representing the number of vehicles participating in this platoon (31)-(32). The fuel consumption associated with this platoon for the given number of vehicles is bounded from below by the fuel consumption (33).

4.3.2 Determination of the Fuel Consumption as Costs for Travelled Connections

In contrast to the evaluation (i.e. distance calculation) of the costs associated with a vehicle route in a CVRP we cannot exploit given parameters like arc lengths in the VRP-PF. Therefore, the length of the arcs connecting customer as well as depots nodes with a platoon have to be "coded" in the model. We use the decision variables $cost_{ijf}^{NN}$, $cost_{ipf}^{NP}$ as well as $cost_{pif}^{PN}$ to store these costs. There are no costs associated with PP-connections since the last node in the paths of the first visited platoon coincides with the first node of the subsequently joined platoon.

$$cost_{ijf}^{NN} = x_{ijf}^{NN} \cdot d_{ij} \ \forall (i;j) \in \mathcal{C}^{NN}, f \in \mathcal{F} \tag{34}$$

$$\sum_{j \in \mathcal{V}} d_{ij} \cdot p_{jp}^{START} \leq cost_{ipf}^{NP} + \left(1 - x_{ipf}^{NP}\right) \cdot \mathcal{M} \ \forall i \in \mathcal{V}^D \cup \mathcal{V}^C, p \in \mathcal{B}, f \in \mathcal{F} \tag{35}$$

$$\sum_{j \in \mathcal{V}} d_{ji} \cdot p_{jp}^{STOP} \leq cost_{pif}^{PN} + \left(1 - x_{pif}^{PN}\right) \cdot \mathcal{M} \ \forall i \in \mathcal{V}^D \cup \mathcal{V}^C, p \in \mathcal{B}, f \in \mathcal{F} \tag{36}$$

The costs (here: fuel consumption) for used NN-connections are set to the arc length specified in the definition of $\mathcal{G}$ (34). Costs for NP-connections (PN-connections) are limited by a lower bound in case that a vehicle uses such a connection (35)-(36). These cost contributions are integrated into the objective function (minimization of the total travel costs) so that the minimal costs will be determined for NP- as well as PN-connections during the search for least fuel consuming combined vehicle routes covering the complete request portfolio represented by $\mathcal{V}^C$.

4.3.3 Vehicle Operation Scheduling

$$at_{d_f^+ f}^{NODE} = 0 \ \forall f \in \mathcal{F} \tag{37}$$

$$lt_{d_f^- f}^{NODE} \leq T^{max} \ \forall f \in \mathcal{F} \tag{38}$$

$$at_{if}^{NODE} \leq lt_{if}^{NODE} \ \forall i \in \mathcal{V}^D \cup \mathcal{V}^C, f \in \mathcal{F} \tag{39}$$

$$lt_{if}^{NODE} + t_{ij} \leq at_{jf}^{NODE} + \left(1 - x_{ijf}^{NN}\right) \cdot \mathcal{M} \ \forall i \in \mathcal{V}^D \cup \mathcal{V}^C, f \in \mathcal{F} \tag{40}$$

$$at_{if}^{NODE} \leq DD_i \ \forall i \in \mathcal{V}^C, f \in \mathcal{F} \tag{41}$$

All vehicle operations start at time 0 (37) and must be completed before the maximal allowed route duration is reached (38). The arrival of a vehicle at a node must precede its departure from there (39).

The travel time along a NN-connection is calculated recursively (40). The vehicle that serves a customer must not arrive later at the associated customer node than the agreed due date (41).

$$lt_{if}^{NODE} + cost_{ipf}^{NP} \leq at_{pf}^{PLATOON} + \left(1 - x_{ipf}^{NP}\right) \cdot \mathcal{M} \; \forall i \in \mathcal{V}^D \cup \mathcal{V}^C, p \in \mathcal{B}, f \in \mathcal{F} \tag{42}$$

$$lt_{pf}^{PLATOON} + cost_{pif}^{PN} \leq at_{if}^{NODE} + \left(1 - x_{pif}^{PN}\right) \cdot \mathcal{M} \; \forall i \in \mathcal{V}^D \cup \mathcal{V}^C, p \in \mathcal{B}, f \in \mathcal{F} \tag{43}$$

$$lt_{pf}^{PLATOON} \leq at_{qf}^{PLATOON} + \left(1 - x_{pqf}^{PP}\right) \cdot \mathcal{M} \; \forall \, p \in \mathcal{B}, f \in \mathcal{F} \tag{44}$$

$$at_{qf}^{PLATOON} \leq p_q^{ready} + \left(1 - p_{fq}^{join}\right) \cdot \mathcal{M} \; \forall \, q \in \mathcal{B}, f \in \mathcal{F} \tag{45}$$

$$lt_{qf}^{PLATOON} + \left(1 - p_{fq}^{join}\right) \cdot \mathcal{M} \geq p_q^{complete} \forall i \, q \in \mathcal{B}, f \in \mathcal{F} \tag{46}$$

$$at_q^{ready} + p_q^{travel} \leq p_q^{complete} \forall i \, q \in \mathcal{B} \tag{47}$$

Similar constraints are needed for the recursive arrival time calculation along a NP-connection (42) as well as a PN-connection (43) or a PP-connection (44). The platoon execution cannot start before all participating vehicles have arrived at its start node (45). A similar constraint is valid for the departure of a participating vehicle from the platoon's final node (46). Finally the platoon lasts at least as long as the vehicle group requires to travel through it (47).

4.4 Objective Function

$$Z = \sum_{k \in \mathcal{B}} p_k^{cost} + \sum_{(i;j) \epsilon \mathcal{C}^{NN}} \sum_{f \in \mathcal{F}} cost_{ijf}^{NN} + \sum_{i \in \mathcal{V}^D \cup \mathcal{V}^C} \sum_{p \in \mathcal{B}} \sum_{f \in \mathcal{F}} cost_{ipf}^{NP} + \sum_{p \in \mathcal{B}} \sum_{i \in \mathcal{V}^D \cup \mathcal{V}^C} \sum_{f \in \mathcal{F}} cost_{pjf}^{PN} \tag{48}$$

In contrast to vehicle routing problems without platoons we have to consider the scaling effect of a platoon w.r.t. to the fuel consumption. It is therefore not appropriate to just sum up fuel consumptions from all vehicles. Instead, it is necessary to sum up the fuel consumption of all platoons as well as the consumed fuel for all vehicles travelling along NN-, NP- as well as PN-connections (48). The first term on the right side of (48) represents the platoon-related fuel consumption, the second part refers to the direct arc fuel costs and the two remaining parts represent the quantities of fuel for travelling to or from a platoon. This sum must be as low as possible.

The mixed-integer linear program (3)-(48) represents the decision task associated with the VRP-PF.

5. SUMMARY AND CONCLUSIONS

We have identified a research gap in the context of LTL-vehicle operations and simultaneous platoon formation. To contribute to the closure of this gap we have proposed a complex mixed-integer linear program. It is based on the idea to define a vehicle platoon as a path in the network and to optimize these platoon-defining paths in parallel to the routes that represent the individual vehicle trips. Conditionally active constraints are used to integrate platoon-paths into vehicle routes and for the scheduling of vehicle activities. Furthermore, a degressive fuel consumption calculation scheme for the platoon-forming vehicles is integrated.

Our next research step will be to evaluate the proposed model for different parameterized test cases. Furthermore, we will investigate the incorporation of a more realistic capacity-based fuel consumption scheme as well as the usage of a heterogeneous fleet.

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ANALYSIS OF THE POSSIBLE CYCLE TIME SAVINGS ON TRAM LINE NO. 12 IN ZAGREB

ABSTRACT

This paper has explored the ideal and maximum positive cycle time scenario on tram line No. 12 in Zagreb, for simulating cycle time savings ΔT by reducing the total operating time on line T_o, both achieved by the possible implementation of tram priority via traffic lights based on the local automation. The application of the tram priority in urban areas by using the local automatic setting the points and signals for trams on the junctions can provide economic, traffic, safety as well as ergonomic benefits and improvements to some extent. The most important traffic benefit for passengers could be an increase in the operating speeds of trams in Zagreb. Very important traffic benefits for operator ZET in Zagreb could be an increase in the cycle speeds of trams in Zagreb, as well as increasing the gross transport work of a single line with the same number of trams and drivers in one shift. A possible realistic saving of the total operating time ΔT_o on line No. 12 in Zagreb is based on the assumption that all signals at the traffic lights for trams should be green due to tram priority via traffic lights. Measurements of the real operating time savings ΔT_o by using the stopwatch - pencil - record list method were conducted in the middle shift during the afternoon peak load with passengers, as well as in the early shift during the morning peak load with passengers, for all of the seven days in one week on line No. 12., and for the new tram NT 2200 which accounts for 51% of the ZET tram fleet.

KEY WORDS

tram priority; local automation; green traffic lights; cycle time savings; line No. 12;

1. INTRODUCTION

In the whole tramway network in Zagreb the tram speeds are limited to 50 km/h by electronic blockade from the tram. Limiting the trams speed to 50 km/h as well as possible measures to slow down the road traffic should reduce the statistical risk of traffic accidents in urban areas and reduce the consequences of traffic accidents if they occur. The survey results by Vaitkus, A. et al. have indicated a rather positive attitude of respondents to the speed management measures [1].

In reality, the average amounts of cycle speeds as well as operating (travel) speeds on all tram lines in Zagreb are much lower in relation to the border amount of 50 km/h. For example, the measurements conducted in Zagreb on tram line No. 17 [2] point out to a small average amount of cycle speed V_c*=13.15 km/h* as well as a small average amount of operating speed V_o*=15.06 km/h*. It should be noted that cycle speed on the tramway network in 2009 was 13 km/h [3].

This space between the border tram speed of 50 km/h and the real average amounts of operating (travel) speeds on tram lines in Zagreb is a big space for improvements with more simultaneous

economic, traffic, safety as well as ergonomic benefits to some extent, both for users of public transport and for the operator ZET.

For the purpose of simulating the cycle time savings ΔT on line No. 12 by reducing the total operating (travel) time on line T_o, a possible realistic saving of the total operating time ΔT_o in Zagreb was recorded (stopwatch - pencil - record list method). The measurements were implemented during the morning and afternoon peak loads with passengers, for all the days of the week including the weekend, and for the new tram NT 2200, on line No. 12 which is one of the four statistically most dangerous lines operated by the new tram NT 2200 [4].

One of the key parameters that determine the quality of the service offered to tram users is the operating (travel) time T_o [5]. For operators the most important cycle time on line T (min) is defined by Equation (1) where ΣT_o (min) is the total operating (travel) time on the line and Σt_t (min) is the total time at terminals, calculated for both directions:

$$T = \sum T_o + \sum t_t \tag{1}$$

The cycle time on line T (min) is defined by the basic Equation of the transport process (2) on the public transport line which connects the headway of vehicles on line h (min/veh) and the number of vehicles on line N.

$$T = h * N \tag{2}$$

Furthermore, from Equation (2) follows that if the same number of vehicles N are retained, and the cycle time on line T decreases, headway h (min/veh) must also be reduced.

The cycle time on line T can be reduced if the operating (travel) time on line T_o is reduced, in the way that all traffic lights are set to the green light for trams (the tram priority), assuming the real total time at terminals t_t.

The operating (travel) speed V_o (km/h) on the same line length $2L$ (km) will increase if the operating (travel) time on line T_o is reduced, which is defined by Equation (3).

$$V_o = 2L / T_o \tag{3}$$

Consequently, the cycle speed V_c (km/h) on the same line length $2L$ (km) will increase if the cycle time on line T is reduced, which is defined by Equation (4).

$$V_c = 2L / T \tag{4}$$

It will also result in an increase in the transport work of line w (sps·km/h) defined by Equation (5)

$$w = C * L \tag{5}$$

because it has increased the dynamic line capacity C (sps/h) defined by Equation (6).

$$C = C_v * f \tag{6}$$

Thus, with the same vehicle capacity C_v (sps/veh) and for the known number of standing and sitting places in the new tram NT 2200, and the same number of vehicles N on line No. 12 the frequency of vehicles on line f (veh/h) is higher because headway h (min/veh) is smaller.

The information on absolute savings of real operating time ΔT_o is expected, according to the assumption that all tram lights should be green due to tram priority via the traffic lights on open sections as well as on the stations which are equipped with traffic lights. The results of similar model research in which priority is given to trams and restricting other vehicles entering the "yellow line" confirm the increased cycle speed V_c as well as the increased dynamic capacity [6].

2. RESEARCH

Thus, with the aim of studying a real reduction of cycle time on line ΔT two-time scenarios have been compared in this paper, by using the same methodology of the previous research conducted on the tram line No. 17 [2]:

- the objectively measured scenario for line No. 12 (real cycle time on line T for both directions contains all stop times because of red signals at traffic lights for the tram while driving as well as at stations),
- ideal and maximum positive cycle scenario with the possible time savings ΔT of cycle time on line No. 12 in one cycle, based on the measurement of possible time savings ΔT_o of operating (travel) time on line No. 12 as the sum of the duration of all red signals at traffic lights while driving as well as differences between particular times of all red traffic signals at traffic lights at stations and the average amount of all green traffic signals at traffic lights at stations.

Table 1 shows objective individual and average amounts of the total operating (travel) times T_o, total cycle times on line T, operating speeds V_o and cycle speeds V_c, all on line No. 12, for both directions, which represents the first (real and measured) scenario for line No. 12.

Table 2 shows the reduced amounts of total operating (travel) times T_{or} and total cycle times T_r (which include average amount of the real times at terminal t_t from the first real scenario), as well as increased operating speeds V_{oi} and cycle speeds V_{ci}, all on line No. 12, for both directions, which represents the second ideal and maximum positive cycle scenario for line No. 12.

Possible savings of operating (travel) times $\Delta T_o'$ and $\Delta T_o''$ in one direction can be realized by omitting the following times:

- $\sum T_{otl}'$ and $\sum T_{otl}''$ from Table 2 which represent the total times of all red traffic signals at traffic lights in one direction on open sections while driving
- $\sum T_{oss}'$ and $\sum T_{oss}''$ from Table 2 which represent the sum of differences between particular times of all red traffic signals at traffic lights at stations and the average amount of all green traffic signals at traffic lights at stations in one direction (only for all stations which are equipped with traffic lights and only for red traffic signals at traffic lights).

It should be noted that the tram driving path can be usually set:

- manually by setting the points outside of vehicle (with a hand tool),
- manually by setting the points by serving the electrically operated switches from the tram cab,
- by local automation,
- by remote control from one point (centre).

The application of the tram priority in urban areas based on the local automatic setting the points on the junctions will result in the most important ergonomic and safety benefits for tram drivers: reduction of tram driver's workload (by reducing the number of the manually served commands on the control panel connected with the change of direction at junctions) as well as the increase of tram driver's performance level.

Possible savings of cycle times ΔT and operating times ΔT_o as well as possible increase of operating speeds ΔV_o and cycle speeds ΔV_c on line No. 12 are shown in Table 3; these are total amounts for both directions.

Table 1 – Objective operating (travel) times T_o and objective cycle times T as well as objective operating speeds V_o and objective cycle speeds V_c on line No. 12

Day in the week	Date	Driving code	Ljubljanica – Dubrava direction					Dubrava – Ljubljanica direction					T_o	T	V_o	V_c
			1	2	3	t_t''	T_o''	6	4	5	t_t'	T_o'				
			Start of retention time	Time of departure from terminal Dubrava	Time of arrival at terminal Ljubljanica	2-1 (min)	3-2 (min)	Start of retention time	Time of departure from terminal Ljubljanica	Time of arrival at terminal Dubrava	4-6 (min)	5-4 (min)	(min)	(min)	(km /h)	(km /h)
Fri	April 6	B	14:00	14:05	14:43	5	38	13:05	13:11	14:00	6	49	87	98	12.88	11.44
Sat	April 7	C	08:20	08:31	09:09	11	38	09:09	09:21	09:57	12	36	74	97	15.15	11.56
Sat	April 7	D	13:58	14:04	14:48	6	44	13:12	13:14	13:57	2	43	87	95	12.88	11.80
Sun	April 8	E	06:50	07:08	07:38	18	30	06:07	06:21	06:50	14	29	59	91	19.00	12.32
Sun	April 8	F	13:38	13:44	14:21	6	37	14:21	14:28	15:01	7	33	70	83	16.01	13.51
Mon	April 9	G	08:09	08:13	08:54	4	41	07:16	07:24	08:09	7	45	86	97	13.03	11.56
Mon	April 9	H	14:15	14:20	15:01	5	41	13:30	13:32	14:14	2	42	83	90	13.51	12.45
Tue	April 10	I	08:14	08:20	09:03	6	43	07:25	07:35	08:14	10	39	82	98	13.67	11.44
Tue	April 10	J	15:05	15:14	15:52	9	38	15:48	15:54	16:38	6	44	82	97	13.67	11.56
Wed	April 11	K	08:04	08:11	09:00	7	49	07:18	07:25	08:04	7	39	88	102	12.74	10.99
Wed	April 11	L	14:15	14:20	14:59	5	39	13:24	13:28	14.14	4	46	85	94	13.19	11.92
Thu	April 12	M	06:51	06:56	07:28	5	32	07:30	07:33	08:13	3	40	72	80	15.57	14.01
Thu	April 12	N	13:53	14:00	14:41	7	41	14:41	14:47	15:25	6	38	79	92	14.19	12.18
Fri	April 13	NJ	07:47	07:50	08:35	3	45	07:00	07:02	07:40	2	38	83	88	13.51	12.74
Fri	April 13	O	15:23	15:27	16:04	4	37	14:37	14:41	15:17	4	36	73	81	15.36	13.84
					Average amounts:	6.73		39.60		Average amounts:		6.13	37.80	79.33	92.20	14.29

12.22

Table 2 – Reduced operating (travel) times T_{or} and reduced cycle times T_r on line No. 12

Day in the week	Date	Vehicle number	Driving code	Ljubljanica – Dubrava direction					Dubrava – Ljubljanica direction					T_{or}	T_r	V_{oi}	V_{ci}
				1	2	3	1-(2+3)		4	5	6	4-(5+6)					
				T_o'' (min)	$\sum T_{otl}''$ (sec)	$\sum T_{oss}''$ (sec)	T_{or}'' (sec)	t_t'' (min)	T_o' (min)	$\sum T_{otl}'$ (sec)	$\sum T_{oss}'$ (sec)	T_{or}' (sec)	t_t' (min)	(min)	(min)	(km /h)	(km /h)
Fri	April 6	2268	B	38	132	169	1979	5	49	230	100	2610	6	76.48	87.48	14.66	12.81
Sat	April 7	2284	C	38	183	101	1997	11	36	153	37	1970	12	66.12	89.12	16.75	12.58
Sat	April 7	2218	D	44	358	118	2164	6	43	174	122	2284	2	74.13	82.13	15.12	13.65
Sun	April 8	2250	E	30	128	108	1564	18	29	70	104	1566	14	52.17	84.17	21.49	13.32
Sun	April 8	2248	F	37	167	45	2008	6	33	61	80	1839	7	64.12	77.12	17.48	14.56
Mon	April 9	2296	G	41	365	128	1967	4	45	250	96	2354	7	72.02	83.02	15.56	13.50
Mon	April 9	2218	H	41	241	108	2111	5	42	78	104	2338	2	74.15	81.15	15.12	13.81
Tue	April 10	2274	I	43	276	112	2192	6	39	56	35	2249	10	74.02	90.02	15.14	12.45
Tue	April 10	2252	J	38	207	51	2022	9	44	310	61	2269	6	71.52	86.52	15.67	12.96
Wed	April 11	22120	K	49	273	96	2571	7	39	177	35	2128	7	78.32	92.32	14.31	12.14
Wed	April 11	2282	L	39	155	114	2071	5	46	199	121	2440	4	75.18	84.18	14.91	13.32
Thu	April 12	2234	M	32	214	57	1649	5	40	241	52	2107	3	62.60	70.60	17.91	15.88
Thu	April 12	2266	N	41	266	119	2075	7	38	101	99	2080	6	69.20	82.25	16.19	13.63
Fri	April 13	2288	NJ	45	280	110	2310	3	38	147	141	1992	2	71.70	76.70	15.63	14.61
Fri	April 13	2206	O	37	165	46	2009	4	36	154	34	1972	4	66.35	74.35	16.89	15.08
Average amounts:				39.53	227.33	98.80	2045.93	6.73	39.80	160.07	81.40	2146.53	6.13	69.87	82.74	16.20	13.62

Table 3 – Possible savings of cycle times ΔT and operating times ΔT_o as well as possible increase of the cycle speeds ΔV_c and operating speeds ΔV_o on line No. 12

Day in the week	Date	Vehicle number	Driving code	T_o	T_{or}	ΔT_o	T	T_r	ΔT	V_o	V_{oi}	ΔV_o	V_c	V_{ci}	ΔV_c
				(min)	(min)	%	(min)	(min)	%	(km /h)	(km /h)	%	(km /h)	(km /h)	%
Fri	April 6	2268	B	87	76.48	-13.76	98	87.48	-12.03	12.88	14.66	+12.14	11.44	12.81	+10.69
Sat	April 7	2284	C	74	66.12	-11.92	97	89.12	-8.84	15.15	16.75	+9.55	11.56	12.58	+8.11
Sat	April 7	2218	D	87	74.13	-17.36	95	82.13	-15.67	12.88	15.12	+14.81	11.80	13.65	+13.55
Sun	April 8	2250	E	59	52.17	-13.09	91	84.17	-8.11	19.00	21.49	+11.59	12.32	13.32	+7.51
Sun	April 8	2248	F	70	64.12	-9.17	83	77.12	-7.62	16.01	17.48	+8.41	13.51	14.56	+7.21
Mon	April 9	2296	G	86	72.02	-19.41	97	83.02	-16.84	13.03	15.56	+16.26	11.56	13.50	+14.37
Mon	April 9	2218	H	83	74.15	-11.94	90	81.15	-10.91	13.51	15.12	+10.65	12.45	13.81	+9.85
Tue	April 10	2274	I	82	74.02	-10.78	98	90.02	-8.86	13.67	15.14	+9.71	11.44	12.45	+8.11
Tue	April 10	2252	J	82	71.52	-14.65	97	86.52	-12.11	13.67	15.67	+12.76	11.56	12.96	+10.80
Wed	April 11	22120	K	88	78.32	-12.36	102	92.32	-10.49	12.74	14.31	+10.97	10.99	12.14	+9.47
Wed	April 11	2282	L	85	75.18	-13.06	94	84.18	-11.67	13.19	14.91	+11.54	11.92	13.32	+10.51
Thu	April 12	2234	M	72	62.60	-15.02	80	70.60	-13.31	15.57	17.91	+13.07	14.01	15.88	+11.78
Thu	April 12	2266	N	79	69.20	-14.16	92	82.25	-11.85	14.19	16.19	+12.35	12.18	13.63	+10.64
Fri	April 13	2288	NJ	83	71.70	-15.76	88	76.70	-14.73	13.51	15.63	+13.56	12.74	14.61	+12.80
Fri	April 13	2206	O	73	66.35	-10.02	81	74.35	-8.94	15.36	16.89	+9.06	13.84	15.08	+8.22
Average amounts:				79.33	69.87	-13.50	92.20	82.74	-11.47	14.29	16.20	+11.76	12.22	13.62	+10.24

Average amounts of results from Table 3 point to the possibility for the cycle time savings $\Delta T = -11.47\%$ as well as the possibility for the operating time savings $\Delta T_o = -13.50\%$, during the morning and afternoon peak loads with passengers, for all days of the week including the weekend (Saturday and Sunday).

Possible increase of the individual and average amounts of cycle speeds ΔV_c as well as possible increases of the individual and average amounts of operating speeds ΔV_o on line No. 12 are also shown in Table 3; these are the total amounts for both directions in one cycle.

Table 4 - Comparison of possible savings of cycle times ΔT and operating times ΔT_o on lines No. 17 and No. 12

	T_o	T_{or}	ΔT_o	T	T_r	ΔT
	(min)	(min)	%	(min)	(min)	%
Average amounts for tram line No. 12:	79.33	69.87	-13.50	92.2	82.74	-11.47
Average amounts for tram line No. 17:	101.7	84.59	-20.20	116.2	99.09	-17.35

Source: Supplemented and taken from Sumpor et al. [2]

Table 5 - Comparison of possible increases of the cycle speeds ΔV_c and operating speeds ΔV_o on lines No. 17 and No. 12

	V_o	V_{oi}	ΔV_o	V_c	V_{ci}	ΔV_c
	(km/h)	(km/h)	%	(km/h)	(km/h)	%
Average amounts for tram line No. 12:	14.29	16.20	+11.76	12.22	13.62	+10.24
Average amounts for tram line No. 17:	15.06	18.09	+16.77	13.15	15.42	+14.69

Source: Supplemented and taken from Sumpor et al. [2]

It is obvious that the final results shown in Table 4 and Table 5 compared for tram lines No. 12 and No. 17 are different in relation to each other. It should be noted that the total length of line No. 12 in both directions (Dubrava – Ljubljanica, Ljubljanica – Dubrava) is *2L = 18,682 m* in relation to the total length of line No. 17 in both directions (Borongaj – Prečko, Prečko – Borongaj) which is *2L = 25,536 m* [7]; therefore tram line No. 17 is longer. Afterwards, the differences in results shown in Table 4 and Table 5 are related to the different real traffic situations on the lines and different real state of the infrastructure on the lines, as well as because of the fact that tram lines No. 17 and No. 12 have different number of traffic lights, different number of stations as well as different number of intersections along the route of the line.

Most researchers from different areas (economists, engineers, ergonomists) who explore the possible benefits of the application of public transport priority in the city network share similar attitudes. In the City of Zagreb, public transport attractiveness is possible to improve significantly by raising the quality of service. In the current network state, the operating speed increase related to the quality of service could bring significant passenger travel time reduction, and this can be done by introducing public transport priority in the network [8].

3. CONCLUSION

Results for tram line No. 12 in this paper as well as the results of the previously conducted research on tram line No. 17 have proven the possibility of significant simulating cycle time savings ΔT by reducing the operating time ΔT_o, both achieved by the possible implementation of tram priority via green traffic signals at traffic lights based on the local automation. Based on the proved cycle time savings ΔT realized by the operating time savings ΔT_o on line No. 12, the average amount of the increased cycle speed $V_{ci} = 13.62$ *km/h* which contains a speed increase of 10.24% as well as the average amount of increased operating speed $V_{oi} = 16.20$ *km/h* which contains speed increase of 11.76%, indicate the need for further research of potential increase of cycle speed and operating speed on other tram lines in Zagreb for the purpose of achieving the results for the whole tramway network, because the above mentioned results for the tram line No. 12 are different in relations to the results of previous research conducted on tram line No. 17.

The application of the tram priority in urban areas by using the local automatic setting of the points and signals for trams at junctions can provide the following ergonomic and safety benefits to some extent: reduction of tram driver's workload by reducing the number of the manually served commands on the control panel connected with the change of direction at junctions as well as increase of tram driver's performance level.

For a final study conclusion for the whole tramway network in Zagreb and the final results of the larger scale research, the results for line No. 12 which are published in this paper will be compared with the possible cycle time savings by reducing the total operating time on other tram lines in Zagreb. It is necessary due to different real traffic situations on lines and different real state of the infrastructure on the lines, as well as because of tram lines in Zagreb having different lengths, with different number of traffic lights, with different number of stations as well as with different number of intersections along the route of the line. Because of the above mentioned reasons the final results of a larger scale research should not be limited only to tram lines No.12 and No.17. in the entire tramway network in Zagreb.

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PROSPECTS FOR THE DEVELOPMENT OF INTERMODAL TRANSPORT IN POLAND

ABSTRACT

Intermodal transport is a popular mode of freight transportation over long distances. One of elements in the intermodal transport chain are freight handling points. Throughput and reliability of operation in the container terminals affect the processes of freight handling in intermodal transport. Interest in intermodal transport is still growing. In Poland the point and line infrastructure expands, also new terminals. The article analyses the market in Europe and in the world. The aim of the article is analyse intermodal transport growth trend at last years, as well as intermodal transport forecast to 2025 in Poland.

KEY WORDS

intermodal transport forecast; container terminal market; inland terminal;

1. INTRODUCTION

Intermodal transport is becoming more and more popular. The author at work [2] defines this transport as the transport of persons or loads from the place of order to the place of destination, using at least two different transport modes. In the case of goods moving, intermodal transport gives the possibility of using integrated loading units, i.e. container, swap body or semi-trailer. In that, it is possible to transport loads over long distances without interfering with the cargo itself. This is done with the use of point infrastructure, which includes seaports and inland terminals as well as appropriate transshipment facilities.

In recent years, the topic of intermodal transport has been increasingly discussed in the literature. In [4] the author discusses the subject of optimization in distribution subsystems. In turn in the work [1] the author describes in detail the implementation of cargo handling in the sea-land chain. The work shows the division of activities performed in a seaport into three groups, i.e. main, complementary and auxiliary. In the paper [6] the situation of seaports in Poland is described. The author draws attention to the equipment of port terminals as well as the operation of the operating system in port container terminals. In work [5] attention was paid to the efficiency of terminal operation. Papers [7,8] present the method of scheduling operations at the inland terminal in the wagon-yard relation. In [9,10], the authors pointed out to the characteristics of the intermodal market in Poland.

The efficiency and dependability of intermodal transport depends on the availability of point infrastructure. Point infrastructure includes: inland terminals, seaports, and depot network. In the lack of development of this infrastructure, intermodal transport will lose interest, will be less economical, will be more undependable and cost-ineffective. The purpose of this article is to present the dynamics of the development of intermodal transport in Poland. The article also forecasts container transport until 2025 in Poland.

The number of transported integrated cargo units in the world and Europe is increasing each year. Reason is a simply, development of new technologies as well as competitive prices compared to other modes of transport. The characteristics of the intermodal market in ports in northern Europe is shown in *Figure 1*.

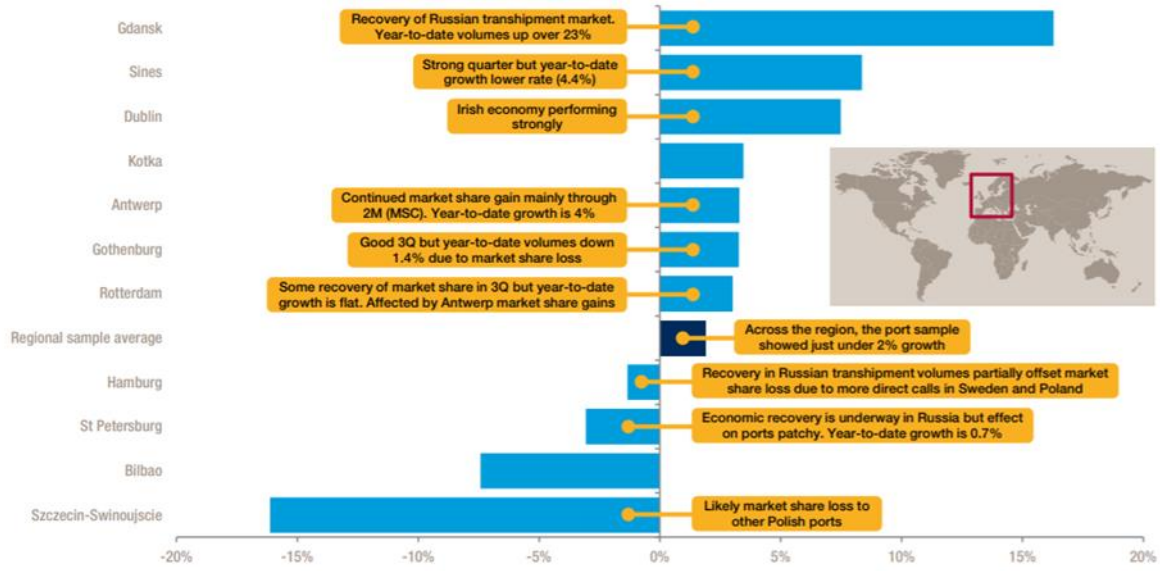


Figure 1 – The dynamics of port development in northern Europe. Comparison of the 3rd quarter of 2016 to the 3rd quarter of 2015. Own work based on [11]

In the port of Gdańsk there was an increase in cargo handling, which was supported by the recovery of the Russian market. The recovery of the volume of transshipment in Russia has partly compensated for the loss of market share due to more direct connections in Sweden and Poland. Decrease cargo handling in transport in the Szczecin-Świnoujście port complex was most probably caused by the relocation of reloading to other ports in Poland. When analyzing the situation of port development in northern Europe, most of them have a rising trend. If, in one quarter, the loss in cargo handling was included, then in relation to the whole year, an increase was noted up to the previous year. The largest ports in Europe operation in 2017 vs. 2007 is presented in *Table 1.*

Table 1 – Ranking of the largest ports in Europe

Rank 2017	Rank 2016	Rank 2007	Port	2017 kTEU	Growth 2016/2017	Growth 2007/2017
1	1	1	Rotterdam (NL)	13735	10,90%	27,30%
2	2	3	Antwerp (BE)	10451	4,10%	27,80%
3	3	2	Hamburg (DE)	8820	-1,00%	-10,80%
4	4	4	Bremerhaven (DE)	5537	0,90%	13,20%
5	6	8	Valencia(ES)	4832	2,10%	58,80%
6	5	6	Algeciras (ES)	4381	-8,00%	28,10%
7	8	-	Piaeus (GR)	4060	10,50%	195,70%
8	7	7	Felixstowe (UK)	3810	-5,10%	14%
9	9	12	Marsaxlokk (MT)	3150	2,30%	65,80%
10	13	10	Barcelona (ES)	2969	32,70%	13,70%
11	11	9	Le Harve (FR)	2884	14,50%	9,30%
12	12	14	Genoa (IT)	2638	14,80%	42,20%
13	10	5	Gioia Tauro (IT)	2449	-12,40%	-28,90%
14	14	13	Southampton (UK)	2035	-0,10%	8,90%
15	15	-	Sines (PT)	1669	10,30%	1012,70%

Source: [17]

The situation of the development of seaports is unchanged for a few years. From 2007 to 2017, the largest number of goods was transshipped at the port of Rotterdam (13 375 TEU). On the following places are the port of Antwerp (10451) and Hamburg (8820 TEU), while the last place is the port of Sines in Portugal (1669 TEU). The most losses are made in port in Hamburg (almost 11%) and port in Italy Gioia Tauro (almost 29 %). The remaining ports are dynamically developing, which means that the cargo handling is still increased. The biggest increase had been by the port in Greece (Piaeus) and the port in Portugal (Sines).

The statistics presented in *Table 1* shows the largest ports in Europe, while *Figure 2* presents statistics on the number of transshipments in each country in Europe.

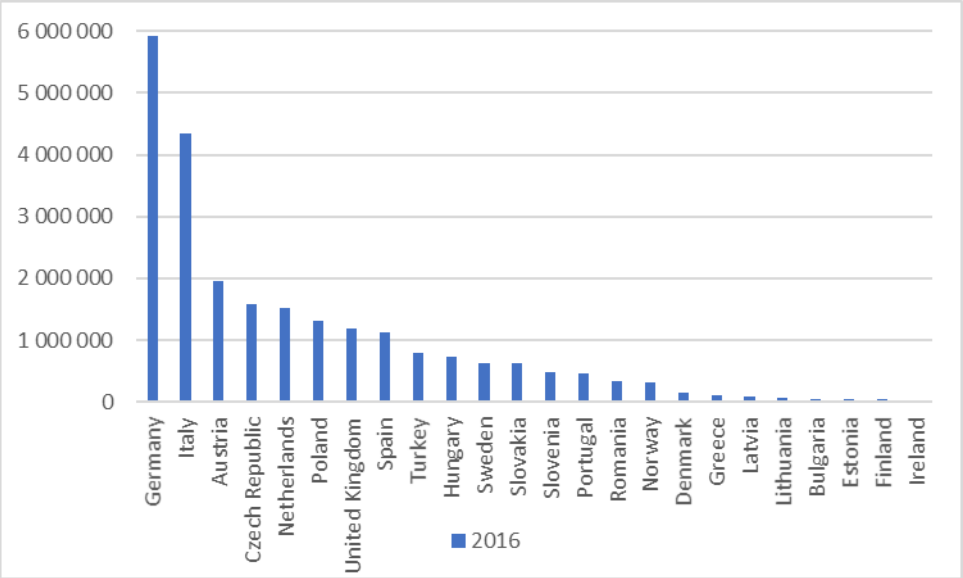


Figure 2 – Annual number of empty and loaded intermodal transport units carried on railways in 2016.
Source: Own work based on [14]

Germany is at the first place in operating nearly 6 mln TEU, the second is Italy with over 4 mln TEU operated, the third the Austria around 2 mln TEU. In this statistic Poland is in 6th place, while at the last places are Estonia, Finland and Ireland.

2. THE GROWTH TREND IN POLAND

Three groups of container operators can be distinguished in intermodal transport [3]:

1 maritime shipping companies - so-called sister companies; enterprises invest in port terminal facilities to support their business in shipping. In many cases, there is a structure in which a separate business unit or sister companies operating in shipping are separated or as operators. The terminal facilities can be operated on a single-user dedicated base or alternatively also be open to third shipping lines. For example, in this way APM Terminals was created, which is the largest enterprise in shipping and is the sister of the Maersk Line company,

2 stevedores - port terminal operators who deal with the unloading and loading of ships and the placement of cargo on ships; their knowledge leads to the development of new markets and increase of income,

3 financial holdings - includes various financial interests ranging from investment banks, by the port terminal sector as an asset class and for revenue generation potential.

There are several rail operators operating in Poland who provide transport services of integrated cargo units. *Table 2* presents list of rail operators in 2013-2016.

Table 2 – Rail operators in Poland

Container transport rail operators				
	2013	2014	2015	2016
PKP Cargo	56,34%	47,19%	44,95%	43,81 %
Lotos Kolej	15,06%	19,37%	23,92%	17,06 %
DB Cargo Polska	17,85%	21,04%	19,42%	18,57 %
Freightliner	-	2,40%	5,49%	5,10%
Ecco Rail	0,56%	2,18%	2,13%	3,56 %
PKP LHS	1,38%	2,06%	1,75%	2,23%
CTL Logistics	6,42%	4,82%	0,93%	0,71%

Source: [13]

In *Table 2* the rail operators which in 2016 do not carry out any intermodal transport and have had insignificant part of intermodal transport, they have been lost. PKP Cargo has the largest share - it is almost half of all transports, its strong position on the market has been going on for several years, however, the number of its services has been decreasing slightly over the past three years, dropping by around 13% in three years. The next places are Lotos Kolej and DB Schenker Rail Polska, each of them has approx. 18% of transport on the market. The remaining 20% is attributable to several smaller rail operators. In *Table 3* presents statistics on intermodal transport in 2010-2017.

Table 3 – Intermodal transport in 2010-2017 in Poland

Number of TEUs of intermodal transport						
	I quarter	II quarter	III quarter	IV quarter	Total	Change to the previous year [%]
2017	393 702	406 479	416 855	448 143	1 665 179	15,93
2016	309470	342802	368887	415169	1 436 328	24,71
2015	284 399	263 020	281 173	323 161	1 151 753	3,37
2014	279 975	282 886	272 040	279 272	1 114 173	-0,82
2013	266 867	280 848	285 273	290 373	1 123 361	7,30
2012	254 976	264 317	255 742	271 947	1 046 982	31,12
2011	164 763	182 247	208 876	242 598	798 484	36,82
2010	132 412	152 255	152 588	146 368	583 623	-

Source: [13]

Table 3 presents data of intermodal transport in 4 quarters in 2010-2017. Considering the analysed period, the record year of container transport was 2017, in total over 1.6 million TEU were transported. The number of units being transported increases year by year. Only in 2014 there was a slight decrease of 0.82% compared to the previous year (2013). The increase in transport from 2010 to 2017 is 285.32%.

The volume of container transport yearly increase, in addition the network of container terminals is also expanding, and existing ones are further developed in Poland. *Figure 3* presents the current map of inland terminals in Poland. From the map on *Figure 3* it can be read that the most terminals are located around Warsaw, Poznań and Gliwice. Less inland terminals are in the east of the country, which is due to a smaller number of industrial plants compared to the western part of the country.



Figure 3 – Map of inland terminals.
Source: [13]

The largest terminals are in the ports of Gdańsk and Gdynia. The key operators in Poland are: PCC Intermodal (4 inland terminals), Loconi (4 inland terminals), Polzug (4 inland terminals) and PKP Cargo Connect (3 inland terminals). One of the bigger container terminals, which is an example of adapting to the changing market situation is the Schavemaker inland terminal in Kąty Wrocławskie. This terminal has a good connection with ports and different companies. In 2015, the extension of the terminal and the purchase of modern equipment was completed, and the next extension is planned for July 2018.

3. VISION OF THE FUTURE

The intermodal transport market has experienced growth in recent years. The 2008-2010 crisis years and losses from this period are finished. Therefore, it is possible to consider what popularity intermodal transport will enjoy in the next years.

As we know, intermodal transport is essentially different from standard rail transport in the subject of transshipments. In intermodal transport, these products are highly processed, characteristic of developing countries that record GDP growth. Therefore, it seems to the authors that it is right to relate the forecast of intermodal transport to changes related to GDP.

In *Table 4* the changes in GDP in Poland in recent years and the number of transported TEUs are presented. Taking the year 2010 as a starting point, it can be noted that by 2015, GDP increased by almost 16%, while intermodal transport almost doubled. According to the World Bank estimate (2011) and PwC analyzes, the average value of GDP in Poland by 2030 will be 2.3% to reach this year - from today's perspective a small, just 1.1%. Hence, in forecasting the needs for intermodal transport, it was assumed that by 2020. GDP growth will be higher than the mentioned 1.1% and will amount to approx. 3%.

Table 4 – Change in GDP and number of transported TEU in relation to 2010

Year	GDP %	Absolute GDP change	TEU	Growth TEU %
2010	3,8	100,00	583 623	100
2011	4,3	104,30	798 484	136,82
2012	2	106,3	1 046 982	179,39
2013	1,6	107,9	1 123 361	192,48
2014	3,3	111,2	1 114 173	190,91
2015	3,7	114,9	1 151 753	197,35
2016	3,8	118,7	1 436 328	246,11
2017	4,6	123,3	1 665 179	285,32

Source: Own work based on [13]

In *Table 5* the forecasts for intermodal transport in 2020 and 2025 were established, using linear regression, where on the base calculation, parameters are: α = 22.571 and β = 89.48.

Table 5 – Forecasting the number of TEUs in relation to 2010

Year	Forecast %	TEU
2010	100	583 623
2020	337,76	1 971 245
2022	382,90	2 234 709
2024	428,05	2 498 169
2025	450,62	2 629 898

Source: Own work

The increase in intermodal transport from 2010 can be interpreted as a year of catching up after years of crisis. The results of forecasts in 2020 indicate an increase in freight transport by 337.76% compared to 2010, which will give a transport of 1.9 million TEU. In 2025 growth is to up to 450%, which will cause increase transport to 2.6 million TEU.

The growth of the intermodal market causes the need to adapt both the line and point infrastructure. Regarding the point infrastructure, some activities can already be observed among inland terminal operators aimed at adapting the transhipment and storage capacities to the market requirements that will soon follow.

4. EXAMPLE OF ADAPTING THE CONTAINER TERMINAL TO MODERN OPERATIONAL NEEDS

The Schavemaker Group started its operations in Poland in 2004 and in the same year also acquired investment land in Kąty Wrocławskie, which is a commune friendly to investors and very well managed. This area has a very good location, directly next to the A4 motorway, and there are two economic zones.

This inland terminal offers comprehensive service of containers trains as well as road transport of containers to the destination of unloading / loading goods. The main clients are shipowners, railway operators who organize sea and inland container transport. The operating policy of Schavemaker Invest gives the sender / recipient the opportunity to decide whether a given load should be transported by road or rail transport.

In *Table 6* basic data about the Schavemaker Invest container terminal are presented, while *Figure 4* shows a view of the railway siding.

Table 6 – Characteristic of inland terminal – Schavemaker Invest

Parameters	
Area [m^2]	50 000
Tracks [rm]	800
Storage capacity [TEU]	3000
Cargo-handling equipment	**Lifting capacities [t]**
Kalmar DRG 450-75C5XS	45
Kalmar DRF 450-75C5XS	45
Kalmar DRS 4527	45
Konecranes SMV 4531TB5	45
Rubber tyred gantry crane Kalmar	45
Forklift trucks 2 pc.	16
Trucks 30 pc.	-

Source: [15]

The Schavemaker Invest inland terminal in Kąty Wrocławskie has an area of 50,000 m2, this is one of the biggest terminal in Poland. In 2018 is also planned further his extension. Storage capacity is estimated at 3000 TEU. *Table 6* contains a detailed list of cargo-handling equipment available on the terminal. This inland terminal has additional advantage, which is the rubber tyred gantry crane, more often appeared at ports. *Figure 4* shows the view of the railway siding with a storage yard.



Figure 4 – Railway siding of the Schavemaker Invest inland terminal in Kąty Wrocławskie
Source: [15]

Figure 4 presents 2 railway tracks, each have 400m. An interesting solution that has been applied at this reloading point is the varied height of both tracks. Track 2 further from yard field is higher by 40 cm, this solution has enabled better visibility for the operator, and reduced the time of carrying out reloading operations. *Figure 5* presents the reloading devices during operation.



Figure 5 – Equipment of the Schavemaker Invest
Source: [15]

4.1 Development Plan of Inland Terminal

The inland terminal (Schavemaker Invest) is part of the existing multimodal infrastructure on the AGTC (European Agreement on Important International Combined Transport Lines and Related Installations) network and on the TEN-T (Trans-European Transport Networks) railway goods network. Expansion of the terminal will contribute to increasing the level of transport integration of the Wrocław agglomeration with the European transport network TEN-T.

The investment development will concern:

- increasing the length of railway tracks on the terminal to 2 x 600m - increasing the number of train reloading,
- extension of the storage yard by approx. 1 ha - increase of the container storage area,
- modernization of entry to the terminal - improvement of the process of servicing trucks transporting containers,
- purchase of additional equipment- reachstackers and rubber tyred gantry crane.

Achieving detailed objectives will affect the implementation of the main objective of the project, i.e. it will contribute to increasing the inland terminal's reloading capacity.

As a result of the project, the maximum annual terminal transshipment capacity will increase. This will directly contribute to increasing the level of competitiveness of rail transport (it will also indirectly affect the competitiveness of multimodal transport). As a result, the volume of cargo transported by goods of intermodal transport will increase, and thus the use of an environmentally friendly transport system will increase in freight transport.

The implementation of a larger number of transports by means of rail transport will result in a reduction in the number of transports of goods made using trucks. Because of moving a significant number of transports from the road network to the railway network, the traffic of trucks transporting goods will be reduced. The implementation of the project will therefore contribute to the reduction of road traffic, and thus indirectly will also have an impact on the improvement of road traffic safety - including reduce the number of accidents, as well as to increasing the dependability of intermodal transport.

5. CONCLUSION

In the case of the number of intermodal transport operations in the best ports in the world, an increase is recorded every year by several percent. In Europe, the Russian market has significantly recovered in recent years, which has positively influenced the increase in the number of supported intermodal units. The port in Rotterdam, Antwerp and Hamburg has been the leading ports in Europe, unchanged for several years. Germany and Italy, in turn, are at the top of ranking in intermodal transport in Europe. Poland is ranked 6th place, but taking into account the last two years and the record year 2017, this situation may change slightly in the near future. When analyzing the dynamics of intermodal transport in Poland, one can expect a further increase in transport in intermodal transport. In 2017, over 1.6 million TEU were transported. In 2020, an increase to 1.9 million TEU is forecasted, while in 2025 it is to be more than 2.6 million TEU.

There are almost 30 inland terminals in Poland. Most terminals are located in the west of the country, which results from the location of industrial comapanies in this part of the country. One of the largest handling points is the Schavemaker Invest indland terminal in Kąty Wrocławskie. In 2015, the extension of the terminal, under which an rubber tyred gantry crane, two reachstackers with a lifting capacity of 45 tons were purchased, and a modern IT system was introduced. A further expansion of this reloading point is planned in 2018. Schavemaker Invest is one of the few entrepreneurs who accurately adjusts to market needs.

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AN ESTIMATION OF OPERATING SPEED INCREASE BY TRAM SIGNAL PRIORITY

ABSTRACT

Due to the excessive private car usage, the City of Zagreb is faced with motorization rate increase in the past few decades, constantly reducing the operating speed in tram network to its lowest values at the present, rendering public transport unattractive. Besides the partial integration within the road network and therefore interactions with motor vehicles, an additional reason for such values is very poor signal priority for trams at intersections. The previous research on tram signal priority has predicted significant operating speed increase for the network if the technology was implemented only partially, so this paper presents a simple methodology based on vehicle running times for estimating time savings and operating speed increase. The results in the paper estimate if signal priority could increase the operating speed to satisfactory levels by European standards, for shifting users from private cars, and making transport system in the city more sustainable in terms of finances, space and environment.

KEY WORDS

City of Zagreb; operating speed; signal priority; time savings; tram network;

1. INTRODUCTION

The City of Zagreb is the capital and the largest city of the Republic of Croatia, with population of an estimated 0.8 million [1], and a population density of 1,200 residents per square metre. The metropolitan area has the population of 1.1 million. The City itself is located on the southern slopes of Medvednica mountain, divided by the Sava river, with rough terrain only in the northern peripheral parts of the City. It consists of 17 municipalities, divided into 70 neighbourhoods.

The road traffic in the City is characterized by local streets, higher priority streets, and city avenues. Most of city avenues stretch from east to west, making the current state of traffic subject to the capacity of roads connecting northern and southern parts. Since motorisation rate is 430 vehicles per 1000 inhabitants, and passengers are used to their private cars, traffic congestion is usual in the morning and the afternoon peak periods on main road corridors.

The mobility in the City of Zagreb is highly related on purchasing power, comfort provided by the private cars, and a poor transport policy by the city administration. Due to the financial crisis starting in 2008, one third of people use private cars, one third use public transport, and the remaining third is divided into pedestrians and cyclists, with a continuous increase of bicycle traffic in the past several years. Although public transport has become financially more acceptable than private car, it still does not represent an acceptable choice for passengers.

Public transport in the City is organized mostly by trams and buses. Passengers ride on 140 bus lines and 15 tram lines, with approximately 740,000 daily trips, and the public transport vehicles record very high passenger densities in morning and afternoon peak periods. Public transport network is stretched throughout the City, covering every significant part of the City, resulting in 10-minute walks in the city centre and 15-minute to 20-minute walks in the periphery. Dynamic performance of public transport operated by trams is the weak link, with approximately 12 km h^{-1} operating speed unsatisfactory for passengers.

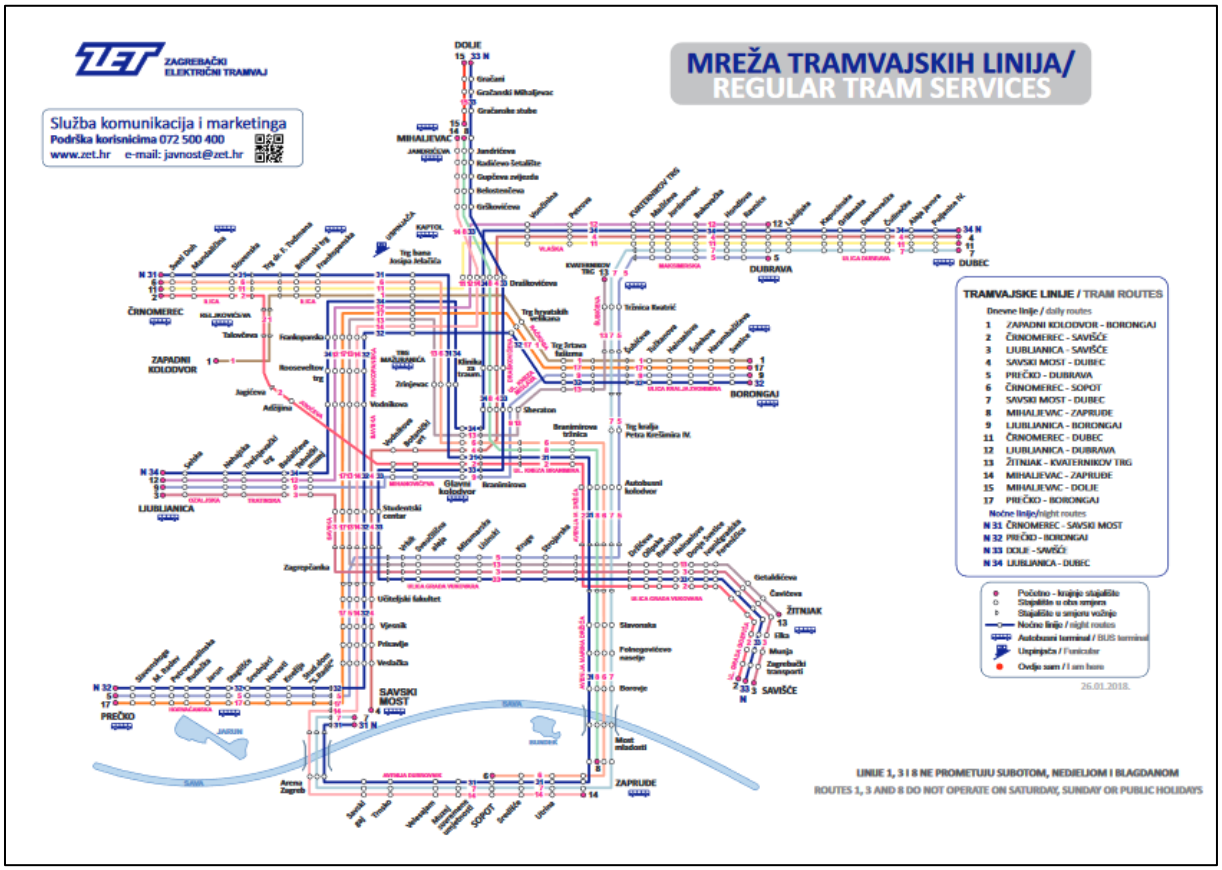


Figure 1 – Zagreb tram network
Source: [2]

Tram network in Zagreb (Figure 1) is a part of the urban road network, on which:

- 53 % of lanes are segregated completely (green lanes),
- 21 % of lanes are in separate road lanes (yellow lanes),
- 26 % are shared with other modes of transport (white lanes).

The operating speed of tram network in the City of Zagreb is has been steadily reduced from 15.4 km h^{-1} (in 1999) to 13.0 km h^{-1} (in 2009), which is approximately 16 %. This decline is the result of the increasing usage of urban road network by private cars. In this decade, the speed is usually between 12.0 and 12.5 km h^{-1}. Besides the private cars freely using the white lanes, an additional problem is yellow lane contravention, and there is not any kind of yellow lane enforcement present in peak periods. The increasing usage of urban road network by private cars is also the reason for shorter green light percentages for trams at intersections, making benefits for trams considerable only in tram lanes stretch on main city avenues.

Because it plays a significant part in quality of service, public transport priority is a subject of much research. In recent times, different kinds of solutions related to signal priority have been developed to increase performance of public transport network, and they are mostly based in implementing

communications technologies and intelligent transport systems. Once implemented, the technologies usually result with considerable improvements if compared to no priority at all. Wahlstedt (2011) studied bus signal priority in Stockholm by implementing simulation-based method for analysing partial dynamic signal timings and fully-adaptive signal control systems with the Swedish PRIBUSS method. Public transport priority results in shorter travel times for buses up to 20 % depending on the method, and longer travel times for crossing traffic and traffic following the prioritized buses in one direction [3]. Pyrgidis & Chatziparaskeva (2012) studied signal priority of tram network in Athens and found that it is possible to expect increases in commercial speed between 15 % and 25 % [4].

There is also research with estimations on operating speed increase for tram network in the City of Zagreb. The analysis of yellow lane priority on a single tram line in Zagreb tram network was conducted by Brčić, Slavulj & Šojat (2012). By using optimization tools, the result was operating speed increase of 8 % and savings of one transport unit, which is 7 % of the total number of transport units on the line [5]. Based on the research results from [5], Brčić, Slavulj & Šojat (2014) conducted another research where they estimated that yellow lane enforcement, if implemented, would result in 3.6 % operational speed increase in the network and estimated operating speed increase by 30 % with every type of priority combined [6]. The research on public transport priority based on two scenarios was conducted by Šojat, Brčić and Slavulj (2017). The operating speed increase was 7 % in case of minimum delays, and 41 % in case of the absolute tram priority [7]. The mentioned research for the City of Zagreb suggests that there is a considerable space for improving the operating speed based on signal priority only.

Within the Civitas project family implemented in Europe, many measures related to public transport have been implemented. Such of the measures are: new traffic lights and bus priority in Malmö, bus priority in Prague, public transport priority in Ljubljana, Rotterdam, Kraków and Suceava, bus rapid transit corridors in Toulouse, Lille and San Sebastián, new traffic light regulation in Vitoria-Gasteiz, yellow lane surveillance in Perugia and high-mobility corridor in Genova. All the measures resulted in commercial speed increases, travel time reductions and eventually, passenger satisfaction linked to modal shift [8]. The Civitas-Elan project was carried out in Zagreb, with one of the measures named „Giving priority to public transport“. Signal priority was implemented at three intersections in Savska Street, resulting in 5 % time saving for the entire corridor [9]. In addition, a pilot-project was carried out which involved yellow lane enforcement by traffic police at the same corridor. Significant time savings of 25 % throughout the corridor were achieved [10]. However, besides the mentioned two pilot project, there has not been a single comprehensive project implemented in the City which would introduce long-term priority solutions for the network.

Considering signal priority for trams, this paper presents a methodology for estimating the operating speed increase if tram signal priority was implemented in the City of Zagreb based on the collected data in trams during the afternoon peak periods, and the results, compared with the results of previous research, should serve to more accurately describe the extent of improving the service for passengers.

2. METHODOLOGY AND RESULTS

The data used for this paper was collected in Zagreb tram network in the afternoon peak periods. Since the representative data can be obtained only in morning and afternoon peak periods, and the students of the Faculty of Transport and Traffic Sciences in Zagreb were the ones collecting the data, the afternoon peak period was chosen because it was more suitable for most students than the morning peak period, considering their schedules (this type of task demands significant resources in time and people). The measurement period, October and November 2016, is representative for tram network in Zagreb. The data was provided by GPS data loggers, measuring speed and position in one-second intervals. The students holding data loggers were standing in vehicles near the driver cabin. The measured routes showed no major errors in collected routes due to lost GPS signals (by vehicle

roof or the high-voltage wires). The gathered data was then processed by using *Google Earth*, *CanWay*, *Microsoft Excel*, and *QGIS*.

The data sample encompassed every tram line on the network except the line 15 (which is much shorter than the rest, and completely segregated from the network). Therefore, on corridors with more lines, the sample was satisfactory (more than five samples were collected), and on corridors with fewer lines or only one tram line operating, the sample was scarce (between three and five samples were collected).

Between the stops, there is usually more than one factor affecting the driving speed, so determining the driving speed improvements based on signal priority becomes complex. So, to draw conclusion regarding signal priority only, we considered only stop spacings with signalized intersections as the sole operators on them (Figure 2) – in these spacings, there are no obstacles for trams (such as pedestrians at crossings, vehicles in the same lane or possible yellow lane contraventions) except the signalized intersections blocking the vehicles on completely segregated tram lanes (green lanes). For tram network, these spacings are totally 42,3 km out of 107,9 km (39 %). For the rest of the network (where such measurement could not be made), we presumed that the 39 % of network would be enough to represent the entire network, i.e. the operating speed change for this part of the network would be mandatory for the entire network without the major deviations in reality (although this cannot be proven).

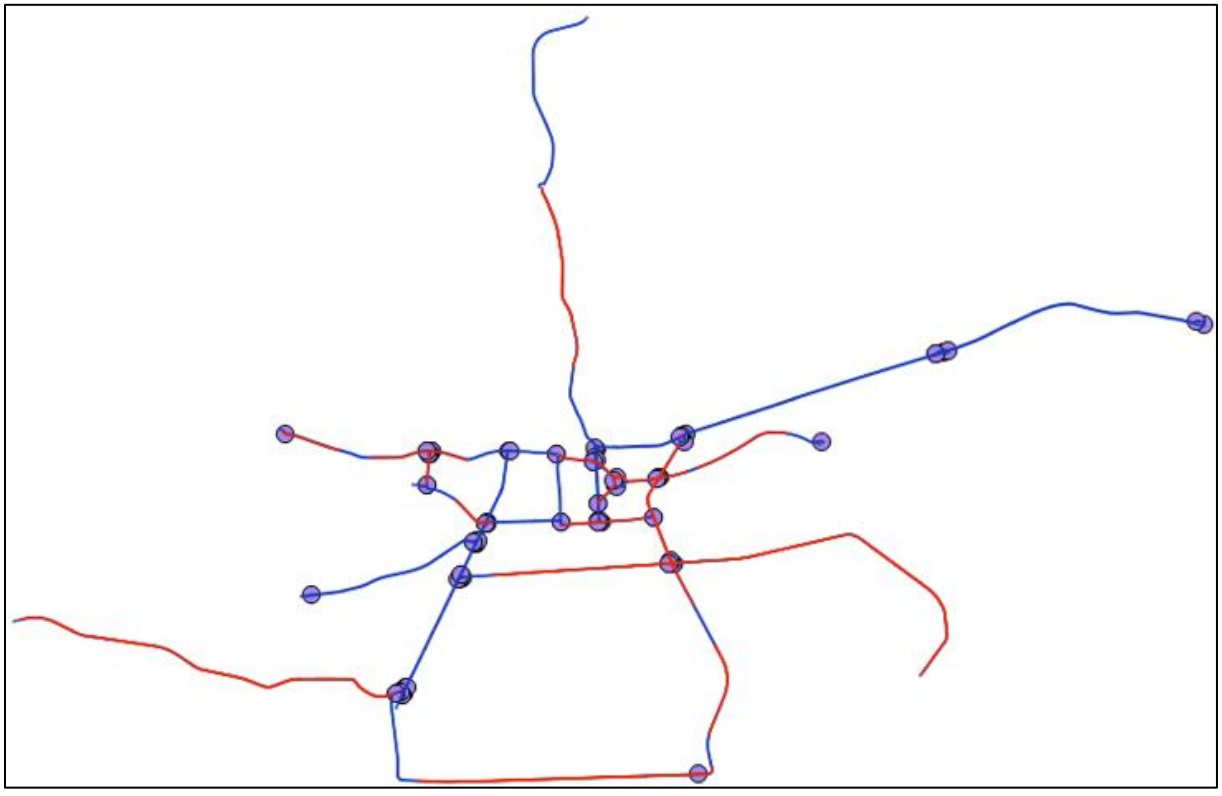


Figure 2 – Parts of tram network where the measurements could be made (in red)
Source: by authors

For measuring the possible improvements from signal priority, average driving time and minimum driving time were extracted to calculate average and maximum driving speed from times and spacing lengths. For each spacing, there were two possible measures for determining minimum times:

- Movement speed method (a priori): the minimum time Δt_{MIN} is a result of several input variables - maximum speed on the spacing v (usually limited by traffic regulations), l is length of the spacing, a is vehicle acceleration, and b is vehicle deceleration (each value positive):

$$\Delta t_{MIN} = \frac{v}{2a} - \frac{v}{2b} + \frac{l}{v} \quad (1)$$

- Fastest vehicle method (a posteriori): the minimum time Δt_{MIN} is determined by the fastest vehicle in the sample of times t_n – the coefficient k is used for corrections if necessary:

$$\Delta t_{MIN} = k * \min_n t_n \quad (2)$$

From these two measures, the measure (2) was chosen because the results were more precise – the former measure often resulted with unrealistic results due to the complex network geometry or the problems with drivers exceeding speed limits (legislation problems). Based on the times, the priority was calculated based on average V_{AVG} and maximum possible speed V_{MAX}:

$$p_n = \frac{V_{AVG}}{V_{MAX}} \quad (3)$$

To get the average priority p for the network, for each spacing separate priority p_n was multiplied by the spacing length l_n, then summed and divided by the total length (the priority on spacing was weighted onto the network):

$$p = \frac{\sum_n p_n \, l_n}{\sum_n l_n} \quad (4)$$

Based on the (4), for the value p we got 77 % - therefore, the operating speed in the network, due to the the signalized intersections, is 23 % less than it could be, and if we consider the current operating speed of 12.6 km h^{-1}, there is a possibility to increase that speed on the network up to 15.5 km h^{-1}.

3. DISCUSSION

The results indicate that the possible space for improving operating speed in tram network is possible similar to the predictions in [5], [6] and [7] – since the speed can be improved up to 23 %, signal priority stands out as the most prominent method if the implementation costs are considered, in contrast to lane segregation (the costs are significantly higher, and there is still need to introduce signal priority in some cases) or yellow lane enforcement (the effect is smaller – 3.6 % operating speed increase [6], although important for timetables).

The sample explained in the previous section contained enough samples on high-frequency corridors in the network; however, on corridors where fewer lines operate the number of samples was less (since the measurement was conducted for tram lines). On those corridors, measurements should be higher for more accurate results.

In the previous section, two possible methods for obtaining minimum driving times at spacings were mentioned, and the latter one was used, because it produced more accurate results than the former one. However, there are problems with the fastest vehicle method as well, that can be divided into two possible cases:

- The times are too low, or speeds too high – this is mostly the case when the fastest vehicle runs faster than the speed limit by traffic regulations – in these cases, a coefficient should be used for time compensation, or the sample (if big enough) should be observed to a percentile (e.g. the fastest vehicle not included);
- The times are too fast, or speeds too low – this is mostly the case when the signals between public transport stops are coordinated, and regardless of vehicle performance, minimum driving times will always be the same, while they could be smaller.

Therefore, to reach the most precise results, the times should be obtained by the first method, accompanied by a comprehensive network analysis, considering geometry, traffic regulations, and vehicle performance.

Another methodology for estimating operating speed increase by signal priority (not covered by this research) is the one that considers vehicle frequency – since the vehicles are the units for measuring operating speed, besides the length of the spacing, this methodology should also consider vehicle frequencies on network corridors to estimate operating speed improvements. However, this methodology should consider the entire network since vehicle frequencies vary among corridors with different priority operators.

Another factor that should be considered when estimating signal priority is the complexity of intersections – if at intersection trams operate only in one direction (and the opposite direction), and the intersection is not highly complex regarding other traffic (number of phases, phase length, pedestrians), implementing signal priority for trams would result in considerable time savings. However, if the intersection is complex (trams coming from multiple directions, more phases, or phases that require coordination with other intersections), implementing tram priority could have a very low impact. Since the number of complex intersections makes a considerable percentage, the 23 % operating speed increase would be smaller, since introducing signal priority on different intersections would result in different effects.

4. CONCLUSION

The research in this paper has confirmed the estimation from previous research – if signal priority was implemented on tram network in the City of Zagreb, the operating speed could increase up to 23 % - from the existing 12.6 km h^{-1} to 15.5 km h^{-1}. This is only the increase due to signal priority, so if yellow lane enforcement and lane segregation were considered as well, the network could easily have vehicles operating above 16.0 km h^{-1}, which is the value recommended by the European standards, regardless of low spacing and high vehicles to network length ratio.

If tram priority was considered in the City of Zagreb, there are large possibilities for improving the operating speed. If compared to tram lane segregation and yellow lane enforcement, signal priority has the best potential for improvement because the investments are minimal, and the effects are considerably high. The decision on improving tram priority must be made on the decision-making level with a sound traffic policy. The higher operating speed should be an imperative if public transport is to be made more attractive for passengers, thus making them shift from private cars, resulting in better mobility in peak periods for every citizen.

The further step in analysing tram and bus priority in the City of Zagreb would be a comprehensive analysis to show the intersections with the highest effectiveness if the signal priority was implemented, as well as the intersections where such measure could result in slight or no improvements at all. The intersections should be mapped, and simulation tools used to precisely estimate if implementing signal priority is time-effective or cost-effective.

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NON-MOTORIZED TRANSPORT INTEGRATION – CASE STUDY ZAGREB CITY CENTRE

ABSTRACT

With the ongoing problem of air pollution and CO_2 emission generated from the traffic system and in accordance with the EU policies regarding air pollution, many cities are implementing measures for the reduction of the negative environmental impacts. The intention is to release city centres from the big traffic demand and promote alternative, sustainable modes of transportation by giving them priority over individual transport which is highest polluter.

The purpose of this article is to show example of the methodological approach to the implementation of measures for the reorganization of the road infrastructure in favour of non-motorized modes. Main steps toward the more effective and sustainable mobility system are presented through the Case Study.

KEY WORDS

Innovation; pedestrians; push & pull measures; sustainability; transport management;

1. INTRODUCTION

Jammed city centres and negative environmental impacts generated by vehicles and transport infrastructure are some of the most visible negative impacts on the life quality within the urban city centres. Most of the present transport studies, sustainable urban mobility plans, strategies and policies are being made with a goal to encourage use of alternative modes of transport, especially in urban areas.

In theory, decision makers would like to change current modal share and other negative trends. Although they have vision, implementation of the push & pull measures to favour more sustainable transport modes requires short and long-term strategic planning.

City centres should be divided into zones based on the modes of transportation which means that some zones would be available only for pedestrians and cyclists while motorized vehicles would be redirected through other zones. This plan sounds logical and easy to implement, but previous system planning without clear vision about sustainable development created nowadays system which does not allow alternatives.

Article is structured to give a project overview from the vision to the final proposal of the measure for the prioritisation of the non-motorized transport over motorized.

2. PUSH & PULL APPROACH

The restriction of personal vehicles usage in the city centres is one of the key success factors in the function of sustainable urban mobility development. Except for the main reasons such as noise and pollution reduction, restrictions are measures to encourage non-motorized and public transport.

Advantage of the usage of PUSH & PULL measures is a possibility of making a visible step forward towards sustainability with minimal investments.

2.1 Objectives

In order to connect trip generators in an attractive but sustainable way, City of Zagreb has a vision to create a pedestrian-cycling zone in the city centre near the Art pavilion. To make this possible, it is necessary to carry out PUSH & PULL measures with a goal to provide enough space for non-motorized transport as an alternative to motorized traffic.

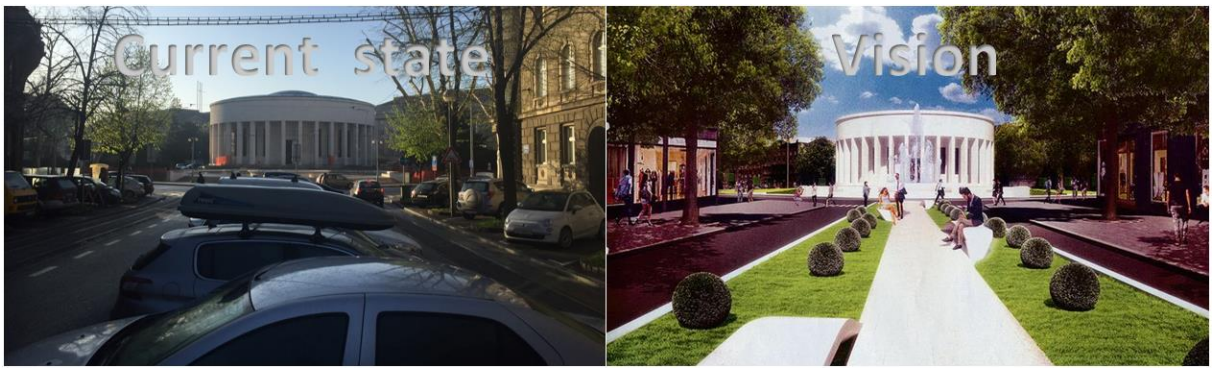


Figure 1 – Vision of sustainable mobility concept
Source: https://www.vecernji.hr/zagreb/obnova-trga-zrtava-fasizma-povratak-mestroviceve-ideje-1185064

The measures should be implemented to reduce number of parking lots and restrict traffic flows in order to create additional space for pedestrians and cyclists.

2.2 Description of the Case Study

The main goal is to establish a pedestrian zone which implies removal of central parking lots, traffic flow reorganization and signal plan optimization.

To identify modal split, infrastructure barriers and to understand traffic flows and parking system, it was necessary to create a traffic study. Considering the complexity of the planned future state, elements which were analysed for the implementation of PUSH & PULL measures are traffic flow structure and volume, current signal plan, parking demand and offer.

At the main analysed intersection, which is located in the city centre, total daily volume was app. 20.000 vehicles. In the peak hour, the biggest volume was at the Ignjat Đorđić street with the 1.345 vehicles per hour which presents the challenge for the implementation of the potential pedestrian - cycling zone. The zone is planned in the central line of the street so it is not possible to use current signal plan.

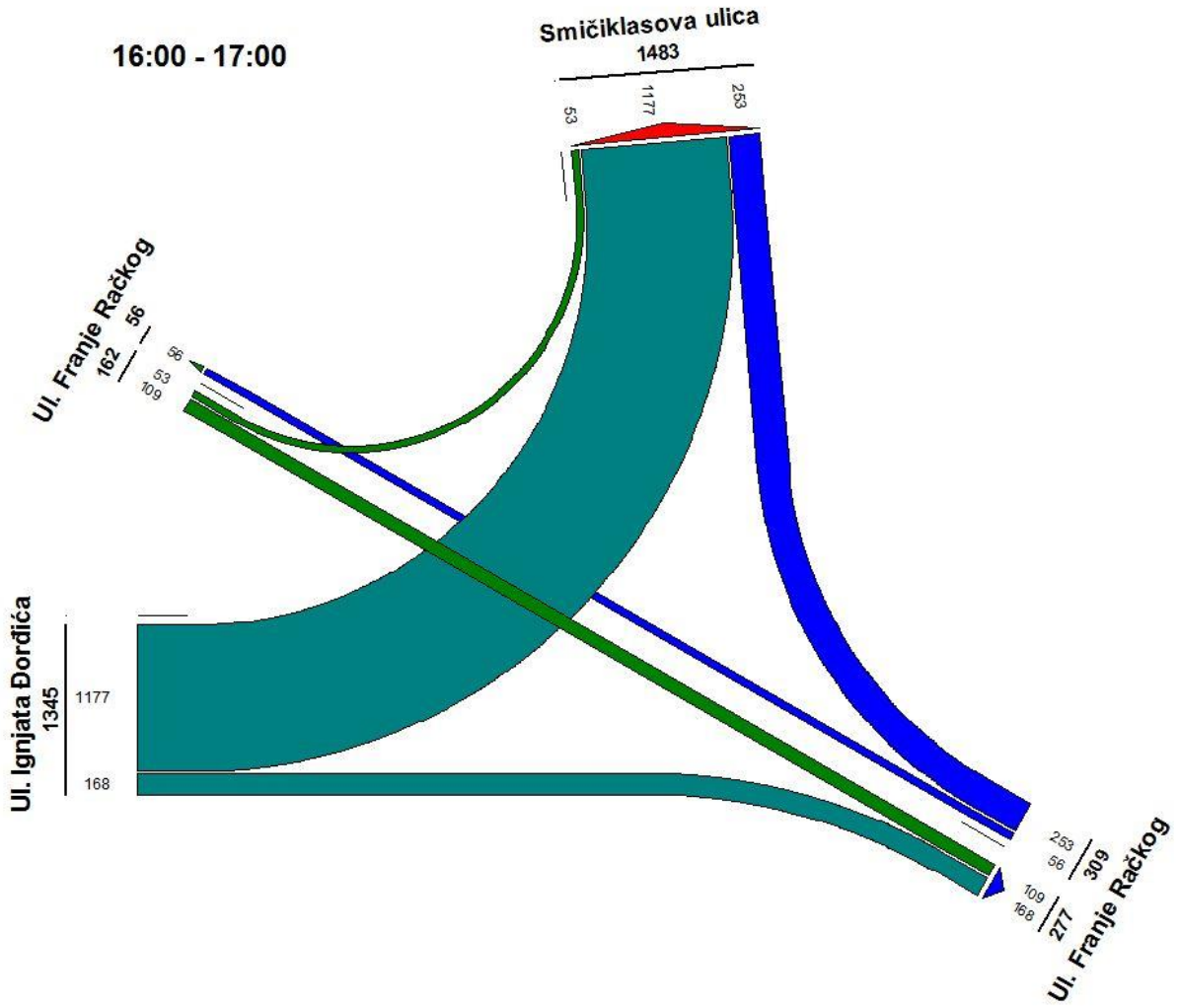


Figure 2 – Traffic flows
Source: [1]

On the Franjo Rački street where the planned zone should be implemented, traffic flow structure is complex because of the public transport, motorized traffic and cyclist. Additional conflict is made by allocation of the parking lots which directly affects traffic flows. The solutions for the Franjo Rački street organization were:

- pedestrian zone + public transport single lane + motorized traffic single lane
- pedestrian zone + public transport and motorized shared lane

Since the potential pedestrian zone should be located in the middle section along the Franjo Rački street which is currently used as a parking area, it was necessary to make detailed analysis of the parking offer and demand. For this purpose, the parking demand matrices are made (Figure 3) and vehicles exchange coefficient and coefficient of occupancy per parking lot were calculated.

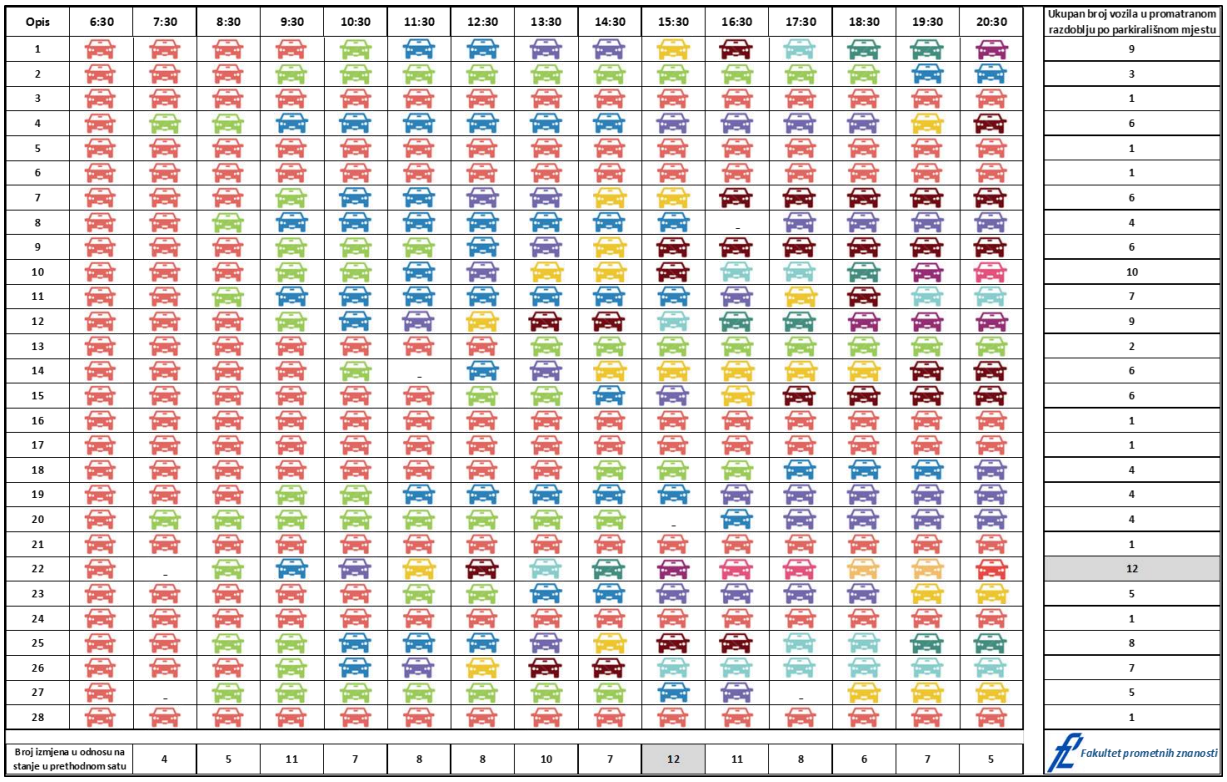


Figure 3 – Parking demand matrix
Source: [1]

The purpose of the demand matrices was to determine the structure of the parking lots users in the analysed area. The maximum number of changes per classic parking lot is 12 while the minimum number of changes is 1. It can be assumed that the parking lots without vehicle exchange are occupied by the residents while the occasional users and employees occupy parking lot for a shorter period. With that in mind, alternative parking solutions are proposed.

3. PROPOSED SOLUTIONS

The analysis of the intensity and distribution of the traffic demand have shown that around 60% of the demand is at the route Ignjat Đorđić Street - Tadija Smičiklas Street and 40% is at the Franjo Račkі Street which is the subject of reconstruction. The largest part of the traffic volume at the Franjo Račkі Street is south-north transit and vehicles looking for attractive parking lot near the Zagreb City center. The research has shown that the parking lots are nearly constantly full which confirms it´s attractiveness.

The main hypothesis of the Study is the possibility for development of the pedestrian zone in the middle section along the Franjo Račkі street which needs to be confirmed or denied. For the pedestrian zone to be implemented, it is necessary to create preconditions through regulation and organization of the traffic flows in the zone.

The traffic solution proposes usage of a common area for the motorized traffic and public transport on the Franjo Račkі street with the pedestrian zone in the middle as a replacement for the parking lots. The southern road section of the Franjo Račkі street heading towards north has two solutions, with common lane for public and motorized traffic and with two lanes, one for motorized and one for public transport. Those two solutions will be validated in the next section based on queue length. The queue length is important because of the short section (75 meters) so the traffic on the nearby road could be disturbed in case of long queue at the intersection. The solution with two lanes is shown at the Figure 4.



Figure 4 – Proposed solution
Source: [1]

The signal plan for the signalized intersection needs to be adapted and modified because of the new signal group just for pedestrians and cyclists. In this signal group it would be allowed for the non-motorized traffic to move in any direction so the intersection would be turned into a pedestrian zone during this phase of the cycle.

The non-motorized signal phase is a common thing in the developed countries with significant pedestrian or cyclist traffic, but it has not been implemented in Croatia. The example of a non-motorized signal phase is shown at the Figure 5.



Figure 5 – Non-motorized phase (Japan)
Source: https://www.fun-japan.jp/my/articles/7853 (15.4.2018.)

4. SIMULATION MODEL

PTV Vissim simulation software is used for the evaluation of the proposed solution in comparison with the current condition. For the definition of the optimal solution two traffic models are made, one for the current condition and one for the proposed solutions. Simulation gave relevant data that made basis for the comparative analysis of the proposed solutions and current condition. The analysis is made based on basic traffic flow characteristics.

Detailed on-field research and conducted traffic counting defined period from 16:00h to 17:00h as a peak period of the day so the simulation of the scenarios is made with the input data for the peak hour.

4.1 Methodology

The research showed that the results gathered through traffic counting represent real traffic demand on the analysed intersection which can be confirmed with the fact that all the vehicles in queue pass through the intersection in the period of one cycle.

The purpose of the intersection reconstruction is implementation of the pedestrian zone within the observed area which requires modification of the signal plan and addition of the signal group just for pedestrians. The current condition is simulated with an implemented signal plan while the proposed solutions are simulated with modified plans.

Solution A eliminates lanes at the eastern and western approach so the new approaches would be single-lane contrary to previous two-lane approaches. In the solution B the western approach is a single-lane and eastern is a two-lane approach. Both solutions require significant modification of the signal plan by adding pedestrian signal group in which the entire intersection turns into a pedestrian zone.

4.2 Validation

Basic traffic flow characteristics were taken into consideration for the comparative analysis of the proposed solutions and current condition:

- Queue length
- Delay time
- Number of stops
- Level of service

The analysis determined solution B as an optimal one, while the solution A showed as an impracticable proposal. The simulation confirmed that the proposed optimal solution can technically replace current condition.

Solution A defined reduction of the motorized traffic area and increase of the pedestrian area. Current western and eastern approach two-lane roads would be reconstructed into single-lane roads and the parking lots between roads would be removed and reconstructed into the pedestrian non-motorized zone. The solution is showed as a doable regarding the intersection capacity but the problem is a queue length. In the scenario of a single-lane used by motorized vehicles and public transport there is a big possibility of queue that would have negative effect on the next street(Figure 6). Only two trams and a few vehicles are enough or the creation of critical queue which is why the solution A is marked as an impracticable.

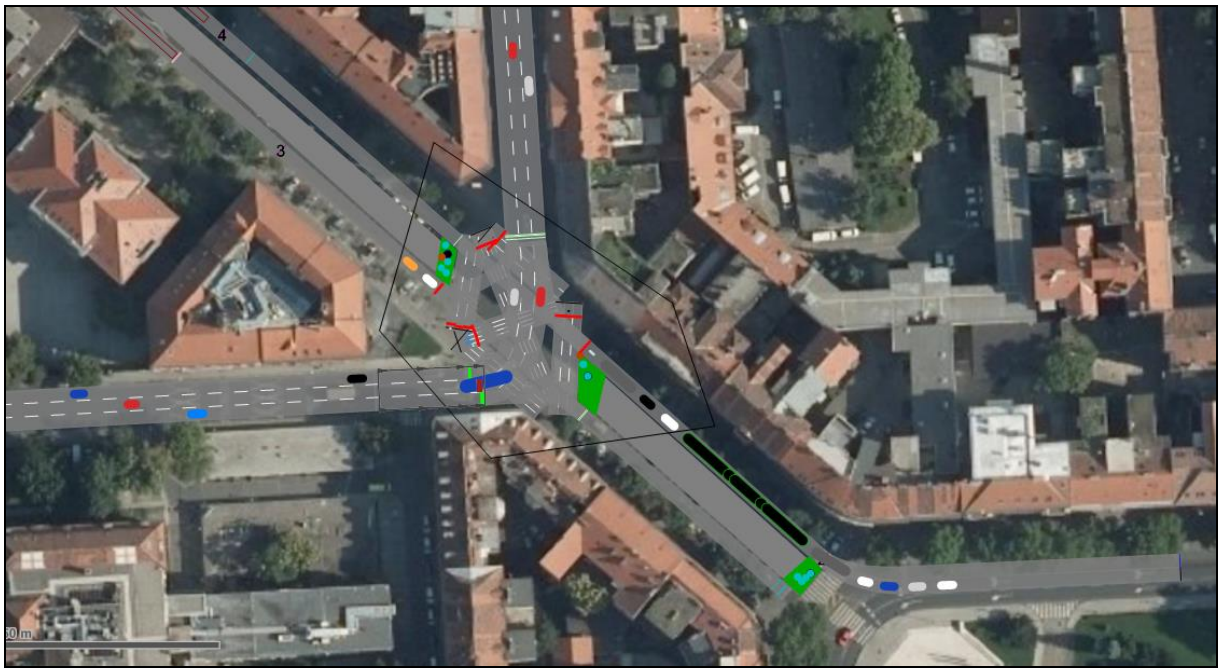


Figure 6 – Simulation of the solution A
Source: [1]

By adding another lane in the solution B, the queue length decreased within the maximum allowed values. The characteristics of a traffic flow are a little bit better in the current condition compared to solution B which was expected, because the pedestrians are included as a new signal group. The comparative analysis results are shown in the Table 1.

Table 1 – Comparative analysis

Traffic flow	Queue length (m)		Delay time (s)		Number of stops		Level of service	
	before	after	before	after	before	after	before	after
Đorđić – Račkisouth	13,16	25,97	17,08	29,31	0,68	0,77	B	C
Đorđić - Smičiklas	13,16	25,97	14,63	26,89	0,55	0,74	B	C
Račkisouth - Smičiklas	9,32	15,16	23,66	34,49	1,11	1,18	C	C
Račkisouth – Račkinorth	9,32	15,16	24,17	40,99	1,11	1,48	C	D
Račkinorth – Račkisouth	7,91	10,75	25,52	35,08	0,84	0,83	C	D
Račkinorth - Smičiklas	7,91	10,75	22,95	36,82	1,28	0,91	C	D

Source: [1]

Implementing a pedestrian zone and adding a pedestrian phase into the signal plan has a negative impact on the capacity of the intersection because of the longer cycle and longer needed time for the pedestrian group which reduces green phases for other groups. Optimal solution has one advantage regarding motorized traffic and that is elimination of the pedestrians which have advantage over the vehicles making a right turn from the eastern approach road.

The results of optimal solution are acceptable for the highly urbanized areas but the real situation might be on the even better. Setting a pedestrian zone along the road section eliminates 110 parking lots and automatically eliminates vehicles looking for a parking lot are which by previous researches [2] making up to 30% in the Zagreb centre.

With that having said, it can be concluded that the traffic demand will be reduces, especially at the eastern approach road. Considering that the simulation is made with input data gathered for current condition, the results are showing the worst-case scenario and by that are confirming the future functionality of the proposed solution.

5. CONCLUSION

Pedestrian areas are mostly designed as attractions which should provide complete experience of surrounding environment. In case when it is necessary to carry out some of PUSH & PULL measures with the aim of creating conditions for implementation of the planned sustainable concepts, it is important to simulate impacts of proposed changes on the analysed system.

Although presented Case Study recommended complex solutions which include traffic flow reorganization and signal plan optimization set to enable third signal phase only for pedestrians, largest impact of the PUSH & PULL approach will be visible through the reduction of the street parking capacity. If proposed solutions offer an adequate alternative to the restricted stakeholders, over the time, it is possible to demonstrate positive effects of implemented measures.

In order to develop sustainable mobility system, the effective management and methodological road-use strategy are needed.

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ANALYSIS OF METHODS FOR DETERMINING TRANSPORT ROUTES

ABSTRACT

In order for business organizations to meet the increasing expectations of users, a quality transport organization is one of the most important factors in the overall process chain and cost optimization. The service user wants a quality, favorable and fast service and therefore it is extremely important to rationalize the transportation. One of the ways to make the service faster, cheaper and better in implementing the technological process is by using mathematical models and software routing tools. The purpose of this paper is to analyse the different ways of determining the route and how they affect the overall delivery process of delivery to the ultimate recipient in the urban area. Concrete comparisons, along with certain route parameters, will also show the delivery results.

KEY WORDS

routing; optimization; methods for determining transport routes; intuitive route determination; nearest neighbour algorithm; modern software tool route determination;

1. INTRODUCTION

One of the goals of every business organisation is to optimise its expenses through an effective logistics system and so become more competitive on the market and to acquire as many satisfied customers as possible. Based on these notions, this thesis will show how expense optimisation via transport route determination works. The vehicle-scheduling problem involves the design of several vehicle tours to meet a given set of requirements for customers with known locations, subject to a capacity constraint for the vehicles and a distance (or time) constraint for vehicle tours. [1] Dantzig and Ramser [2] laid out the Truck Dispatching Problem – TDP in 1959 which set a base for theoretical exploration and practical application in the vehicle routing field. The Vehicle Routing Problem (VRP) can be described as the problem of designing optimal delivery or collection routes from one or several depots to a number of geographically scattered cities or customers, subject to side constraints. The VRP plays a central role in the fields of physical distribution and logistics. [3] Important variants of VRP are described in a book written by Toth and Vigo [4].

Taking the importance of optimal routing into consideration this thesis will analyse the following methods for determining routes: an intuitive way of determining a route, a mathematical model of determining a route and determining a route by using a modern software program designed for determining routes. Realistic package delivery practice examples will be used for demonstration. The goal of this paper is to show which way of determining routes is optimal, by analysing and comparing, and to substantiate that with concrete analysis results.

2. METHODS USED FOR DETERMINING ROUTES

This thesis analyses three different ways of determining routes and package delivery schedules in an urban environment. These are as follows:

- Intuitive Route Determination (IRD)
- Mathematical Model Route Determination, MMRD (Nearest Neighbour Algorithm, NNA)
- Modern Software Tool Route Determination (MSTRD)

2.1. Intuitive Route Determination (IRD)

Intuition would be to see things directly without discursively pondering about, in other words, direct cognition. There is a definition of intuition which states that it is more or less the exact feeling for things that have not happened, which are yet to come [5].

Concretely, routes that are being analysed are the ones which the person who is driving has chosen intuitively based on their experience or preference while making a delivery in an urban environment. That would mean that the person has chosen the delivery routes and came up with an order of delivery on their own.

Transport routes, travelling distance, time and sequence of delivery analysed for IRD method were gathered by tracking the vehicle via a GPS device. In that sense, intuitive route delivery was the choice that the person doing the delivery made for getting from point A to B based on their own intuition and experience, without anyone's help.

2.2. Mathematical Model Route Determination, MMRD (Nearest Neighbour Algorithm, NNA)

The mathematical model used in this case is the Nearest Neighbour Algorithm. By using this heuristic the order of delivery was improved until a satisfactory model was made, the one which guaranteed minimal travelling distance. Reason for choosing this type of a mathematical model was its relative simplicity and easy application.

The NNA method is the algorithm used to randomly select a location x out of a set of all locations that need to be visited. Location x will be the first delivery location. Next, select the location closest to the location x - location y, then select the location closest to the y - location z and repeat until every location is visited. Different first location can be selected as many times as necessary until a satisfactory solution is reached [6].

The NNA method requires a distance matrix. A distance matrix is a matrix which holds the names of all destinations and distances between them. Each day a distance matrix was made. Distances were gathered from Google Maps. Since Google Maps gives a number of alternate routes to a location, shortest routes were chosen for the matrix data. More iterations of the matrix were made each day and the shortest routes were chosen for further analysis.

2.3. Modern Software Tool Route Determination (MSTRD)

Modern software tools are used not only to determine routes; they have the option to provide much more information than the route itself. Besides intelligent route planning modern software tools can track vehicles via satellite, determine the optimal size and number of a delivery area (region) and command infrastructural resources [7].

By using dynamic calculation, optimal route determination software provides a detailed analysis of expenses and profits of distribution. Route creation is done by calculating optimal routes and sequencing them while taking into consideration a set of key criteria. Those criteria are route length,

expected delivery time, expenses for using a vehicle, expenses for the services of the person who is driving [6].

A modern software tool used for the analysis is in the ownership of the service provider which provided the data about the routes. The software tool had to be given coordinates of each delivery destination as input. Based on coordinates the tool gave optimal routes and sequences for delivery as output.

3. ANALYSIS OF THE RESULTS

Time period in which the analysis was made is the last week of March 2017. Analysis was made on Monday, Wednesday and Friday. The delivery was performed in the city Pula and its near surroundings. The analysis was deliberately made in that period to get stable data which is not the case for the summer period and December. Data that was analysed was provided by a post office delivery service and it corresponds real package deliveries that were performed in that time period.

A vehicle used for delivery was a light delivery vehicle. Analysed cases showed no problems with vehicle's capacity. Vehicle's motor type is Diesel and its average consumption is 7.5 litres per 100 kilometres. On May 23rd 2017 the price of Diesel fuel on a gas station was HRK 8.57, which was the price that the analyses were based on.

Figure 1 shows delivery locations for Monday, Wednesday and Friday. Most locations are in the central area of the city but there are locations which are quite far from the city itself which is the case for Monday and Wednesday while on Friday delivery is made in the city itself only.

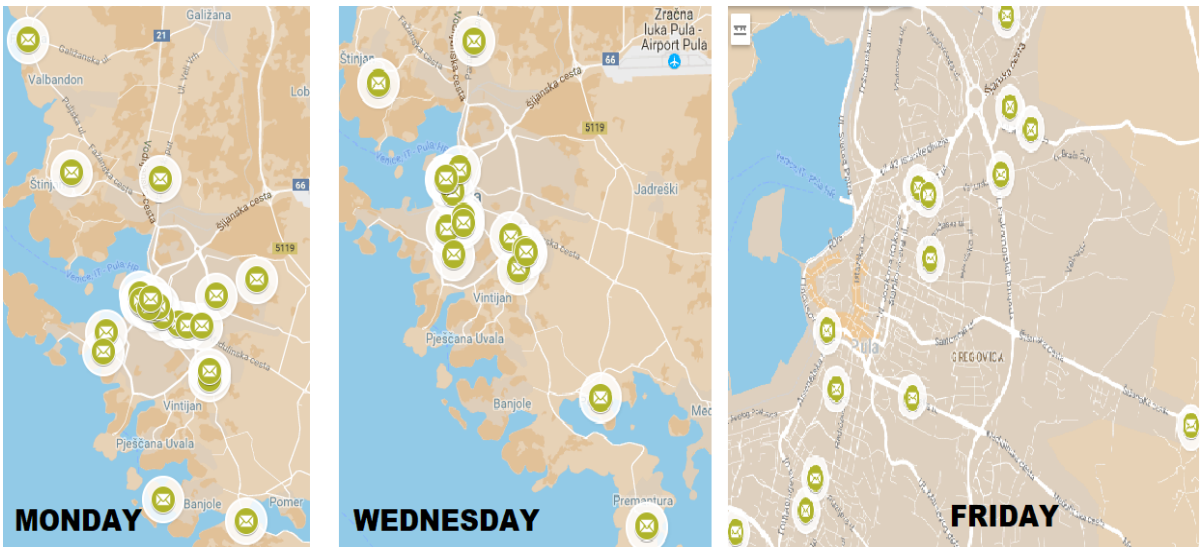


Figure 1 – Delivery locations
Source: Authors adapted in Google maps

Figure 2 shows the difference in traveling distances crossed respectively to the routing method. A difference of 10.32 kilometres can be observed between the IRD method and the MSTRD method. Difference between the NNA method and the MSTRD method is 6.37 kilometres. Difference between the IRD method and the NNA method is 3.59 kilometres. Charts also show the amount of fuel that would be saved if the routes were made with MSTRD method exclusively. The amount of fuel saved gets bigger as the total distance crossed increases in other words as the number of deliveries increases. The amount of fuel saved by using the MSTRD method compared to the IRD method financially translates to HRK 6.64 while in regard to the NNA method it's a little lower HRK 2.32 in favour of the modern software tool.

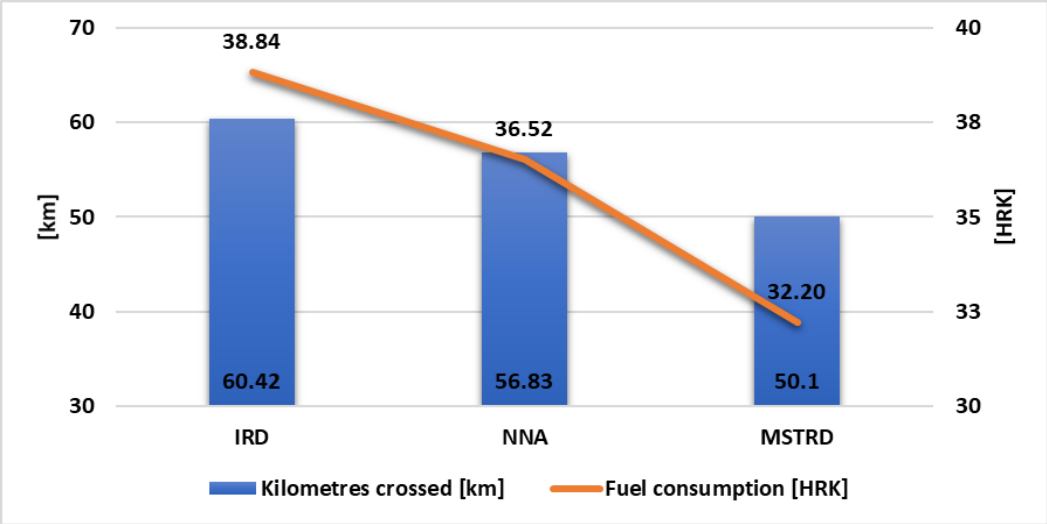


Figure 2 – Fuel consumption and kilometres crossed for presented routing models on Monday

Figure 3 shows the difference in amounts of money paid for the fuel respective to the routing method. Based on this information a conclusion can be made that the amount of money saved if we choose the MSTRD method over the IRD method amounts to HRK 3.84 in this particular case. The difference in kilometres crossed between the IRD method and the MSTRD method given by the software tool is 5.96 kilometres in favour of the software tool while compared to the NNA method it amounts to 1.3 kilometres also in favour of the software tool.

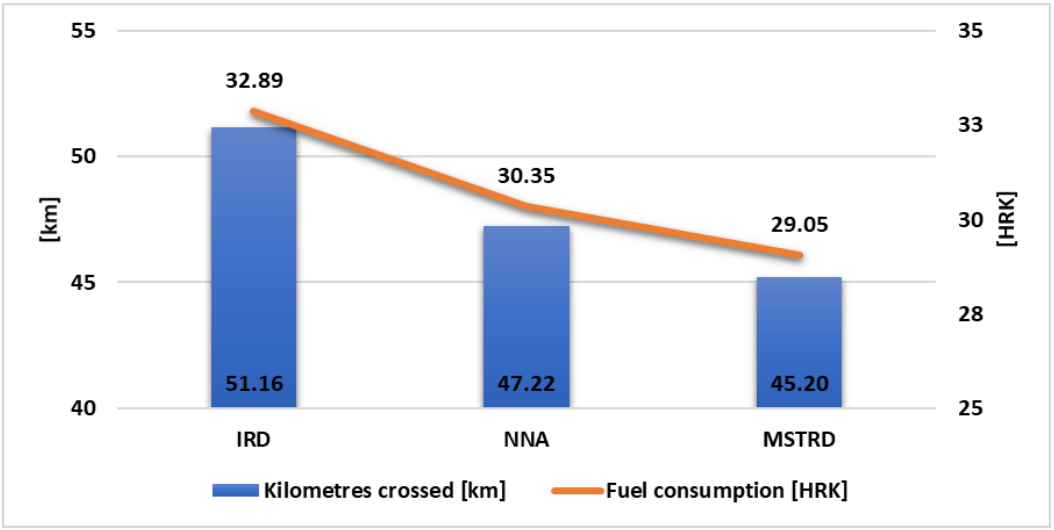


Figure 3 – Fuel consumption and kilometres crossed for presented routing models on Wednesday

Figure 4 shows the amount of fuel spent and kilometres crossed on Friday. The chart shows that the IRD method and the NNA method have identical results while the MSTRD method brings a decrease. That decrease translates to a saving of HRK 1.81 and 2.81 less crossed kilometres respectively. The reason for the identical results of the IRD method and the NNA method can perhaps be found in a relatively small number of destinations that were visited that day which makes the ability to perform route optimisation fairly small in a short period of time.

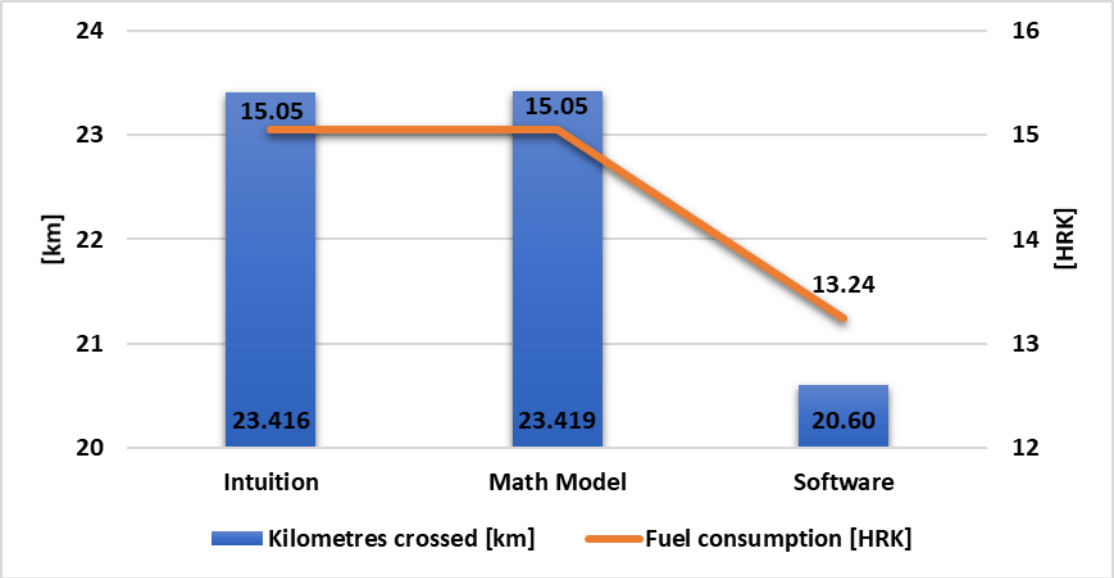


Figure 4 – Fuel spent and kilometres crossed for presented routing models on Friday

Figure 5 shows differences in kilometres crossed among different routing methods. It can be noticed that the difference increases in relation to the increase in the number of destinations and that it decreases in relation to the decrease in the number of destinations. The biggest difference in kilometres crossed was on Monday when the number of delivery destinations was the biggest and the smallest difference was on Friday when the number of delivery destinations was the smallest.

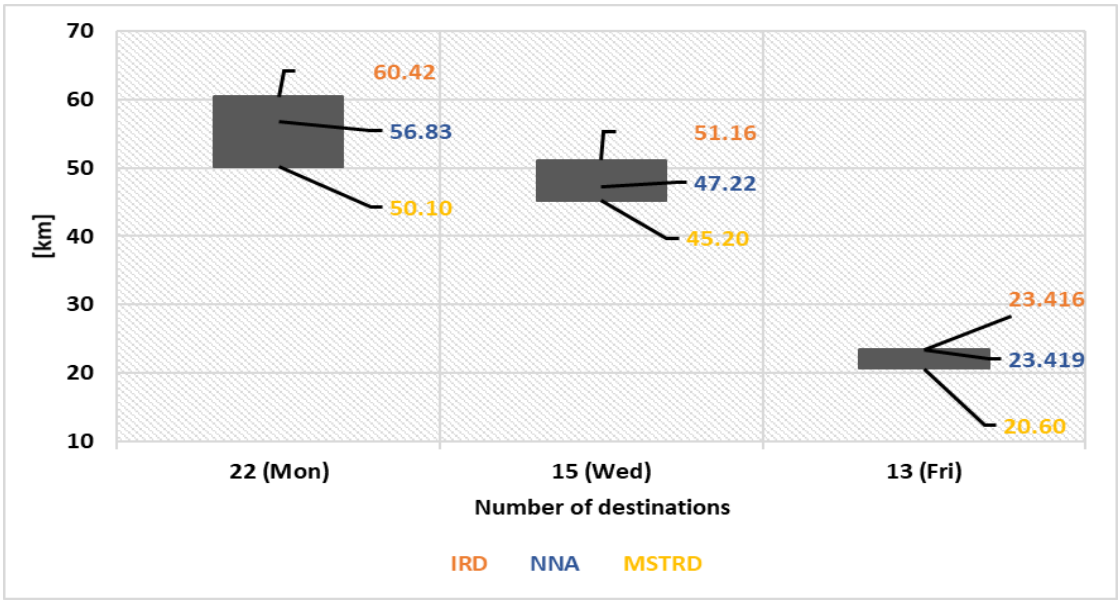


Figure 5 – Differences between kilometres crossed based on the day and the method

4. SAVINGS CAUSED BY ROUTING WITH SELECTED MODES

Considering all average decreases in regard to the IRD method there are significant savings considering concrete examples used in this thesis. Parameters taken for comparison were kilometres crossed and fuel consumption in all three days. Concrete examples take into consideration the data when the IRD method gave better results than the NNA method.

Table 1 shows the average savings while routing with the NNA method and the MSTRD method in relation to the IRD method. Multiple benefits can be seen with the MSTRD method while choosing routes. A concrete example shows that the modern software tool decreases the length of the route, for a substantial 13.6 % while the NNA method decreases it for 4.5 % in relation to the IRD method. When the results are observed financially the MSTDR method decreases the fuel expenses for 13.6% while the NNA method decreases it for 4.6 % in relation to the IRD method.

Table 1 – An average decrease of chosen parameters in relation to the intuitive route determination method

Routing method	Nearest neighbour algorithm	Software tool
Kilometres crossed [km]	4.5%	13.6%
Cost of fuel spent [HRK]	4.6%	13.6%

5. ANALYSIS OF THE SEQUENCE OF TOURS

The delivery sequence has significant consequences in relation to route lengths, delivery times and total expenditure. It is very hard or almost impossible to make an optimal delivery sequence intuitively. The NNA method makes it possible but all possible sequences have to be calculated which represents extra work that consumes time. Modern software tools are, among other things, capable of finding the optimal delivery routes and that is one of their numerous advantages.

Table 2 shows the sequences of delivery by days. With the Monday sequences (22 delivery destinations) each route begins with a different sequence and ends with a different place of delivery. The Monday delivery sequences best show the differences of methods for determining routes because the sequences are not even remotely similar. One of the reasons for the significant differences is the big number of destinations which makes the number of combinations much larger, but it also makes the possibility of savings much greater.

Table 2 – Sequence of delivery by days

	Monday			Wednesday			Friday		
	IRD	NNA	MSTRD	IRD	NNA	MSTRD	IRD	NNA	MSTRD
O1	9	22	5	**14**	**10**	**14**	9	7	7
O2	17	7	19	**13**	**11**	**13**	5	9	9
O3	16	6	18	**16**	**9**	**15**	8	11	11
O4	18	9	20	**15**	**8**	**16**	2	14	14
O5	15	8	17	**3**	**12**	**5**	4	13	13
O6	10	23	4	**4**	**14**	**4**	3	12	12
O7	6	16	7	**2**	**13**	**6**	7	10	10
O8	3	12	22	**12**	**7**	**7**	14	5	5
O9	8	13	2	**8**	**2**	**11**	10	6	6
O10	4	10	21	**11**	**4**	**8**	13	4	4
O11	7	14	3	**7**	**3**	**12**	11	2	2
O12	2	11	23	**9**	**6**	**10**	12	3	3
O13	5	15	6	**10**	**5**	**9**	6	8	8
O14	12	2	14	**5**	**16**	**2**			
O15	11	3	13	**6**	**15**	**3**			
O16	13	4	15						
O17	14	5	16						
O18	23	19	9						
O19	22	18	10						
O20	21	17	8						
O21	20	21	11						
O22	19	20	12						

By analysing the sequence of delivery for Wednesday (15 delivery destinations) it can be noticed that the IRD method sequence and the MSTRD method sequence give the same results for some destinations while on Monday (22 delivery destinations) there were no similarities. This shows that with the smaller number of destinations, the possibility of route similarities increases for different routing methods.

Delivery sequences for Friday bring an interesting situation. The NNA method and the MSTRD method have the identical sequence, however the route given by the software tool is shorter by 2.81 kilometres (Figure 4.), which proves that the software tool found shorter routes. It is also interesting that the NNA method route is three meters longer than the IRD method route and that they have very different sequences. Based on these results it can be concluded that if there are fewer destinations, differences between different routing methods will be smaller and vice versa.

6. CONCLUSION

Modern software tools raise opportunities for expense rationalisation. Further development of such tools will go a long way with bridging the gap between consumers and service providers which is what logistics is all about.

Savings brought by modern software tools should not only be seen through fewer kilometres crossed, even though that is a key component. The advantages are also less fuel consumption, time-saving, less vehicle amortisation, increased traffic safety, decreased emission of toxic fumes and many others.

Modern software route determination tools bring significant savings when there are many destinations on a given route, and do not bring significant savings compared to other analysed methods of routing when there are few destinations on a given route. The question is, is it still worth it for business organisations which don't have a great number of destinations on their route and they have a small rolling stock. Implementation of such systems can be expensive and there are alternative methods which are free and provide significant savings as well. A quality cost-effectiveness analysis should be made before making a final decision about which methods should be used for route determination

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ANALYSIS OF WAREHOUSE LAYOUT INFLUENCE ON PICKING PROCESS

ABSTRACT

Engineering principle used in calculating efficiency of the picking process is guided by the phrase: "A process which you can measure, you can optimise". The result of performance analysis is a key indicator of efficiency or inefficiency and it points to where cost reducing improvements can be made. The core subject of research is the warehouse layout and its influence on the picking process. Focus of paper is also directed to advantages, disadvantages and picking process efficiency calculations under multiple layouts.

KEY WORDS

warehouse; warehouse layout; warehouse performance; picking efficiency; literature overview;

1. INTRODUCTION

Warehouse as an important component in the supply chain is often part of research, especially considering process analysis. Despite technology, labour and space costs associated with operations, warehouses are still unavoidable due to reasons that among other include fluctuating demand and demand costs in bulk transportation and value added services [1].

First thing which is critical to know before any warehouse planning is type of goods which will be stored. Storage layout is chosen depending on the type of goods and storage equipment.

The warehouse layout decisions such as height, width, lane depth, aisle width, cross aisle location and location of I/O point are important as they affect both capital investment (construction od facility) as well as operational costs (space costs, handling costs, etc.)[1].

The dimensions of time, space, and costs are three cornerstones by which an efficient and effective warehouse is measured. A warehouse that is able to accomplish its mission while saving time, space, and costs in the process is on its way to world-class status. Knowing how to use these measures in warehouse design becomes a definite advantage to a warehouse manager [2].

Warehousing represents the management of space and time. The warehousing costs refer to the money allocated for the goods to be moved into or outside the warehouse. These expenses cover equipment and energy costs like ordering, storing and loading the goods, as well as more human costs like labour, shipment or delivery. Warehousing itself refers to taking care, transportation,

loading, unloading, packing and processing of goods between the production and consumption for commodity and other various functions. According to authors Bartholdi and Hackman [3], the warehouse process of order picking takes 70% of time and 55% of costs which makes it a significant process in a warehouse.

The aim of this article is to review the recent research conducted by reference authors in the field of performance evaluation depending on the storage layout. Considering that the picking as a warehouse process takes the biggest amount of time and represents the biggest cost, this paper will show its optimisation due to the storage layout.

2. WAREHOUSE LAYOUT

Warehouse layout is one important factor affecting the order picking proces. Layout design has an effect of more than 60% on the total travel distance, which proves the relationship between warehouse layout and order picking travel distance. Therefore, warehouse layout has to be taken into account while designing the order picking system.

Usually, the unit-load warehouse layout is based on a rectangular shape, in which stock keeping unists (SKUs) arrive on pallets and leave on pallets. Because pallets are mostly standardized and handled one at a time, models of space and labour are simple linear models. It takes about n times the space to store n pallets; and it takes about n times the labour to pick n pallets. Furthermore, in such warehouses, the number of trips to pick full pallets is equal the number of pallets sold. When picking in volume, cartons are stored on pallets and so replenishing is a unit-load process, but picking is not, it creates extra complexities in models of space and labour [4].

Larger warehouses impose greater travel distances for the items inside, and greater travel distances lead to higher labour costs. Unit-load warehouses can, for slow-moving items, be rarely visited, but many have several workers actively storing and picking pallets. The labour cost associated with unit-load warehousing can be significant, especially for large retailers and other importers. The key of reducing labour (picking) cost is organising warehouse layout and storage places [5].

2.1 Classic Single Depth Pallet Rack Warehouse

In traditional warehouse design, storage racks are arranged to form parallel picking aisles, with a cross aisle along the bottom. Figure 1 shows the typical warehouse layout characterized a parallel storage aisle with inbound, outbound (I/O) - point located in the middle. If there are additional cross aisles in a traditional design to facilitate travel between picking aisles, they are arranged at right angles to the picking aisles. Cross aisles are appropriate for order picking operations, in which more than one location is visited per trip, but are inappropriate for the single-command operations considered in this article [5].

In Figure 1. recieving and shipping are on the same side of the warehouse, product flows in and out the same side of the warehouse which is sometimes referred to as a U-flow configuration. The best storage locations, which are at the middle of the common receiving and shipping dock are convenient because a location that is close to receiving would also be close to shipping.

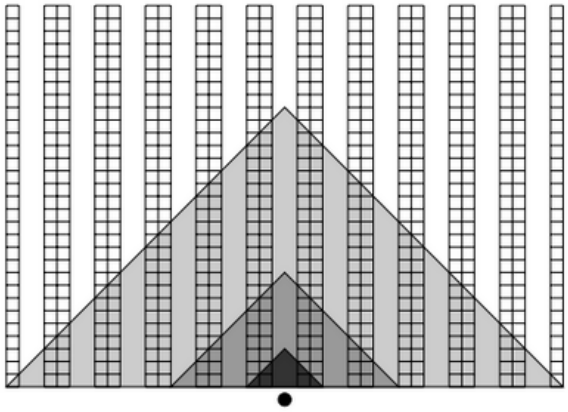


Figure 1 – Classic single depth pallet racking, U-flow
Source: [6]

Some basic characteristics of U-flow configuration are:

- Receiving and shipping located on the same side of warehouse
- Makes the more convenient locations still more convenient, less convenient locations even worse
- Appropriate when product movement has strong ABC analysis
- Provides dock flexibility for both shipping and receiving, e.g. if one experiences a surge of activity it can make use of additional doors from other function [6].

2.2 The Flying-V Warehouse Layout

The flying-V (Figure 2.) layout has a curved cross aisle instead of a cross aisle that is perpendicular to the aisles. This enables travel from the starting point (depot) to the storage locations that can be 10% shorter than those of the standard layout. Disadvantage assumes that pickers must make a rather sharp turn when entering the lower part of the pick aisle from the crossing aisle [7]. To solve this problem and simultaneously reduce travel distances, authors suggest fishbone storage layout to be used.

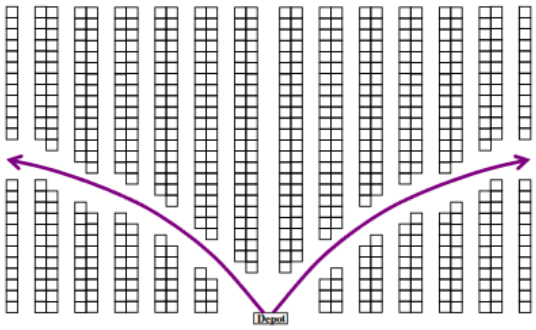


Figure 2 – Flying-V layout
Source: [7]

The model that relaxes the straight middle aisle assumption comes up with a V-shaped middle aisle with an increasing intersection angle with the pick aisles as one moves away from the I/O point. The Flying-V design offers about 10% improvement over the traditional design, because the main advantage behind the Flying-V design is the crossing aisle that cuts diagonally across the picking aisles which enables the workers to move faster and get to most of the locations more quickly [8]. Workers still need to travel in a strict rectilinear fashion only for locations near the bottom of the warehouse.

2.3 The Fishbone Warehouse Layout

Fishbone warehouse layout assumes that the picking aisles must be parallel to each other while picks along the bottom of the Flying-V design still require rectilinear travel. The fishbone aisle design (Figure 3.) overcomes this disadvantage by rotating picking aisles in this region by 90 degreees.

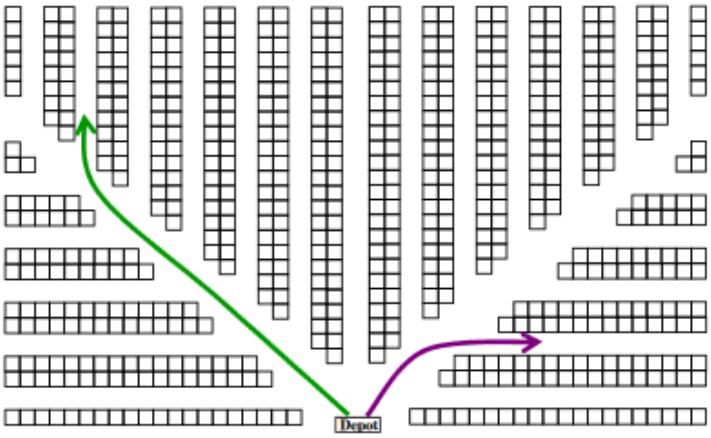


Figure 3 – Fishbone warehouse layout
Source: [7]

Using the fishbone layout it is possible to reach any of the storage locations by almost straight travel from the depot. This strongly decreases the required travel distances. It must be noted that the fishbone and flying-V layouts appear to be most effective for unit load operations, when the number of stops per route is once or twice [7].

The fishbone layout also incorporates the V-shaped cross-aisles, below the V are horizontal, while the aisles above the V are vertical. The expected distance to a pick in the fishbone design are approximately 20% shorter than of those in a traditional warehouse. Similar to traditional layouts with cross-aisles, these alternative layouts also require a facility 3-5% larger than those of traditional layout, which was designed to minimize the footprint of a warehouse. According to authors Đukić and Opetuk [9], a comparison of fishbone warehouse that has been optimized for dual-command with traditional warehouses which have been optimized in the same manner has shown that an optimal fishbone design reduces the dual-command travel by 10-15%.

A drawback of the fishbone design is limited access to the storage space due to the single central P&D point.

3. KEY PERFORMANCE INDEX - PICKING

The order picking process in a warehouse involves selecting and gathering specified amount of right SKU's in accordance with the order and it is composed of lifting, moving, picking, putting, packing and other related activities [11]. The process involves one individual collecting order, or more warehouse workers, also order picking can be manual or automated. In manual order picking, the picker gathers units from their locations and then transports them to a packaging area. In the case of automated picking, that is, automated storage and retrieval systems, system retrieves one or more unit loads and places them to a picking station. After that, the picker takes products on orders, and the remaining items on the unit loads are transferred to storage again.

Order picking typically accounts for about 55% of warehouse operating costs, and order picking itself may be further divided into activities described in the following table [10]:

Table 1 – Order picking activities

Activity	Order picking time [%]
Traveling	**55**
Searching	**15**
Extracting	**10**
Paperwork and other activities	**20**

Source: Made by the authors according to [10]

The warehouse worker's travelling makes up the greatest part of the expense in order-picking, which in itself is the most expensive part of warehouse operating expenses. Much of the design of the order-picking process is directed to reducing this unproductive time. In manual order-picking each worker is given a pick sheet, which lists the SKUs to be picked, in what amounts and where they are to be found. The SKU's are listed in the order in which they are normally encountered as the picker moves through the warehouse [12].

$$Pick_t = \frac{\sum \Delta t(Pick)}{OrdLi\ Pick}\left(\frac{hour}{Orderline}\right) \text{ [13]} \qquad (1)$$

Where are:

∑Δt (Pick) - time between the instants when operator starts to pick an order and when the picking finishes (hour)

OrdLi Pick - number of order lines picked (nb/month)

This formula represents the picking time, lead time to pick an order line. Picking time can be reduced by choosing an optimal storage layout and by planning the SKU's through ABC analysis or placing I/O on the different sides of the warehouse.

$$Pick_p = \frac{OrdLi\ Pick}{WH\ Pick}\left(\frac{Orderline}{Labor\ Hour}\right) \text{ [13]} \qquad (2)$$

Where are:

OrdLi Pick - number of order lines picked (nb/month)

WH Pick - sum of employee labour hours working in picking activity (hour/month)

$Pick_p$ represents picking productivity, it is productivity indicator. Productivity can be defined as the level of asset utilization, or how well resources are combined and used to accomplish a specific or desirable result. Picking productivity is the total number of products picked per labour hours in a picking activity. Every warehouse has typically labour-intensive activities. This indicator can be looked as labour efficiency, but labour efficiency includes working hours.

$$Pick_Q = \frac{Cor\ OrdLi\ Pick}{OrdLi\ Pick} \text{ [13]} \quad (3)$$

Where are:

Cor OrdLi Pick - number of order lines picked with the right product and the right quantity (nb/month)

OrdLi Pick - number of order lines picked (nb/month)

Picking accuracy is the number of orders picked correctly per orders picked. It measures quality which can be divided in two groups: some metrics are related to internal quality operations, where others focus on the customer level. Picking accuracy is one of the few metrics which measure the internal warehouse quality of operations. Picking accuracy can vary depending on the picker, while human error is a key factor here.

Picking productivity and picking time can be improved by reducing the time or travel between SKU location for each order. SKUs with a lot of movement per storage location must be stored in the best locations. If we identify those SKUs that generate the most frequent visits per storage location, it can be stored in best locations.

$$Average\ visits\ per\ storage\ location = \frac{Number\ of\ units\ shipped}{Number\ of\ units\ in\ storage} \quad [3] \qquad (4)$$

For example, SKU's that are stored in average quantity 5 and which moved 20 units last year would have generated about 20/5 = 4 visits per storage location, which is more than SKU's that move 100 units but was stored in quantity 50.

So to minimize labour costs the following actions are required:

- Rank all the available pallet positions of the warehouse from least cost to greatest cost
- Rank all SKUs from most to least turns
- Move down the list, assigning the pallets of the next fastest-turning SKU's to the next best locations available [3].

3.1 Routing Methods in Traditional Layout Warehouse

The picking starts at the depot, and the picker has to visit all pick locations and finally has to return to the depot. The objective of routing policy is to sequence the items on the pick list to ensure a route with efficient travel through the warehouse. The layout of this type of warehouse consists of parallel aisles, and two cross aisles, one in the front, and the other in the back.

In addition, optimal routes may seem illogical to order pickers. So in this paper the most common practice for routing orders will be described.

The most common practice for routing the order picker is an S-shape seen in Figure 4 (traversal).

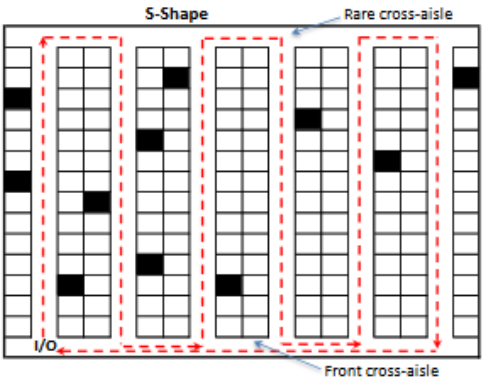


Figure 4 – S-shape routing
Source: [4]

Under this policy, the order picker begins by entering the pick aisle closest to the I/O point. Any isle containing at least one item is traversed over the entire length. No backtracking is permitted in any isle. Aisles with no picks are skipped. After picking the last item, the order picker takes the shortest route back to the I/O point [4]. S-shape starts with the left-most pick aisle and traverses in

order each nonempty pick aisle completely except possibly the right-most one, resulting in a serpentine path.

Second most common strategy is the largest gap strategy shown in Figure 5. It looks similar to the mid-point strategy except the order picker enters an aisle as far as the largest gap within an aisle.

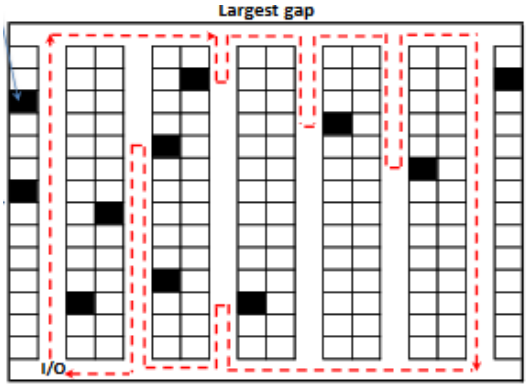


Figure 5 – The largest gap routing
Source: [4]

The gap represents the separation between the two adjacent picks, between the first pick and the front cross-aisle, or between the last pick and the rear cross-aisle. If the largest gap is between two adjacent picks, the order picker performs a return route from both ends of the cross-aisle. Otherwise, a return route from either the front or rear cross-aisle is used. So the largest gap within an aisle is the portion of the aisle that the order picker does not traverse [4]. According to Moayad [14] the heuristic calculation for the largest gap separation should calculate each pick aisle, and the maximum of the largest gap between any two items, the distance between the front corner and the item nearest to it, and the distance between the back corner and the item nearest to it. The picker starts traversing the left-most pick aisle completely, enters from the back cross aisle to the pick aisles, picking the items until the largest gap, and returning to the back cross aisle. After traversing the right most nonempty pick aisle completely, the same procedure is applied from the front cross aisle for the pick aisles where the distances are maximum.

Using the combined (composite) heuristic, aisle with picks are either entirely traversed or entered and left at the same end. This methods were originally developed for single-block warehouse.

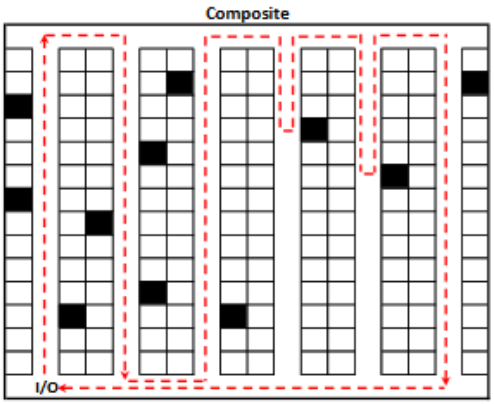


Figure 6 – Composite routing
Source: [4]

The combined routing is an extension of aisle-by-aisle in that it also allows for entering and exiting a pick aisle more than once, but the sub aisle can still be entered only once.

4. CASE STUDY

Case study in this paper will be a review and retrospect. The researcher [14] took sample of 600 items and 6 feasible layout alternatives for implementation of the methodology and for performing the desired numerical analysis in such a way to combine effects of the three storage assignment policies and the warehouse shape on the efficiency of order picking in terms of the travel distance and performance.

The author presented six different feasible warehouse layout structure alternatives represented by D= [(M1=30, B1=31), (M2=15, B2=60), (M3=10, B3=90), (M4=8, B4=112), (M5=6, B5=148), (Mf=5, Bf=178)]. The alternatives are selected to be investigated with the three storage assignment policies. All six layout structures share the same dimensional parameters of Wc=11m, Wm=5.8m and Wb=0.8m and number of random runs R. The layouts in Figure 7 have different dimensions between the six warehouse layout alternatives.

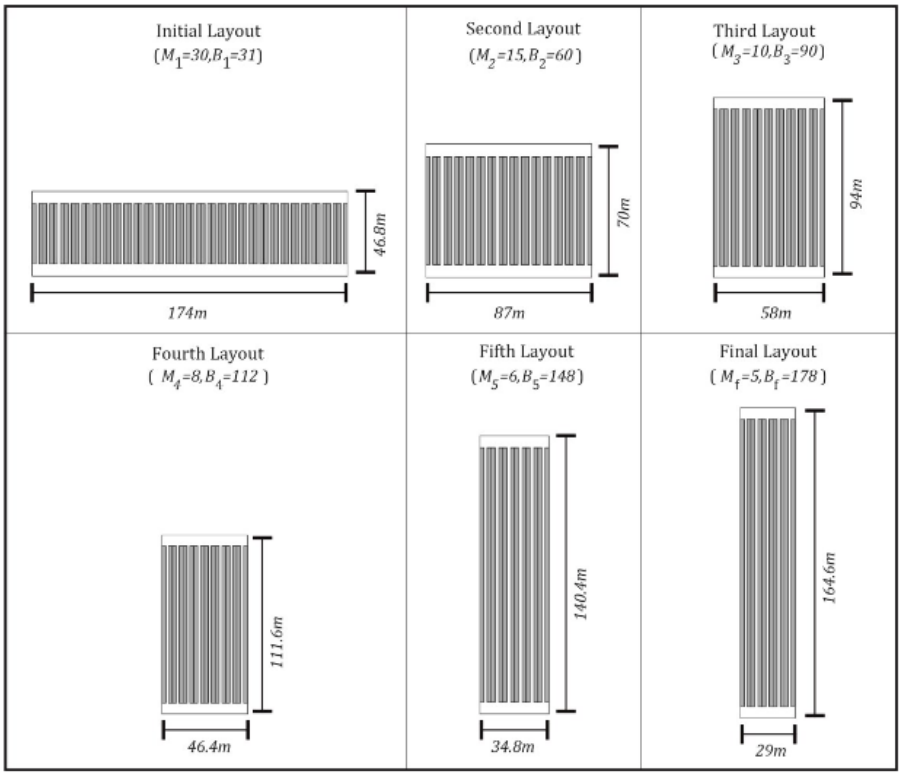


*Figure 7 – Layout representation of the six alternatives in D**

The software for this simulation was Python language, in order to facilitate efficient implementation and to obtain full sets of results for a wide range of scenarios and situations. Entered parameters were M, B, Wc, Wm, Wb and size of the pick list N. The total expected travel distances versus the pick list size under each of the full/turnover policies, including the north-north and north-south assignment directions, nearest location and random storage policies for the layouts are shown on the Figure 8.

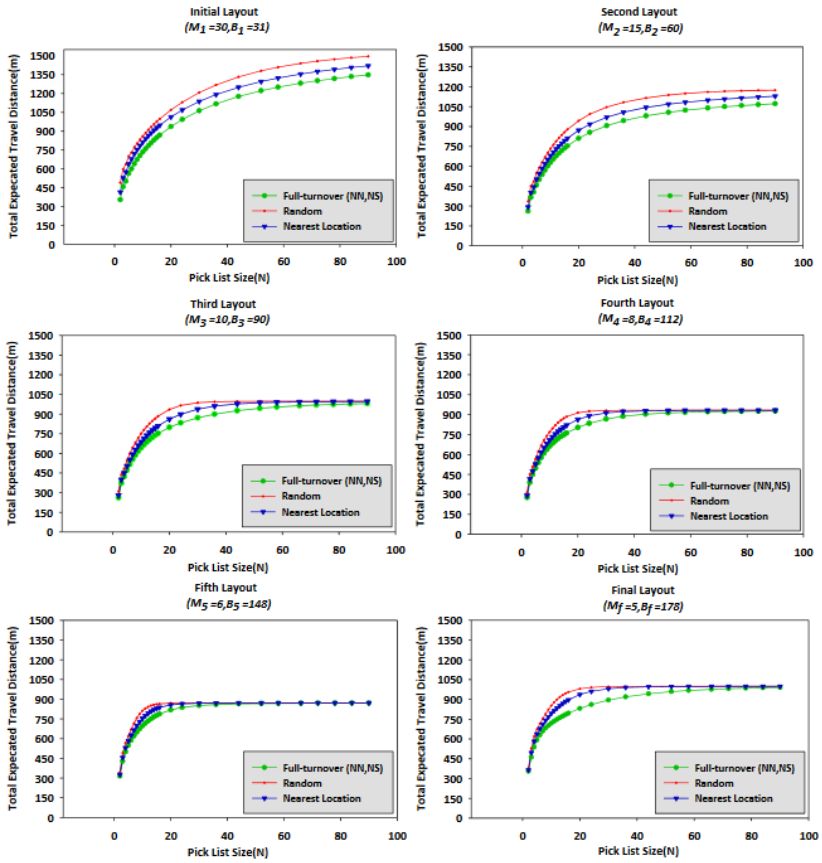


Figure 8 – Values of the three storage policies for the six layouts
Source: [14]

By comparing the total expected travel distance values from all six layouts using the three different policies, as the Figure 8 shows, the effects of the three storage assignment policies can be determined. The full-turnover policy, in which its two distinct assignment directions, north-north, and north-south, have similar outcomes results in the lowest total expected travel distances. This is due to the declining trend of pm(m) values obtained by the full-turnover policy.

The picker is more likely to enter the first few aisles which are closest to the depot and have the highest pm(m) values, rather than entering all M aisles including other aisles with lower pm(m) values, to retrieve the N picks.

The nearest-location policy results in moderate total expected travel distances compared to the full-turnover and the random policies. This is caused by the cyclic behavior of pm(m) values among the aisles, which means that the order picker is more likely to enter aisles with a peak pm(m) value than the other M aisles, including aisles with valley pm(m) values, to retrieve the N picks. The number of aisles in this case is higher than those in full-turnover policy, which is why the full-turnover policy generally results in shorter total expected travel distances compared to the nearest-product policy.

The random storage policy results in the largest total expected travel distances among the three storage policies. Order picker will more likely enter more of the M aisles to retrieve the N picks, when compared to previous storage policies. The results also clearly indicate that the total expected travel distance values obtained by a policy generally approach the values of the order policies as the size of the pick list increases [14].

Looking at the Figure 8 and comparing the first and fourth layout performance, a big difference can be observed. In the first layout the Total Expected Travel Distance is about 1400m and on the

forth layout the Total Expected Travel Distance is about 900 m., which is 500 meters less. If we convert that data to percents, the third layout is 57% more efficient than the first. Earlier in this paper, it was mentioned that the picking cost includes activities such as travelling, searching and extracting. The travelling cost participates with 57% in full picking process cost. The best way to reduce travelling cost is to reduce travel distance and that travel distance could be reduced by optimizing the storage layout.

5. CONCLUSION

Warehouse represents the management of space and time. When optimizing the space segment, time segments could also be reduced. Before any warehouse planning, it is critical to know which type of goods will be stored.

The focus of this article was to show how storage layout affects the process of picking. It is shown that the warehouse process of order picking takes 70% of time and 55% of costs which makes it a significant process in a warehouse.

In order to reduce time segment (travel distance) which is more than 60% effect of the warehouse layout, three types of storage layouts were analysed.

Classic single depth pallet rack warehouse layout is more appropriate for order picking operations in which more than one location is visited per trip. The U-flow configuration makes it more convenient for the locations that are convenient and less convenient locations even worse.

The Flying-V design offers about 10% improvement over the traditional design, because cross aisle cuts diagonally across the picking aisles and offers an advantage in the way that the workers can get to most locations more quickly. Workers need to travel in a strict rectilinear fashion only for the locations near the bottom of the warehouse.

The fishbone layout shortens the expected distance of picking for approximately 20% compared to a traditional warehouse, because it overcomes the disadvantage of travelling in a rectilinear position by rotating bottom picking region aisles by 90 degrees.

The last part of the article shows a case study with six different layouts (in width and length). As it is mentioned earlier the order picking time includes 55% of travelling. The case study showed that the optimal layout can reduce travel distance by 57%.

According to before mentioned facts, it is visible that one of the ways to reduce time of travelling and picking time is to choose an optimal warehouse layout, thus making the picking process more efficient.

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SOFTWARE TOOL FOR PLANNING OF CITY BUS TRANSPORT ELECTRIFICATION

ABSTRACT

This paper presents a software tool that is intended as a support in simulation, optimization and decision making in the process of planning of city bus transport electrification. It provides techno-economic comparison between fleets of conventional buses and different types of electrified buses. The tool consists of four software modules that are responsible for key steps in providing the final result: (i) module for processing of recorded driving cycle data, (ii) module for simulation of city bus fleets, (iii) module for e-bus fleet charging management optimisation; and (iv) module for conducting the techno-economic analysis itself.

KEY WORDS

ICT tool; transport electrification; driving cycles processing; city bus simulation; charging management; techno-economic analysis;

1. INTRODUCTION

Due to environmental concerns, there is a strong tendency of electrifying the existing road transport system, which mainly relies on internal combustion engine (ICE)-based propulsion technology. Electric vehicles (EV) are meant to be most viable solution for the replacement of the ICE-propelled vehicles. Apart from reducing pollutant and CO_2 emissions, EVs are characterised by substantially reduced noise pollution, lower operating costs (including energy and maintenance cost) and generally better driving characteristics; while on the other hand, higher investment cost, slow battery charging and limited driving range inhibit their faster proliferation. This is why the transition to fully electric vehicles (FEV or BEV) is characterized by the presence of hybrid electric vehicles (HEV) and plug-in hybrid electric vehicles (PHEV).

A natural candidate for electrification relates to city bus fleets, aiming at improvement in city air quality and reduction of noise. Since the city bus operation is highly determined (i.e. known in advance) and intermittent, the range- and charging-related issues may be overcome to a significant extent by combining fast charging at end stations and slow charging in depot centre. In order to encourage and accelerate replacement of conventional vehicle fleets with electric ones, detailed techno-economic analyses comparing the conventional and EV fleets should be conducted.

First, all routes on which a conventional bus fleet operates should be analysed, and the most relevant ones to be covered by EV buses (e.g. routes in city centres) should be identified. Then, driving cycle data (e.g. vehicle velocities, GPS positions, elevation, etc.) and powertrain data (e.g. engine speed and torque, gear ratio, etc.) should be recorded and collected in real time for the buses

that operate on the selected routes, based on installation of a GPS/GPRS tracking. In order to cover all typical operations of the considered bus fleet, the driving data should be continuously recorded over the full year period. Then, the recorded driving data should be post-processed and analysed in order to reveal the main characteristics of the considered fleet. Afterwards, a hypothetical fleet of e-buses should be simulated over the given bus routes in order to obtain the information about the total amount of fuel and electricity consumed. This information is fed into an EV charging management optimisation algorithm to determine the charging schedules for both fast (daily) charging located at the end stations and slow (overnight) charging conducted at depot. Finally, a detailed techno-economic analysis of conventional and e-bus fleets should be conducted by using the obtained data.

To facilitate this process, a software tool for planning the city bus transport electrification has been developed and it is described in this paper. The overall tool is organised into four modules: (i) post-processing and analysis of recorded driving cycles, (ii) simulation of conventional and e-bus fleets, (iii) e-bus fleet charging management optimisation, and (iv) techno-economic analysis.

Similar efforts in calculating cost-effectiveness of city buses exist in literature. Software tool presented in [1] uses defined bus schedules and routes along with assumed fuel and energy consumption, whereas tool presented in this paper uses real driving data recorded on actual vehicles as well as detailed simulation models of e-buses which allows more precise fuel and energy consumption calculation.

The paper is organised as follows. Section 2 describes the architecture of the developed software application. Sections 3 describes the individual software tool modules. Section 4 describes the obtained simulation results of a techno-economic analysis for an illustrative example of conventional and electric vehicles. Concluding remarks are given in Section 5.

2. ORGANIZATIONAL STRUCTURE OF SOFTWARE APPLICATION

The developed software tool for planning of city bus transport electrification is implemented in the object-oriented programming language Python by using built-in modules and packages like *numpy* and *scipy*, whose main advantage is that they are implemented in C++ programming language, thus significantly increasing the program execution speed. The overall application consists of the following tools (see Figure 1): (i) Data Post-processing Module (DPPM) – tool for post-processing and analysis of recorded driving cycles, (ii) E-bus Simulation Module (EBSM) – tool for simulation of various bus models (i.e. conventional, hybrid electric, plug-in hybrid electric and fully electric ones), (iii) Charging Optimisation Module (COM) – tool for EV fleet charging optimisation, and (iv) Techno-Economic Analysis Module (TEAM) – tool for techno-economic analysis related to the replacement of conventional vehicle fleet with an electric one. The aforementioned tools are organized within the application as independent modules.

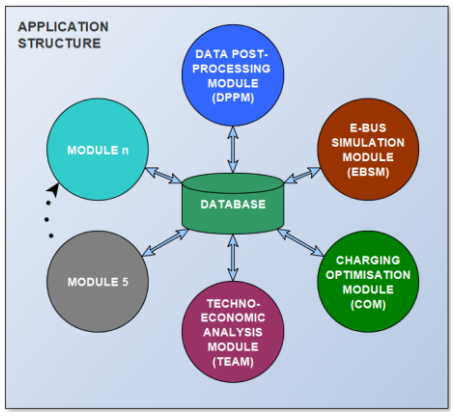


Figure 1 – Modular structure of the developed software application

Connections between the developed ICT modules (DPPM, EBSM, COM and TEAM) are defined as shown in Figure 2. The application takes recorded driving cycles data as main input, which represent the basis for further calculations. Each of the developed modules has its own output dataset, along with the dataset which it shares or passes to the other modules (data streams are defined by the colourful arrow lines). The data exchange between the software modules is realised through a shared database and specific files (i.e. CSV, JSON, TXT file formats). The overall operation of the ICT tool is designed as follows, and it results in calculation of the *total cost of ownership* (TCO) of a vehicle fleet, as its final output:

- The recorded driving cycle data is processed and stored into database by DPPM, thus preparing it for using in other modules. Data processing includes various filtering and interpolation methods, along with calculation of basic statistics of the city bus transport system.
- Various types of buses (conventional, HEV, PHEV, and BEV) are meant to be simulated within EBSM over recorded driving cycles in order to calculate their fuel and electricity consumption. Apart from providing the operational cost of bus fleet, the EBSM is also designed to be the platform for optimisation, development and verification of realistic powertrain control strategies, whose description is beyond the scope of this paper.
- A hypothetical fleet of e-buses is simulated within COM over the given driving schedules and using the driving cycles processed in DPPM. This simulation includes both daily charging of e-buses via fast chargers and overnight charging in depot. As a result, the information related to a total distance travelled, required amount of electric energy needed for charging, and the required number of e-buses and charging stations, necessary to fulfil the daily driving schedule, is obtained.
- The TCO is calculated within TEAM for both conventional and electric vehicles by using the aforementioned resulting datasets, and data regarding the loan payments, registration renewal, insurance, maintenance, and irregular costs as inputs to TEAM.

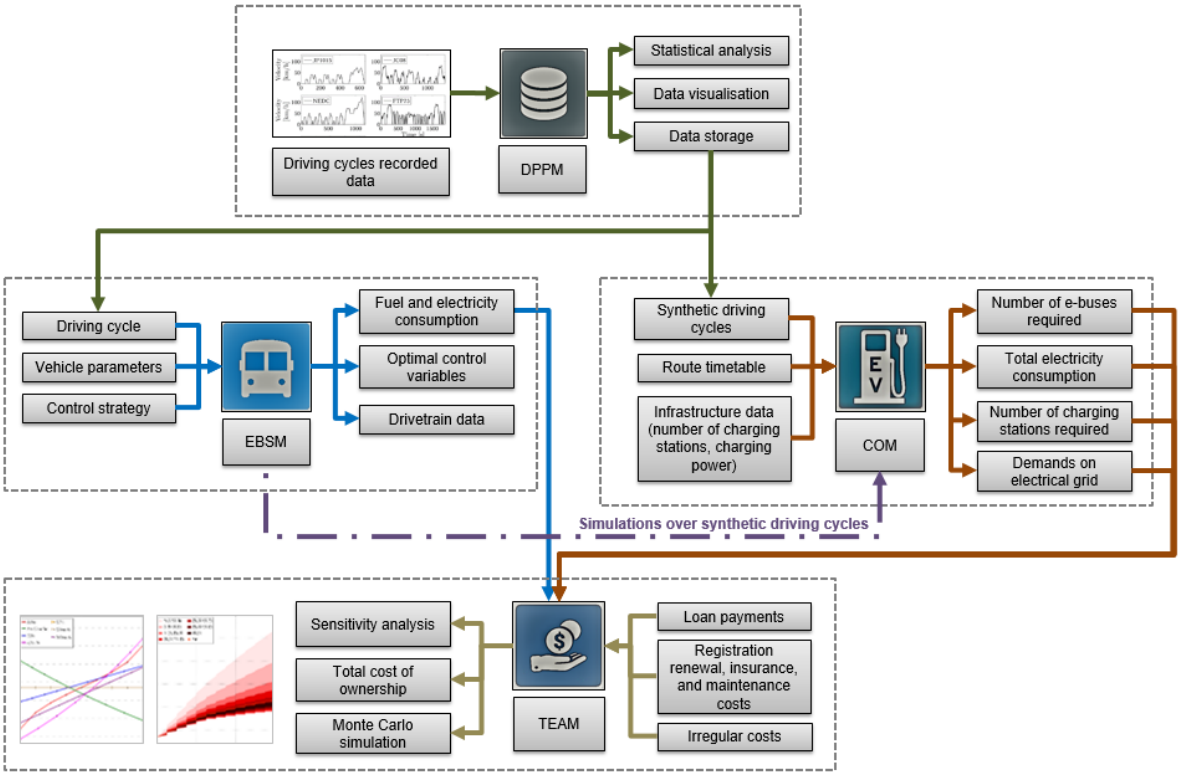


Figure 2 – Scheme of connections between developed ICT modules (DPPM, EBSM, COM and TEAM)

3. DESCRIPTION OF ICT TOOLS

This section gives brief description of the developed ICT tools (DPPM, EBSM, COM and TEAM), including their main functionalities and the role in calculation of the TCO as the final output.

3.1 Data Post-processing Module (DPPM)

Methodology of recording the driving routes and taking measurements of relevant driving parameters/variables for public-bus fleet is based on utilizing the telemetry electronic tracking module (e.g. STM-Eagle unit, manufactured by Artronic, Croatia), which is equipped with GPS receiver, GPRS communication line and CAN communication with vehicle powertrain. These recorded (raw) driving cycles (velocity vs. time and road slope and vehicle mass vs. travelled distance profiles) are then post-processed inside DPPM software module, thus representing key inputs to be used in computer simulations of conventional and e-bus fleets, aimed at calculation of related operational costs and defining proper charging system structure and management. The module is divided into three main categories:

1. **Data insertion** - operations related to insertion of recorded driving data into the database. These operations include various methods for adapting the input data format along with the validity checks (e.g. existence of duplicate data within files).
2. **Data processing** - operations related to organisation of stored driving data as driving cycles (an unique driving cycle number is assigned to each data record), along with the data filtering and interpolation. Fig. 5 in Subsection 3.2 shows an example of driving cycle data postprocessed by the DPPM.
3. **Calculations** – operations related to calculation of: (i) vehicle parking time, (ii) basic statistics and (iii) limit powertrain curves. The process of vehicle parking detection calculates when, where and for how long the vehicle has been parked. The basic statistics is calculated for entire vehicle fleet, individual vehicles and their respective driving cycles and includes a total of 43 features (e.g. vehicle total distance travelled, idle and cruise time share, number of stops per kilometre, mean, maximum, and minimum values of velocity, acceleration and elevation height, corresponding values of standard deviations, etc.; see Fig. 3 for an example). The limit curves calculation process includes vehicle maximum acceleration in dependence on velocity, and maximum acceleration and maximum velocity in dependence on road slope.

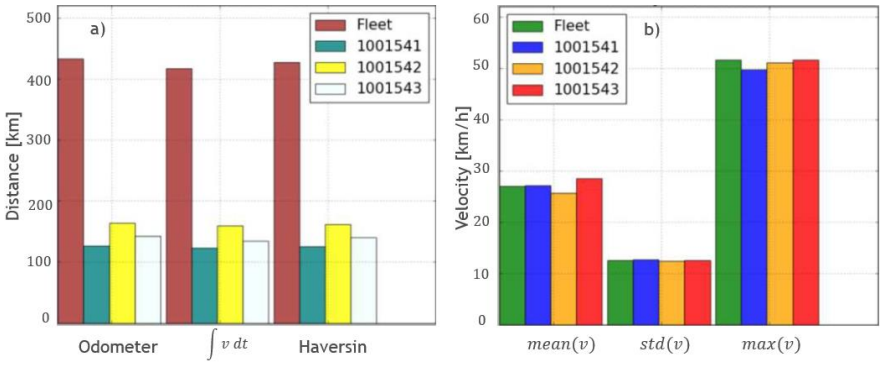


Figure 3 – An example of basic statistic plot: a) total distance travelled, and b) velocity characteristics for individual vehicles and entire fleet.

3.2 E-bus Simulation Module (EBSM)

This module provides a simulation environment for different types of buses (i.e. conventional, HEV, PHEV and BEV), where the considered bus model is meant to be simulated over realistic driving cycles (obtained and prepared by DPPM module), thus providing a basis for a comparative analysis of

different types of buses in terms of fuel and electric energy consumption. The e-bus simulation also provides an insight into vehicle operation characteristics such as demanded power on wheels, torque and rotational speed values of an electric motor and internal combustion engine, amount of energy recuperated by regenerative braking, etc. Simulation models of the selected bus configurations (conventional, HEV, and PHEV and BEV) are built up along with the corresponding realistic powertrain control strategy. Also, the off-line control variable optimisations are conducted for HEV and PHEV powertrains by using dynamic programming (DP) optimisation method, in order to gain insight into the optimal powertrain operation for different driving conditions and the optimal/minimal fuel consumption. The globally optimal DP results are used as a benchmark for the design and verification of a realistic energy management control strategy. The proposed online control strategy combines the rules (rule-based strategy, RB) and the instantaneous optimisation of equivalent consumption (Equivalent Consumption Minimisation Strategy, ECMS) for which is verified that even with the lack of road grade and driving cycle preview, it can still approach the globally optimal results by the margin of up to 2% in terms of fuel consumption for both HEV- and PHEV-type.

Currently at the market, Volvo 7900 city bus platform all three EV variants (HEV / PHEV / BEV [2], [3]). Therefore, this bus platform has been taken as a basis for this research, without losing generality of the research, because powertrain simulation model can easily be modified, either by changing powertrain parameters (e.g. battery capacity), consumption and efficiency maps, or by changing the powertrain structure (e.g. from parallel to series), thus representing another bus type. Volvo 7900 HEV and PHEV are parallel hybrid powertrains, which at the current state-of-the-art may be considered as a good trade-off choice between operational and investment cost of the bus. For the purpose of simulation, all Volvo e-buses were modeled as backward models based on point mass representation of the vehicle given in configurations showed in Fig. 4.

By using the developed ICT tool (EBSM), a simulation of Volvo 7900 HEV over the selected driving cycle (see Fig. 5) has been conducted for demonstration purposes. The driving cycle was recorded on the circular bus route, by using a precise GPS receiver [4]. The bus station Babin kuk is considered to be the starting and the end point of each driving cycle, which is terminated on the eastern part of cycle by the bus station Pile. The total length of the given route (Babin kuk – Pile – Babin kuk) is around 11.8 kilometers. The initial vehicle battery state-of-charge (SoC) value is set to 0.5 (50% of battery capacity), while the previously developed realistic control strategy RB+ECMS is used for powertrain control [5]. The internal combustion engine (ICE) fuel consumption map and the electric motor/generator (M/G) efficiency map are represented by Willans approximation maps [6], while each of the battery types are represented by the exact numerical maps (i.e. battery open circuit voltage *OCV*(*SoC*) and internal resistance *R*(*SoC*) profiles). The corresponding ICE and M/G operating points, along with the fuel consumptions and SoC responses are shown in Fig. 6. As it can be seen from these results, operating points of both ICE and M/G largely lie in efficient map regions. The operating points distributed outside of the maximum torque curve in the generator quadrant (electromotor torque is negative, $\tau_{MG} < 0$; braking phase), represent the points where the bus powertrain could not recuperate all the braking energy by the means of regenerative braking (most of the energy is regenerated, while the rest is covered by mechanical brakes).

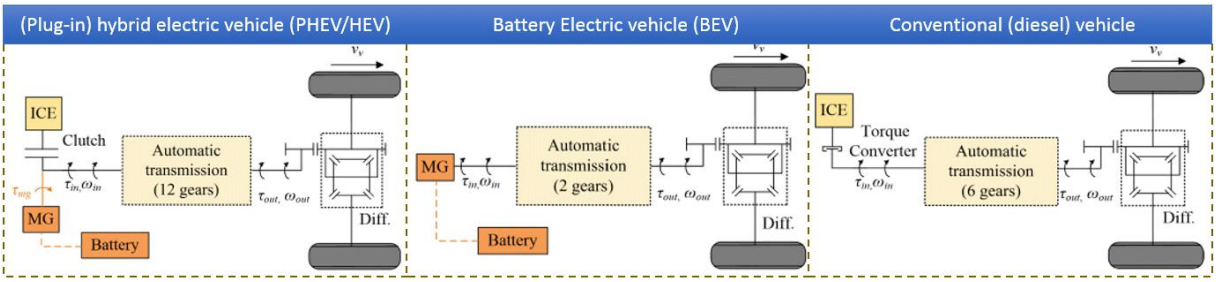


Figure 4 – Driveline configurations of Volvo 7900 PHEV/HEV, BEV, and conventional buses [2].

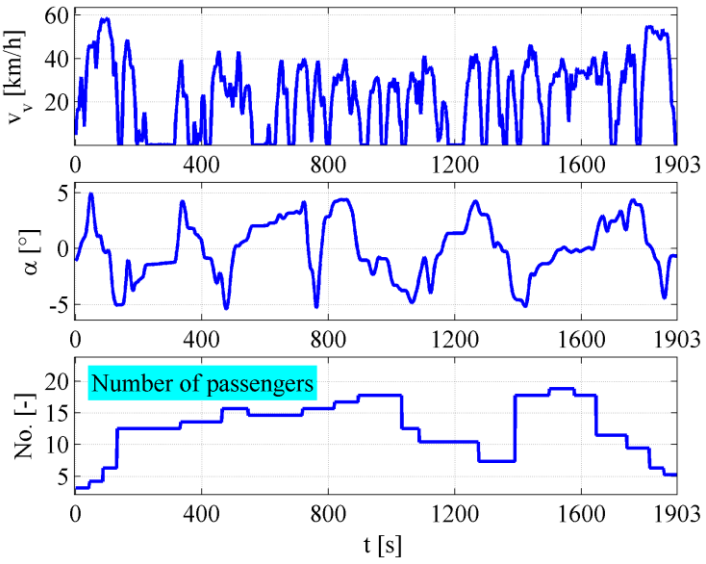


Figure 5 – City bus driving cycle used in HEV/PHEV simulation, including vehicle velocity v_v, road grade α, and number of passengers over time profiles.

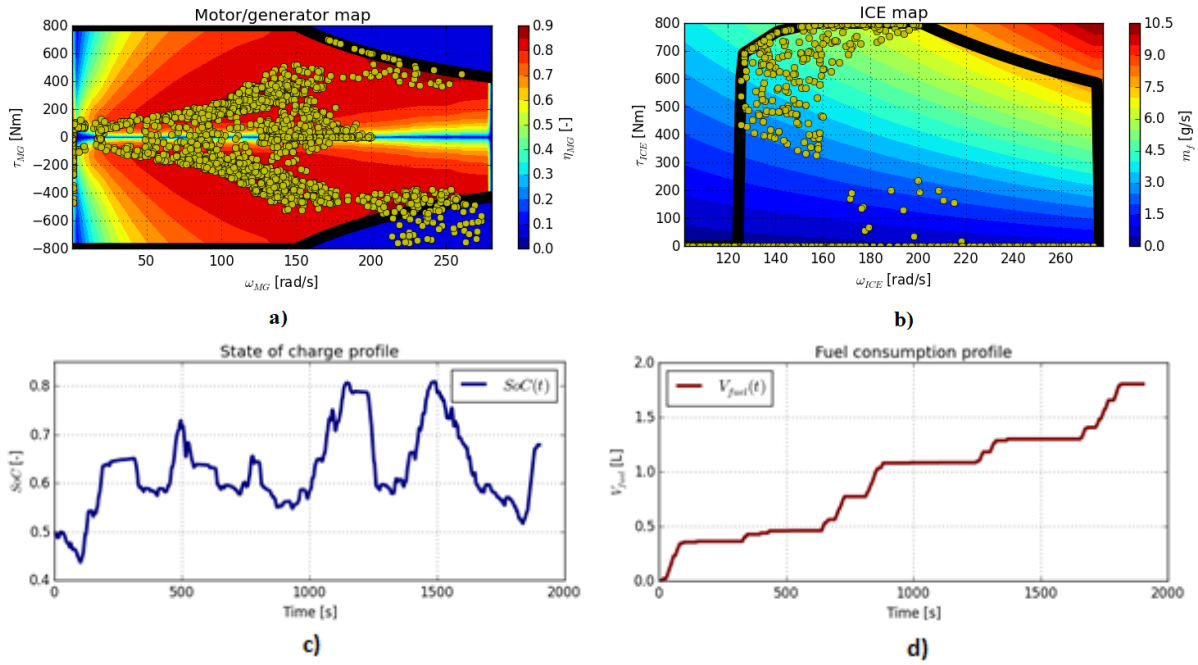


Figure 6 – Simulation results for a Volvo 7900 HEV bus: a) M/G operating points distribution, b) ICE operating points distribution, c) battery SoC vs time profile, and d) cumulative fuel consumption vs time profile.

3.3 Charging Optimisation Module (COM)

A generic framework of e-bus fleet operation is established through this software module, which serves as a basis for conducting an e-bus fleet simulation and charging power optimisation. The generic e-bus fleet operation is divided into two parts: (i) e-buses serving daily city driving missions according to prescribed timetables over given routes, and (ii) e-buses being parked in a depot and being optimally charged according to prescribed criteria. Since e-buses have limited range, a daily fast charging of e-buses is allowed between driving missions in order to ensure that minimal number of e-buses can serve prescribed timetables. In order to provide a realistic e-bus fleet charging conditions, the daily fast charging is separated from the overnight charging in a depot, and is conducted through simple heuristic rules. Functionality of the developed framework was

demonstrated through the case study assuming bus time schedules on the aforementioned circular bus route Babin kuk – Pile – Babin kuk in the City of Dubrovnik. In order to provide realistic scenario, different synthetic driving cycles over the route were generated by using Markov chain statistical methodology and the corresponding transition probability matrix (TPM), which is parameterised by using the previously recorded and processed GPS data on the considered bus route (see Subsection 3.1). The framework involves five different subjects (see Fig. 7):

- **Depot** - a place where e-buses are sheltered, maintained and charged when they are out of service;
- **E-bus fleet** - a hypothetical city bus fleet consisting of all-electric buses (propelled only by electric power from a battery);
- **Home station** - represents the starting point of a given bus route (only one home station is shown in Fig. 7 for the sake of illustration, although the number of home stations in the framework is not limited);
- **EV charging station** - an element of an infrastructure that supplies electrical energy for an e-bus fleet charging (can be placed in depot or on specific location in the city such as end stations, with the maximum charging power allowed to be specified by the user);
- **Route timetable** - a time schedule of bus departures from the corresponding home station that needs to be fulfilled.

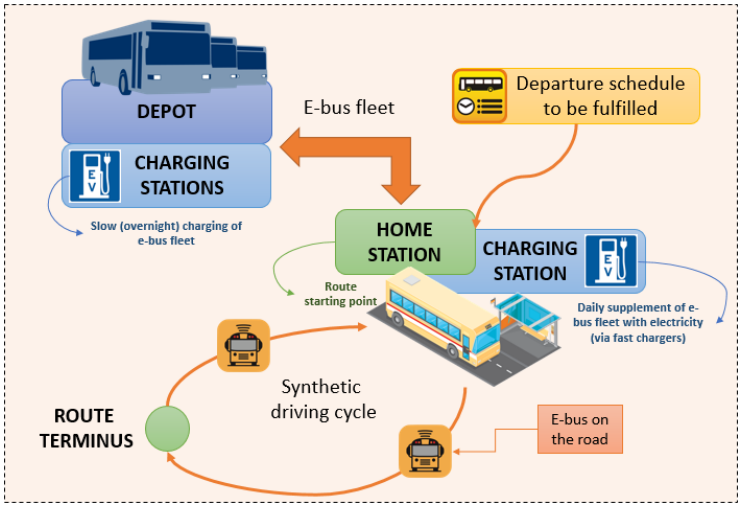


Figure 7 – A generic framework of an e-bus fleet operation.

An e-bus fleet modelled within EBSM (see Subsection 3.2) is simulated over the synthetic driving cycles that are generated based on DPPM outputs. The purpose of the e-bus fleet simulation is twofold: **(a)** to obtain the data required as inputs for the charging optimisation algorithm, and **(b)** to provide specific operating and investment costs for TCO analysis (see Fig. 8). The former data, referring to the charging optimisation, consists of the following distributions: **(i)** departure times of e-buses from the depot along with their SoC-at-departure values, **(ii)** arrival times of e-buses to depot along with their SoC-at-arrival values, **(iii)** time intervals in which the e-buses were available for charging, and **(iv)** time instants in which the e-buses were disconnected from the grid. The latter group of data, referring to TCO analysis, includes the following parameters: **(v)** number of e-buses required for fulfilling the imposed driving schedule for a given route on a daily basis, **(vi)** total amount of electrical energy consumed by charging stations located at home stations (for a daily fast charging of active e-bus), and **(vii)** the number of corresponding fast charging stations required along with the demands on the electrical grid and charging power supply.

The EV fleet slow charging in depot is managed based on optimisation which includes both charging cost minimisation and penalisation of aggregate charging power peaks. The problem can

conveniently be formulated to be solved by using available linear programming (LP) and particularly quadratic programming (QP) solvers [7]. Illustration of the e-bus fleet charging optimisation results, for the case of three e-buses within fleet, are shown in Fig. 9; for the case of only minimising the charging cost (Fig. 9a), and for the case of only minimising the electrical grid power peaks (i.e. peak shaving effect; Fig. 9b). In both cases the upper constraint on the maximum power which can be drawn from the grid is satisfied (i.e. $P_{max,grid}$ = 30 kW). Also, it is worth noting that the aggregate charging power profiles obtained as the LP solution lies within the low-tariff electricity intervals, unlike with QP where these profiles are expanded into the high-tariff intervals to minimise the grid power fluctuations.

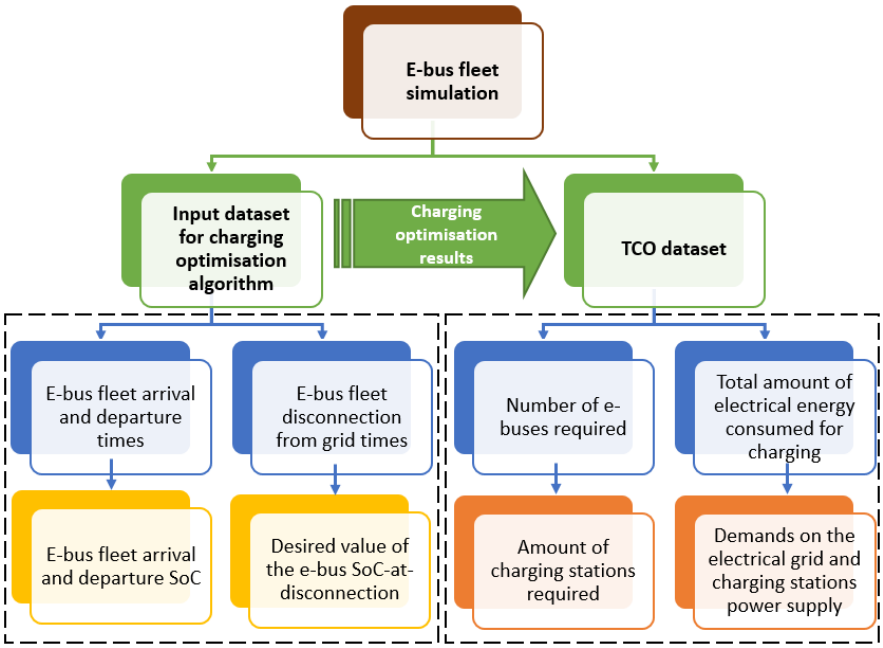


Figure 8 – Interface of e-bus fleet simulation toward the charging optimisation and TCO modules.

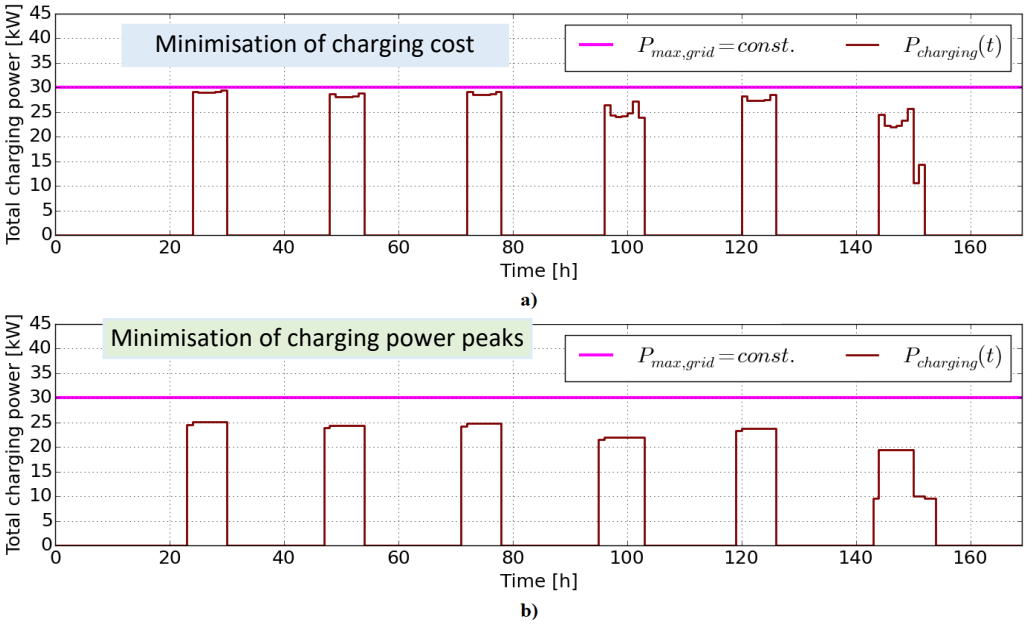


Figure 9 – Illustration of optimal aggregate charging power vs time profile for the case of overnight (slow) charging of three e-buses at depot: (a) LP solution, and (b) QP solution.

3.4 Techno-economic analysis module (TEAM)

The main purpose of TEAM module is to provide a simulation environment for calculation of Total Cost of Ownership (TCO) regarding the conventional and electric city bus fleet. Techno-economic dataset, which is input to this module, contains various cost-related indicators that can be crucial when deciding about electrification of a considered conventional vehicle fleet. The key cost-related indicators can be categorised as:

- **Operational costs** which include daily driving costs manifesting themselves in vehicle fuel and/or energy costs
- **Financing costs** that include one-time purchase costs and/or loan payments costs, as well as corresponding sale taxes (which can also indirectly include state or other incentives for EVs and/or penalties for higher-polluting conventional vehicles)
- **Registration renewal and insurance costs**
- **Maintenance costs**
- **Infrastructure costs** that valorises investment that would likely be needed to accommodate for introduction of an electrified vehicle fleet (e.g. charging stations and related infrastructure).

The dataset also contains data about projected or expected money inflows that a vehicle fleet could provide. That can either be a:

- **Real revenue** that vehicle could provide (in the particular case of a city bus fleet that would consist mainly of passenger tickets), or
- **Salvage value** which is a market value of used vehicle (or its costly components such as batteries), that can be turned into the real revenue at the moment of vehicle sale.

Different costs have different frequencies of occurrence, which are categorised as follows:

- **Daily** – operational costs,
- **Monthly** - loan payments,
- **Yearly** - maintenance, registration, and insurance costs, and
- **Extra** - irregular costs (e.g. tire replacement, repairs, etc.) and/or infrastructure costs (e.g. power infrastructure upgrade to accommodate introduction of an electrified fleet).

TCO is then the Net Present Value (NPV) of all those costs and revenues summed all together with respect to their value over time [8], i.e. taking into account time value of money with inflation and discount rates, respectively. General idea for TCO calculation is illustrated in Fig. 10 [9].

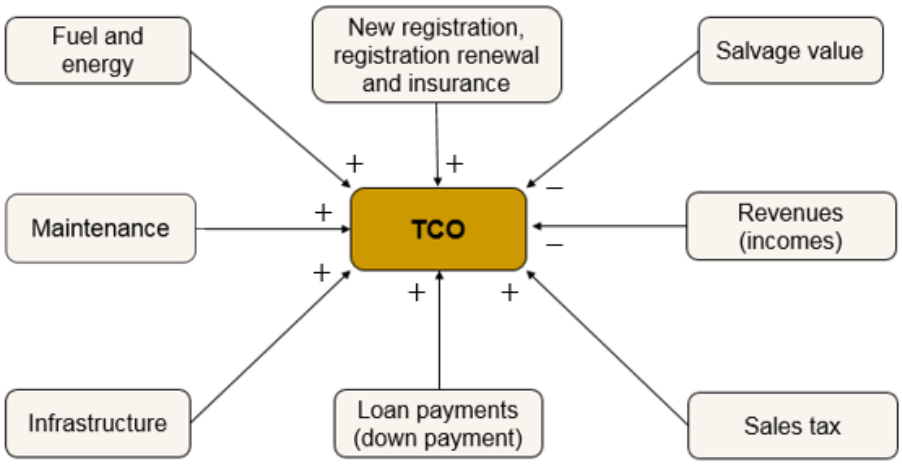


Figure 10 – General representation of calculation of total cost of ownership (TCO).

There are two types of TCO calculation: (i) deterministic calculation where all input parameters are given as single values, and therefore, calculation returns a single-value TCO; and (ii) stochastic

simulation, where some of inputs can be given as stochastic variables (i.e. statistical distributions), rather than single values. The latter approach is useful for taking into account expected volatility of some of the input parameters (e.g. fuel and energy prices, daily distance driven, etc.). The stochastic TCO calculation is carried out using the Monte Carlo approach where significant amount of calculations are conducted with different combination of input samples. Another useful indicator implemented within the techno-economic analysis module is sensitiviy analysis, which allows for investigating to what extent variations of a particular input parameter affect the final result, i.e. the TCO value.

Presented TCO calculation model was firstly developed using GoldSim, a simulation software solution for dynamic modelling of complex systems in engineering and business. It supports decision-making and risk analyses by simulating future performance, while quantitatively representing the uncertainty and risks inherent to all complex systems [10]. It supports Monte Carlo simulations, and provides interface for sensitivity analysis of model parameters. As such, it is convenient tool for development of a preliminary TCO calculation model [11], which has then been implemented as TEAM module of the presented software tool. The input and output components of TEAM module are illustrated as a part of Fig. 2.

4. SIMULATION RESULTS

This section presents simulation results of TCO calculation in general case, i.e. for a generic compact size passenger car. This kind of vehicle was chosen in the initial stage of software tool development, because of amount available information which is used to parametrize the TCO model. Parameters for TCO calculation model were mostly taken from [9], and calculation has not taken into account the salvage value of the vehicle.

Simulation was carried out for expected vehicle usage of twelve years, and for two types of personal vehicles: (i) conventional vehicle (CV), and (ii) electrified PHEV-type vehicle (marked as EV in simulation results) with 60 kWh battery (when battery capacity is not sufficient for a given daily driving cycle, rest of distance is covered with the same expenses as those calculated for the CV). Financing of vehicles is modelled with down payment of $10,000 and rest of price being payed trough loan with equal monthly payments over 5 years. Prices of new vehicles are $35,000 and $25,000 for EV and CV, respectively.

Results of a deterministic simulation are shown in Figures 11 and 12. The cumulative time propagation of costs, along with a simple model [9] of salvage value (SV), is shown in Figs. 11a and 11b for CV and EV, respectively. Sum of all expenses from Fig. 11 (except salvage value), named total expenses, for both types of vehicles, is shown in Fig. 12a. Finally, Fig. 12b shows TCO time propagation, i.e. NPV value of total expenses values from Fig. 12a. EV is more expensive vehicle than CV, so that monthly costs (loan payments) showed with a blue line are significantly higher in this case. On the other hand, EV consumes less energy (in terms of energy price) and has lower maintenance costs. This is the reason why total expenses for EV has lower raise rate after year 5, i.e. after loan is finished.

Figure 13 shows results of a stochastic simulation for the two vehicles, where stochastic inputs were daily driving cycles, fuel and electric energy prices. Areas with different colour represent percentiles of all simulations. Namely, the brightest red colour represent area in which only 1% of all simulations have fallen, while darker the colour, greater percentage of simulations can be found in that area of the plot. Dashed line represents simulation results corresponding to mean values of the stochastic inputs, i.e. these results are the same as the results of a deterministic simulations. It is obvious that the TCO for CV has larger uncertainty, mainly due to high variations in the fuel price that cause high variations in the operational cost.

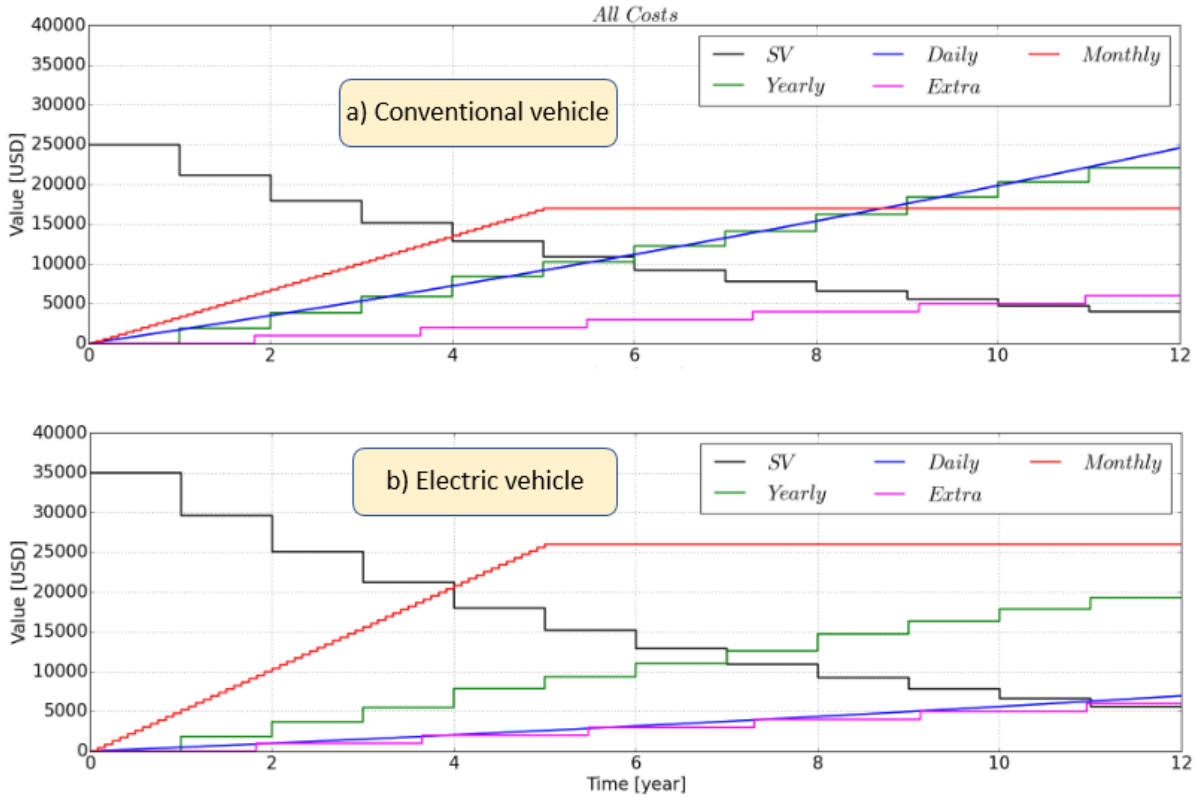


Figure 11 – Expenses by the category for: a) CV and b) EV.

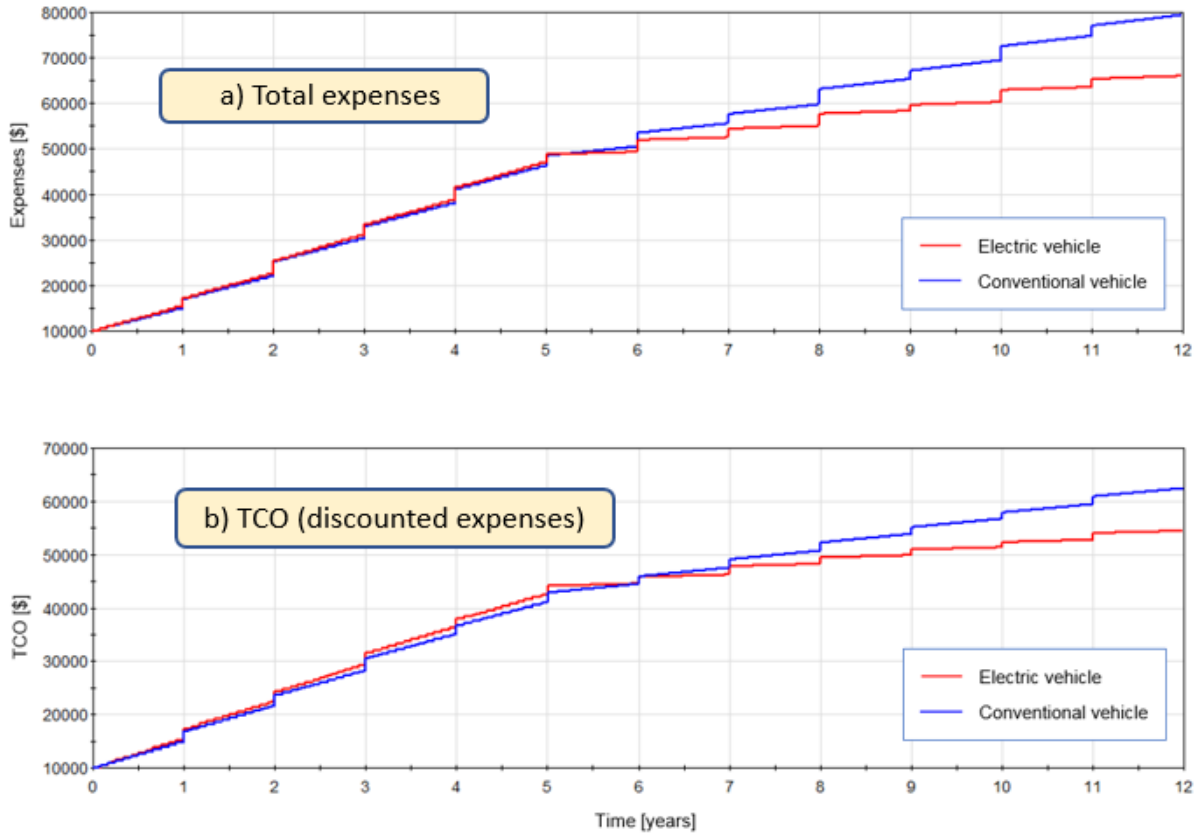


Figure 12 – Deterministic simulation results: a) sum of all expenses for both CV and EV; and b) TCO value (NPV of total expenses) for both CV and EV.

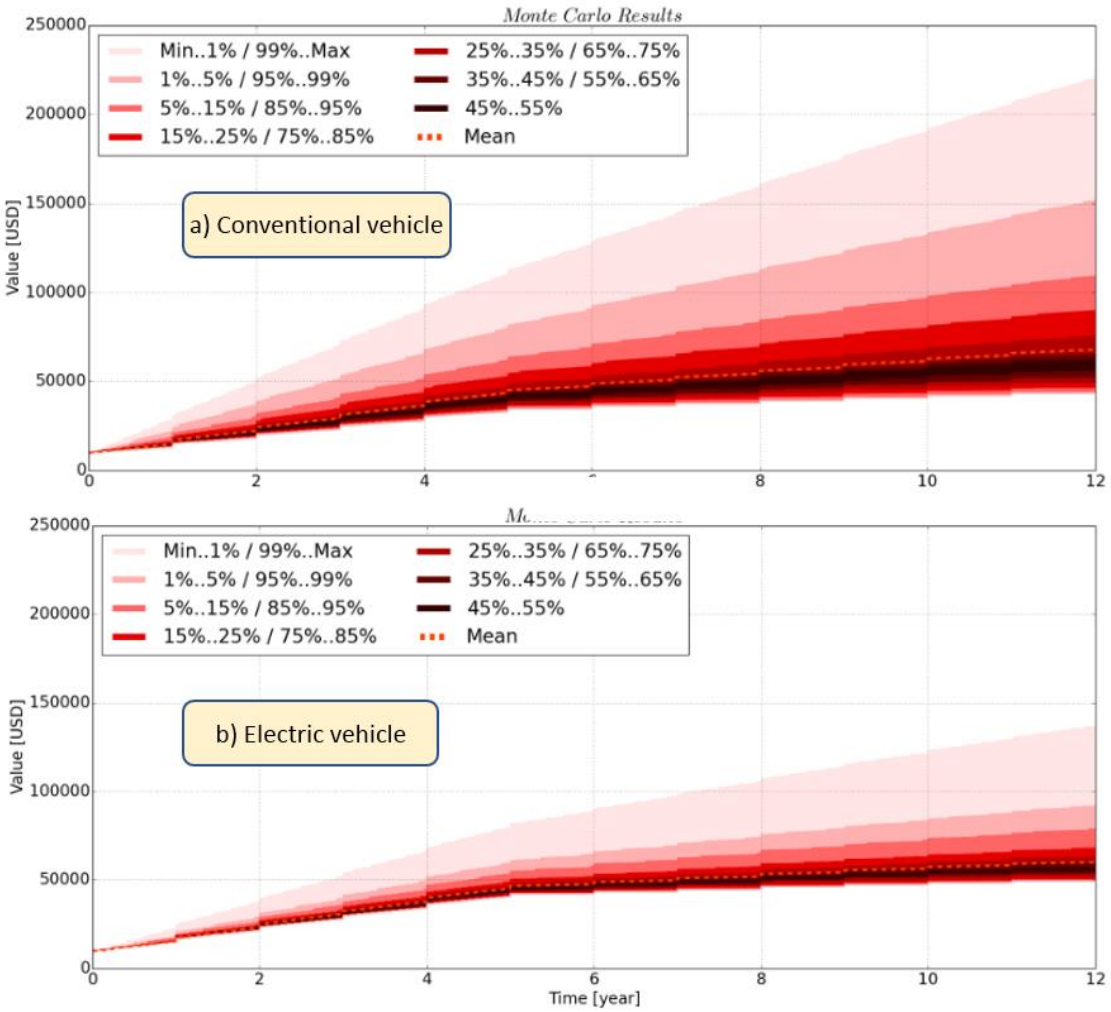


Figure 13 – Stochastic simulation results for: a) CV and b) EV.

5. CONCLUSIONS

The developed ICT tool for planning of city bus transportation electrification utilizes key modules needed for making and valorising decisions related to fleet electrification. With its first module, DPPM, it provides functionality of preprocessing and statistical analysis of raw driving cycle data that is collected from existing bus fleet. The second module, EBSM, includes integrated simulation models of different types of electrified buses (HEV, PHEV, and BEV) as well as of conventional ones, which allows user to parametrize models and conduct related comparative analyses and valorisation of different fleets. The third module, COM, uses driving cycles and bus models prepared in DPPM and EBSM, respectively, for city bus fleet simulation under realistic conditions and driving schedules. These results are used within this module for city bus fleet charging optimisation including determining the number of chargers and buses. The fourth module, TEAM, deals with the electrification techno-economic analysis, and at the end it provides value of Total Cost of Ownership for a given bus fleet.

In the last section, results of TCO calculation for an illustrative example of conventional and electrified (PHEV-type) vehicles were given to provide a sense of what would be final visualisation of the developed tool. It showed time propagation of costs that average conventional vehicle generates, as well as its electrified counterpart. Also, it is showed that variations of future prices (or any other parameter) can be taken into account through stochastic simulation.

ACKNOWLEDGEMENTS

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ABBREVIATIONS

BEV – Battery electric vehicle

COM – Charging Optimisation Module

CSV – Comma-separated values

DP – Dynamic programming

DPPM – Data Post-Processing Module

EBSM – E-Bus Simulation Module

EV – Electric vehicle

FEV – Fully electric vehicle (analogous to the BEV)

GPRS – General Packet Radio Service

GPS – Global Positioning System

HEV – Hybrid electric vehicle

ICE – Internal combustion engine

ICT – Information and communications technology

JSON – JavaScript Object Notation

LP – Linear programming

M/G, MG – (electric) Motor/Generator

NPV – Net Present Value

PHEV – Plug-in hybrid electric vehicle

QP – Quadratic programming

RB – Rule-based

SoC – State-of-Charge

TCO – Total Cost of Ownership

TEAM – Techno-Economic Analysis Module

TPM – Transition probability matrix

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DIGITALIZATION OF MARITIME BUSINESS AND LOGISTICS

ABSTRACT

Digital technologies have improved the maritime industry since 1960s. With the new technology, cyber-physical systems (CPS), there comes new ideas and applications. The industry will enter to a new era of digitalization. This paper introduces the previous and new digital technologies and their influences on maritime logistics. The two ideas which are proposed under the new environment of digitalization are summarized. Finally, the influences of digitalization on maritime business are concluded.

KEY WORDS

digital technologies; cyber-physical systems (CPS); digitalization; maritime business and logistics;

1. INTRODUCTION

Digitalization has been a long process in maritime logistics industry. Within years of internet technology and system developments, it brings about changes and opportunities in the industry continuously. Heilig et al., categorize three generations in the development of port digital transformation, which are paperless procedures, automated procedures, and smart procedures [1]. They point out that the new era of digitalization in seaports is to realize the smart procedures.

The early technology, electronic data interchange (EDI) which dates back to 1960s, has a large influence on maritime logistics. It paves the way for the first digital transformation in the maritime shipping industry [2]. Later the EDI-based port community systems (PCS) are built to exchange electronic documents between maritime actors. The laser technologies, identifying and positioning technologies in 1990s, facilitate the automated handling in port container terminals [1]. The digitalization of maritime logistics is driven by information technologies and systems.

Nowadays, internet of thing, big data, cloud computing, and CPS are largely discussed by the maritime industry. These technologies have been used successfully in other areas. But the implementations in maritime logistics are still at the beginning. Some institutions, like European Commission and Hamburg Port Authority, have already proposed the future vision of using these new technologies. It also emerges opportunities for digital business models in maritime industry.

The purpose of this paper is to summarize the developments of maritime logistics based on digitalization, and to introduce the proposed ideas and implementations in maritime industry as the new technologies are applied. The remainder of the paper is structured as follows. Sections 2 introduces the previous and new digital technologies which play the important roles in maritime digitalization; Section 3 presents the recently proposed ideas in maritime industry; Section 4 summarizes the digitalzation's influences on maritime business; Section 5 is the conclusion.

2. THE DIGITAL APPLICATIONS IN MARITIME BUSINESS AND LOGISTICS

Usually maritime transportation is one part of the whole transportation chain. It connects with railways, road and riverway transportations. The maritime actors that involved in the whole transportation chain are port authorities, freight forwarders, carriers, ship owners, port terminals, etc. Ports play an important role to connect with hinterland transportations in the whole chain. Port community systems are used by most large ports in the world to manage the business affairs and logistics operations. The other important digital developments are positioning and tracking technologies which increase the safety and service quality largely. For the new era of digitalization, CPS are the main technologies to realize the proposed ideas.

2.1 EDI-based Port Community System

Port is an inevitable component in maritime logistics. It is the gateway to hinterlands, or functions as a hub in the transportation. There are terminals, customs, and other logistics companies in ports. They handle with port, administrative, and commercial operations of maritime business. The EDI-based port community systems are largely used by world container ports since 1960s. This enables paperless work processes and improves the efficiency of port operations. For example, the New Orleans port in United States developed the CRESCENT system, which is used for applying berth electronically, registering shipping lists automatedly, searching information of dangerous cargos and freight status, managing import agents, and mailing. The Singapore port started to use the PORTNET system as a data mailbox in 1984, then it cooperated with Hong Kong port to exchange the information of containers electronically [3]. This improves the scheduling work of yards and ships, accelerates the turnaround times of ships.

The EDI-based port community system facilitates the operations and managements in maritime business and logistics. The international EDI standards are settled to ease the data transfer and to improve interoperability. The documents like bill of lading are in the regulated formats which these data can be transferred among different actors' information systems. This largely saves the time for getting and reading the information for the necessary management processes like customs in international maritime transportations.

2.2 Positioning and Tracking Technologies

Navigating and positioning technologies were firstly used by ports in the middle of the 1990s. The existing satellite-based positioning systems are Global Positioning System (GPS) by US, Global Navigation Satellite System by Russian, Galileo by European, and Beidou by China [4]. GPS first became available for private use in 1995 and it is the most popular and least expensive system [5]. However, it is not as precise as expected. Differential Global Positioning System is an enhancement to GPS that provides improved location accuracy. These systems locate and track containers, vessels, trucks and other equipment.

With the GPS technology, Automatic Identification System (AIS) is an automatic tracking system used on ships, as well as the primary method of collision avoidances. The International Maritime Organization's International Convention for the Safety of Life at Sea requires AIS to be fitted aboard international voyaging ships with 300 or more gross tonnage, and all passenger ships regardless of size. With AIS, the maritime actors can track and monitor vessel movements.

Based on these positioning and tracking technologies, the maritime transportation has more security to avoid the collisions. When the shipping liners and port authorities know the position of the ship, the benefits are that customers can get the status of their transport freights and ports can prepare for the ship's terminal operations in advance.

2.3 Cyber-Physical Systems (CPS)

The term Industry 4.0 is proposed by Germany and discussed quite frequently today. It aims to combine production activities with state-of-the-art information and communication technologies. This so-called fourth industrial revolution is on the basis of CPS [6]. This concept promotes the digitalization of maritime business and logistics. The goal of this digitalization is to make the maritime logistics actors connected, to make the information as real-time data, and to improve the automation, efficiency, reliability, and economics of maritime logistics.

CPS are to create a virtual copy of the physical world and then monitor physical processes [6]. There are two worlds in CPS, one is physical world, another is cyber world. CPS combine these two worlds, using cyber networks to control the physical world, to realize the automation in the physical operations. CPS are real-time systems. Timing and special informations need to be captured into programming models [7]. The effective result of applying CPS is to ease the interactions with remote people and environments, to make it nearly the same as interactions with local people and environments.

CPS bring some new capabilities to the maritime industry. Firstly, when the automobiles are imbedded in CPS, they become intelligent and could largely improve safety and efficiency in transportation. The networked autonomous vehicles could enhance the effectiveness in ports. Secondly, the connected control systems could significantly improve energy efficiencies and save more fuels by promoting the transport routes, maximizing the capacity use, and organizing the efficient port operations. Thirdly, these large scale service systems could acquire the nature of distributed real-time control systems [8].

Though CPS have been proposed many years, but the implementation is not very common. In maritime industry, it is still at the beginning. Because there are still many challenges to realize the goal of CPS. For example, the distributed mobile devices with sensors and actuators require a new paradigm for real-time resource managements that go far beyond traditional methods. Furthermore, there is a need for real-time computing and real-time group communication methods for dynamic topology control in wireless CPS systems with mobile components with dynamic topology control [9]. Though the challenges exist, the maritime industry has already proposed to build CPS in the maritime logistics driven by digitalization and Industry 4.0.

3. NEW PLATFORMS FOR DIGITALIZATION IN MARITIME LOGISTICS

The digitalization of maritime logistics will increase the connectivity of the maritime logistics actors, thus create the opportunities for collaboration. In recent years, the most popular ideas that consider digitalization are e-Maritime and Smart Ports. European Commission has proposed e-Maritime, and Hamburg Port Authority has proposed Smart Ports. These are developing blueprints for maritime logistics on the base of digitalization.

3.1 E-Maritime

E-Maritime is proposed by European Commission. It is aimed to simplify administrative procedures, enhance whole transportation efficiency, make benefits for shippers and carriers, and enhance maritime transportation safety. It is a virtual network in an electronic environment with a single, open platform based on open standards to ensure interoperabilities between different maritime-related applications. On this network, the communications are transferred between ships, between ships and shores, which including port communities, administrations, operators, freight forwarders and other hinterland actors. E-Maritime supports online interactions between all the different stakeholders in the maritime sectors. E-Maritime is an online web portal that functions to link the members of the shipping communities by the internet [10]. Through this web portal, shipping liners, shipping agents, freight forwarders and members of the maritime community will have a

medium to facilitate easier communication. To support the implementation of e-Maritime, e-Navigation and e-Freight are also proposed among members [11].

E-Navigation is an international system and supporting shore services driven by users' needs and is establishing the free communications between lands, offshores and vessels for traffic controls, survey activities, maritime traffic facility managements, vessel monitoring and navigation without time and space limits [12].

E-Freight aims to take the paper out of the cargo and to replace it with the exchange of electronic data and messages. Launched by International Air Transport Association in 2006, e-Freight became an industry-wide initiative involving carriers, freight forwarders, ground handlers, shippers and customer authorities.

E-Maritime focus on both administration and business domains. The administration domain includes safety security, environment, risk management, and national single windows; the business domain includes port, ship, and logistics chain applications. The administration domain systems include SafeSeaNet, single windows, port community systems; the business domain systems include port community systems for port operations [13].

3.2 Smart Ports

Ports are necessary interfaces in the global transport chain which includes maritime transportations. When vessels arrive at or depart from ports, the communications occur between ships and port authorities. In most cases, informations are commonly retrieved and distributed manually by the use of emails and phone calls. The digitalization of shipping informations is at the beginning of the stage. Satellite communications are used to replace emails and phone calls [14]. Big Data Analytic can be used to forecast expected arriving and departing time of vessels. Digitalization will optimize the performance of ports as hubs in intermodal and multimodal transportations. It will enhance the connectivity between ports as well as their hinterland regions. Digitalization are linked to Industry 4.0 which refers to the fourth industrial revolution on the basis of CPS using the internet. CPS monitor physical processes and create a virtual copy of the physical world to make autonomous decentralized decisions [6].

The Hamburg Port Authority has facilitated sustainable growth and a better utilization of resources for its customers while minimizing environmental impacts through its Smart Ports concept. Smart Ports logistics stands for intelligent solutions for an improved flow of traffic and goods in the Port of Hamburg, focusing on infrastructure deployments and considering both economic and ecologic aspects.

The international network of Smart Ports is going to interlink information and data between participating ports, creating a platform to develop innovative solutions and digital business models. On this platform, the ports in the multimodal supply chains remain fully independent nodes.

One trend of Smart Ports is the automatic vessels and operations. There are two obvious developments of the Smart Ports. One is about the facilities like automated vessels and port terminals, the other is about the interconnected networks among different ports. Automatic vehicles have developed largely in recent years. The automatic cars and planes have already taken into use. In maritime industry, automatic vessels are also proposed. Meanwhile, the port operations in terminals can also be automatic when the facilities are imbedded in CPS and controlled by the information systems. For example, the port will know the estimated arriving data of the ships, then transfer the tide and weather information to the ship, prepares the terminal operations in advance, and contact with the hinterland transportation. The navigation can also be smart because the buoys know a lot of information about the water. When the ports are connected, they can organize the orders to relieve the congestions in ports. For the container routes, interconnected ports can also share the

information and benefit from it. The interconnected network increases the flexibility and reactiveness of ports.

4. THE INFLUENCE OF DIGITALIZATION ON MARITIME BUSINESS

E-business grows very fast since 1990s. The maritime actors like shipping liners have already developed their e-business. There are also logistics companies that focus on providing the integrated logistics schedules for the customers. These companies are light capacity logistics service providers. They build their collaborative networks with lots of maritime actors such as carriers, ports and information companies. The new digitalization challenges the existing business models [15]. The influence of digitalization on maritime business can be concluded in two aspects. The first is that ports become active to lead the markets; the second is that the logistics services tend to stress on the automation and integration.

4.1 The Influence on the Maritime Actors

The digitalization enables the online markets in maritime industry. Under the popularity of online business, the international shipping liners like COSCO, Maersk, MSC all build their e-business sectors on the homepages. Though the online portal, customers can check the shipping routes, schedules and prices, and book the ships. There are also light capacity companies that have online maritime business. INTTRA, developed in 2000, is the first e-commerce platform and is still at the leading place in this industry. This kind of companies focus on build the collaborative relationship with ports, carriers and information technology companies. The online platforms collect the container orders and provide integrated logistics schedules. Meanwhile, the positioning and tracking technologies and information systems enable the customers to search for their cargos transportation status.

In the new era of digitalization, ports also have the potential to build the e-business. Ports are at the important place in the whole transportation chain. It has the potential to develop the online multimodel transportation business models. Furthermore, there will be more information companies to provide and exploit the logistics information.

4.2 The Influence on Maritime Services

Although there are some additional logistics and financial services in maritime transportation, the basic service is transportation. Digitalization will also influence maritime services.

Firstly, the transportation becomes more safe and flexible. The CPS can be used to control the physical networks according to real-time data. Secondly, the transportation will be automated. As the vessels and port terminals are equipped with automatic technologies, the maritime transportation has the potentials to realize automation. Thirdly, the transport products can be extended with hinterland transportation. Fourthly, when the information is collected and calculated, customers can find their best procurement schedules online.

5. CONCLUSION

Digitalization is the inevitably developing trend in maritime logistics and business. The technologies such as internet of thing, cloud computing and CPS, which have already applied in other industries, have been introduced to maritime industry. The new ideas proposed by European Commission and Hamburg Port Authorities imply the potential applications using the new digital technologies. These all influence the maritime logistics and business. The future platforms in maritime industry will focus to build large networks. The future maritime logistics services will integrate with hinterland transportation, and the websites can provide the combination of different logistics service providers, thus the customers can choose the most suitable service packages.

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