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PERSPECTIVES ON CROATIAN 3PL INDUSTRY IN ACQUIRING INTERNATIONAL CARGO FLOWS

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VALUE ASSESSMENT OF TRAFFIC SIGNS RETROREFLECTION IN THEIR LIFE CYCLE

ABSTRACT

The retroreflective materials for traffic signs began to be applied from 1939 when the experts in the 3M company produced first reflective traffic sign that is set at the intersection of State Road in Minnesota in the United States. Glass beads were applied to the substrate without external protection and were damaged by the atmospheric conditions. The last 30 years numerous studies were implemented and the different reflective materials (High Intensity Grade, Diamond Grade) have been developed and used for making traffic signs with the aim of increasing the visibility, especially at night and harsh conditions, and thus the overall traffic safety on the roads. This paper presents the analysis of the retroreflection value of traffic signs for a certain period of time and their impact on traffic safety. Survey was made on 13,387 traffic signs of different ages and different material classes which were located on 20 different road sections in Republic of Croatia and this article present results of that analysis.

KEY WORDS:

Traffic signalization, retro reflection, maintenance, life cycle

1. INTRODUCTION

The minimum expected road sign visibility includes the minimum distance from which the driver can read the sign and can react on time and do the necessary maneuvers. The factors that help to identify the sign and its understanding are: its size, an ease of symbols or of used text, sign paint.

The night driving conditions and visibility will require driver's different consideration of a number of factors that occur when driving at night. How traffic signs wear off due to the exposure to atmospheric elements, relatively lower level of visibility comes up in which the sign is more difficult to spot and becomes less legible for more drivers. This condition deteriorates progressive, and thus traffic sign becomes inefficient and in the end it must be replaced with new one. At night the vehicle driver is close to the light source (vehicle headlight) and sees the retroreflector as a light, shiny surface. It is obvious that the vehicle headlight plays an important role in the degree of visibility of the retroreflector by night because its luminance is proportional to the light output of headlamp. This reinforcement of nighttime illumination results in a great contrast in relation to the dark environment and gives a needed improvement in visibility for most of the signs that are effective without additional separate lighting.

One of the important factors by which retroreflective material are compared is the power of retroreflection, which describes the amount of light reflected by the retroreflective material. Another important characteristic is the angularity which presents the reflection value at a larger angle of the input light, and as the third important feature we can mention is durability that is shown in the reflection quality value through a certain number of years.

The retroreflective films are available in different colors to cover selected portions or the entire sign surface. These are also available in various qualities that correspond to different levels of retroreflective effectiveness. The different quality of materials allow a particular traffic sign to adjust to higher or lower levels of luminance. Some materials were designed to maximize sign durability, while some others are designed for short-term use.

The basic characteristic of reflective material is based on the properties of built in elements, which can be glass beads or prisms of very small dimensions. Glass beads have a diameter of 0.01 to 0.1 mm and there are about 80 million beads per one square meter of material. Such translucent balls are sealed with a thin, permanent and protective transparent material that has a thickness of 0.14 to 0.22 mm. Today three types of retroreflective material are used:

- material class I – Engineer Grade
- material class II – High Intensity Grade
- material class III – Diamond Grade

Independent reflectors (form of a reflective tape) can be used for inscriptions on road signs. The different material quality for the traffic signs, different production processes of signs, and the selection of materials for sign substrate will have an impact on the ultimate life of a road sign.

2. PREVIOUS OF RESEARCH ON THE RETROREFLECTION OF TRAFFIC SIGNS

Former researches related to the traffic sign retroreflection in most cases were focused on the durability and quality of retroreflection and retroreflection impact on identifying traffic signs by drivers and therefore the safety of traffic flow. Some scientists or groups of researchers have analyzed retroreflection in detail and thus found the factors that affect the quality of retroreflection on traffic signs. Through previous research were obtained some quality maintaining methods of sign retroreflectivity in all weather conditions. Some of the research will be described hereinafter.

FHWA in 1992 conducted a national survey to determine the factors that contribute to the degradation of retroreflection and to develop the probability models for class 3 foil. The data were collected on 5722 signs in 18 different federal states. The conclusion of the study was that old age, precipitation, height above sea level and temperature affect the deterioration of sign retroreflective properties. Also has been showed that the orientation of the sign is not an influential factor in the deterioration of retroreflective properties. For this purpose the linear probability models have been developed and have shown that class III signs have adequate performance up to 12 years [3].

In 2001 in Oregon, research was conducted in order to identify factors affecting the degradation of retroreflection. The data were collected at 80 class III signs (HI) which have been in the use for 10 years. Red, yellow, green and white signs are included in the study (20 of each color) and 10 measurements on each sign was carried out. The initial sample of the 80 characters was proved to be too small, and measurements on the additional 57 signs were conducted.

The other sample had noticeably better results than the first measurement (71% versus 107%). Between two measurements, the measuring device is calibrated at the factory, and it is possible reason for the discrepancy in measurements. The weight factors are calculated from the 3 average percent differences of the second sample measurement compared to the first and were applied to the collection of data collected from the field. An average of 10 measurements per sign is used for the presentation of total sign retroreflection because of a variety of the sign reflective areas. The graphic representation determined correlation between the sign age and retroreflective properties. The conclusion was that the range of age (12 years) is insufficiently large to provide a true picture of retroreflective performance over years of use. The research has shown that most of the signs meets the minimum conditions after 12 years. In the research, correlation between the sign direction in relation to the impact of weather conditions (such as wind-borne dust) and degradation of retroreflection is detected, but there was not enough data to support this idea. It was noticed that the signs turned towards the west had a lower level of retroreflection if they were white, yellow and green, while the signs facing south had less retroreflection if they were red [4].

Department of Transport in Louisiana in 2005 spent collecting data on signs retroreflection to predict the signs performance. They used life expectancy of traffic sign in its method and processed data measurement of 237 signs (class I and III, the white, green and yellow). Overall, 92% of the signs within the warranty period, has meet the minimum requirements of retroreflection, while 43% of the signs which expired warranty period, was above, or at the minimum of required retroreflection value. The research concluded that cleaning up signs greatly contributes to the maintaining of sign retroreflection. Following this investigation, the Department has determined a life expectancy of 25 years for signs made of foil with micro prisms and 20 years for all other foils [5].

In NCHRP Synthesis 431 "Managing retroreflective properties of traffic signs in practice," was documented the practice of government agencies and ways applying in maintaining the retroreflection of signs. The research found out that the most agencies report that the most foils last longer than their warranty period, and that the class I is at least effective and has the shortest shelf life. The research participants have recorded that setting foil class III or IV rather than class I is most cost-effective [6].

3. THE PROBABILITY MODEL OF THE ESTIMATE OF RETROREFLECTION DURABILITY OF TRAFFIC SIGNS

This section will analyze the quality of traffic signs based on the average age of the individual sign classes that meet and do not meet the minimum prescribed requirements, derived from statistical data, to determine a probabilistic model.

The goal of this model is at the basis of traffic sign age define a time interval in which the sign will comply with the values of retroreflection and a time interval in which there is a possibility of termination of its functionality, due to the retroreflection. Also, on the basis of these results, it is possible to predict the measurement of retroreflection time interval to determine whether the sign meets or does not meet prescribed requirements and whether it should be replaced.

a) Retroreflection testing of traffic signs and methodology of data collection

Traffic signs should be checked regularly (depend on regulations in road authority of each country) to verify the retroreflection and appearance when using the low beam headlight. It is desirable to check the quality of the signs at night because that is the only way to determine visual defects that are not visible in daylight. Tests are performed to check whether the traffic signs are in accordance with the "Regulations on traffic signs, equipment, and signaling equipment on the roads", (NN 33/2005.), and if they meet the requirements of the Croatian standards HRN1114: 2002. BS 1115: 2002, BS 1116: 2002, BS 1117: 2002, BS 1118: 2002, BS 1119: 2002 and RN 1126: 2002.

Geometry should be selected so that it corresponds to the values that are listed in national specifications which mean viewing angle of 0.33° and the angle of 5°. Entrance angle is primarily determined by the position of the sign in the edge of the road and geometry of an oncoming vehicle and it is formed between a light beam that falling on the surface of the sign and the line that comes out vertically from the surface. Viewing angle is the angle between the incoming light beam and reflected light beam and it is a function of the height of driver eye compared to the vehicle headlights.

Testing of retroreflection was performed by Department for Traffic Signalization, Faculty of Transport and Traffic Sciences, University of Zagreb by using modern equipment for retroreflection measuring Zehntner ZRS 6060. It is a modern retroreflectometer which greatly facilitate and accelerate the process of retroreflection measurement. The main advantage of the new retroreflectometer compared to the old ones is an interactive overview of the test results in the software ''MappingTools'' by recorded GPS coordinates of each tested data. The said device automatically detects sign color of the sign and offers the possibility of entering additional information (types of sign, the city where the sign is placed, street of setting, date, sign manufacturer, ...) and provides the ability to transfer data for further analysis on the computer, which was not a possibility when using the old retroreflectometer. At each color that is located on the face of the traffic sign is performed threefold measure of the coefficient of retroreflection and as a representative value an average value of the three measurements is taken.

In addition to the coefficient of retroreflection at all measurement locations are analyzed: (1) sign type, (2) sign name, (3) sign code, (4) graphical representation, (5) a form of the sign, (6) dimension of the sign and its deviation, (7) color (a substrate, an edge and an symbol), (8) method of setting, (9) method of affixing, (10) height of sign, (11) distance from the edge of pavement, (12) type of substrate, (13) the method of construction, (14) the date of setting, (15) information about the producer of sign, (16) information about the setter of sign, (17) the class of retroreflective foil, (18) information about the producer of retroreflective foil, (19) the ratio of the smallest allowable and measured values of the retroreflection coefficient [2].

b) Results of analysis

The analysis of performance and characteristic reduction of retroreflective foil was made with respect to age or guarantee deadline. The goal is after the given results get the average age of the signs for each class in order to be able to make an accurate schedule of maintenance and replacement of traffic signs.

A total of 13,387 traffic signs of different ages and different material classes was analyzed. The signs were located on 20 different road sections and presented in Table 1.

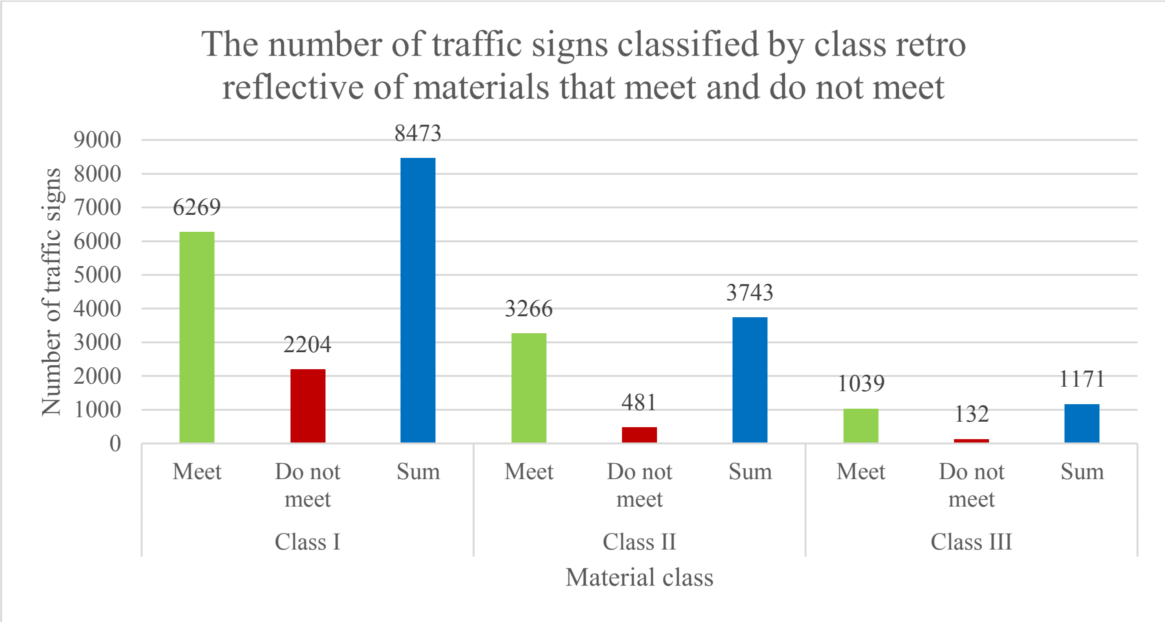
The table shows the number of traffic signs that were measured at each section and their classification according to a retroreflective material they are made. From the shown data, it can be read that out of 13,387 surveyed traffic signs: 8,473 were made of class I material, 3,743 are made of class II material and 1,171 of class III material.

Table 1 - The review of the number of signs that meet and do not meet the minimum retroreflection values on sections

		Meet minimum value of retroreflection		Traffic signs material (number of signs)		
Section of state road in Croatia	**Number of traffic signs**	**Yes**	**No**	**Class I**	**Class II**	**Class III**
Karlovac (D1) - Zdihovo (g.ž.)	676	565	111	415	222	39
GP Terezino Polje - Lončarica (g.ž.)	474	309	166	360	103	11
Vojišnica (g.ž.) - GP Dvor	1346	962	384	1040	139	167
Vrpolje (g.ž.) - GP Slavonski Šamac	489	374	115	351	132	6
Duga Resa (D23) - Kapela (g.ž.)	984	805	180	557	257	170
Ogulinec (g.ž.) - GP Hrv. Kostajnica	1073	847	226	722	259	92
Slatina (D2) - Čađavički Lug (g.ž.)	361	348	13	219	132	10
Gradište (D53) - Banićevac (g.ž.)	874	749	125	609	238	27
Dilj (g.ž.) - GP Slavonski Brod	580	423	157	425	136	19
Borovo (D2) - GP Županja	913	671	242	620	274	19
Drniš (D33) - Crivac (g.ž.)	245	218	27	187	35	23
Veliki Prolog (g.ž.) - Metković (D9)	440	353	87	252	120	68
Slatina (D2) - Novo Zvečevo (g.ž.)	932	845	87	420	200	311
D7 - GP Batina	571	534	37	337	203	31
Mošćenica (D37) - Panjani (D30)	615	379	236	427	137	51
Jurovski Brod (D6) - Karlovac (D1)	652	496	156	379	217	56
Vir - Zadar (D8)	835	700	135	409	420	6
Našice (D53) - Đakovo (D7)	708	658	50	404	268	36
Ada (g.ž.) - Jarmina (D46)	385	341	44	219	137	29
Borovo selo (g.ž.) - Borovo (D2)	239	203	36	121	118	0

Source: By authors

Graph 1.shows that of all measured traffic signs, the number of signs which meet the minimum prescribed value of retroreflection is 10,574, and the number of signs that does not meet the same value is 2,817. The further analysis showed that out of these 8,473 signs that are made of class I material, 6,269 signs meet the minimum requirements of retroreflection, while the remaining 2,204 signs are not functional. Also, out of 3,743 signs that are made of class II, 3,266 of them meet the necessary requirements while 481 sign don't meet. Of the remaining 1,171 signs that are made of class III material, 1,039 meet the necessary requirements, and the other 132 don't meet the set requirements.



Graph 1 - The number of traffic signs sort out by class of retroreflective material that meet and do not meet the minimum value of retroreflection
Source: By authors

Traffic signs average age is calculated only for the signs after the warranty period due to the assumption that the signs which are within the warranty period meet retroreflection required values. The warranty period for a class I is seven years and for class II and class III is ten years (according the producer data in Croatia). After gathering the required data and the analysis and processing, the average age of signs that meet and don't meet the minimum required value at each of the sections has been determined, for each material class separately, as shown in Table 2.

Table 2 shows that signs of class I who meet the minimum retroreflection requirements have an average age of 11.06 years, while the average age of the signs of the same class that do not meet the minimum requirements is 14.71 years. The further analysis showed that the average age of the signs made of class II foil that meet minimum requirements is 12.64 years and the average age of the signs that do not meet is 13.18 years. For signs made of class III material which meet the prescribed minimum of retroreflection average age is 11.46 years, while for signs of the same class that do not meet the minimum of retroreflection, average age is 11.48 years.

Table 2 - The review an average age of signs within the warranty period that meet and do not meet the prescribed minimum requirements

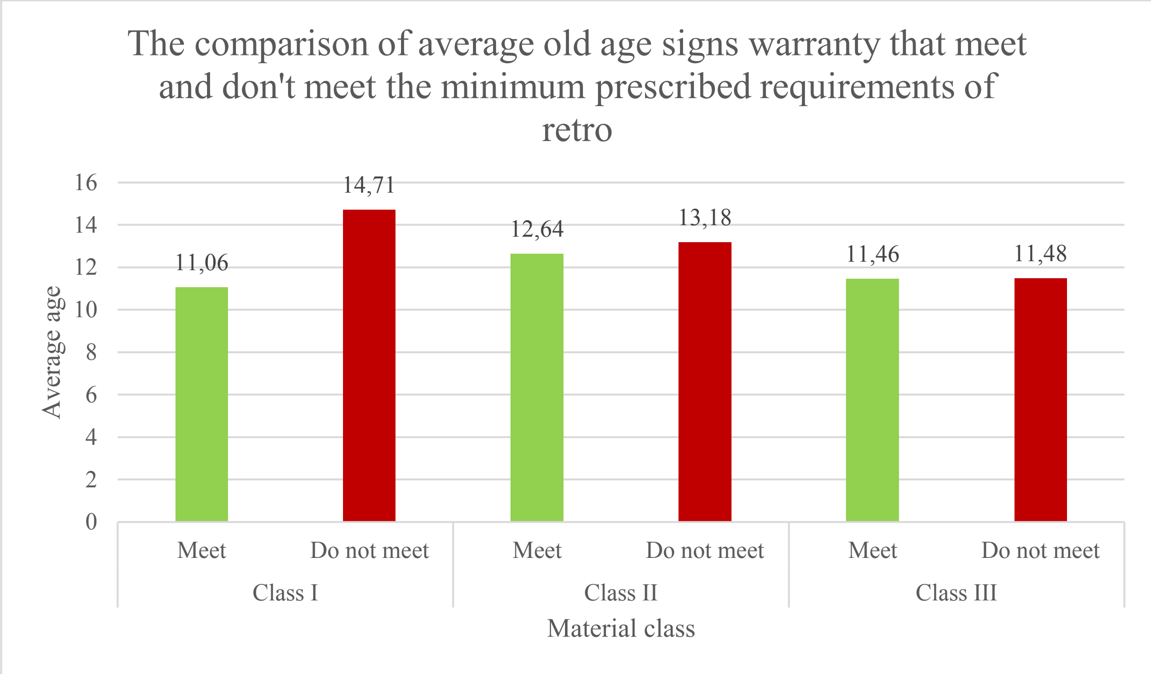
Section	Number of traffic signs	Class I		Class II		Class III	
		Meet	Do not meet	Meet	Do not meet	Meet	Do not meet
Karlovac (D1) - Zdihovo	676	11,69	16,42	13,14	13,00	-	-
GP Terezino Polje - Lončarica	474	10,95	11,79	13,50	14,00	-	-
Vojišnica - GP Dvor	1.346	10,17	16,04	13,00	13,86	11,00	11,00
Vrpolje - GP Slavonski Šamac	489	10,72	13,33	13,75	14,12	-	-
Duga Resa (D23) - Kapela	984	10,87	16,89	12,17	13,07	11,38	11,83
Ogulinec - GP Hrv. Kostajnica	1.073	10,65	15,64	12,40	12,38	11,00	11,00
Slatina (D2) - Čađavički Lug	361	11,33	9,25	-	-	-	-
Gradište (D53) - Banićevac	874	11,57	13,77	13,05	12,40	11,00	11,00
Dilj - GP Slavonski Brod	580	10,31	13,62	12,60	12,00	-	-
Borovo (D2) - GP Županja	913	10,86	15,41	13,41	13,21	12,00	12,36
Drniš (D33) - Crivac	245	10,17	17,22	11,00	12,00	-	-
Veliki Prolog - Metković (D9)	440	10,72	14,72	11,50	15,00	-	11,33
Slatina (D2) - Novo Zvečevo	932	11,46	13,81	12,07	13,50	-	-
D7 - GP Batina	571	10,36	14,76	12,33	-	12,00	-
Mošćenica (D37) - Panjani (D30)	615	10,12	15,43	12,00	12,92	11,33	11,28
Jurovski Brod (D6) - Karlovac (D1)	652	12,03	16,04	13,44	12,91	-	-
Vir - Zadar (D8)	835	10,87	15,50	12,36	12,61	-	-
Našice (D53) - Đakovo (D7)	708	12,26	15,55	12,57	12,80	-	-
Ada - Jarmina (D46)	385	11,58	12,75	12,17	12,50	12,00	12,00
Borovo selo - Borovo (D2)	239	12,66	16,34	13,63	15,00	-	-
Percentage	669,60	11,06	14,71	12,64	13,18	11,46	11,48

Source: By authors

From the analysis above, it can be concluded that the characters average age of all classes that meet minimum prescribed retroreflection value after the warranty period is about 11 years. The specifically for Class I, the average age of signs who meet the minimum prescribed value of retroreflection after the warranty period is 11.06 years while the signs that do not meet the same values is 14.71 years. For Class II, the average age is between 12.64 and 13.18 years, and for Class III between 11.46 and 11.48 years.

From the above it can also be concluded that the signs of all three classes which meet the minimum prescribed retroreflection value are 11 years old. On the other hand, the average age of the signs that do not meet is 13 years. It is important to notice that out of 20 section analyzed, on only eight the presence of class III signs over the warranty period (10 yrs.) was recorded and that is, to obtain more accurate and more objective results, needed to carry out more researches with a larger sample.

It can be concluded that after 11 years of signs age, the retroreflectivity of all material classes should be examined in order to determine whether the signs meet the minimum prescribed requirements.



Graph 2 - The comparison of average signs age in warranty that meet and don't meet the minimum prescribed requirements of retroreflection
Source: By authors

4. CONCLUSION

Traffic signs are installed to provide users with adequate and timely information and thus enable safe traffic flow. The visibility is the primary source of necessary information when driving. In order to the traffic signs visibility and to driver prompt reaction, the signs are made of retroreflective material. An important factor in the traffic signs maintaining is their testing. Due to the external factors the strength of retroreflection reduces with age and it is necessary to carry out periodic measurements to control that the retroreflection value is not below the minimum retroreflection which traffic sign must meet.

Base on the data presented in this paper, which are collected by the Department for Traffic Signalization in Zagreb, it was calculated the average age of the signs within the warranty period for each class of material when it meets and when does not meet the minimum of required retroreflection value. The analysis of the data shows that the average age of the class I signs which meet the minimum retroreflection value is 11.06 years, while the average age of the same class of signs that do not meet the minimum is 14.71 years. The further processing of the data revealed that the average age of traffic signs that meet the minimum of prescribed retroreflection in Class II is 12.64, and in Class III is 11.46 years, while the average age of those who do not meet the requirements in Class II is 13.18 and in class III is 11.48 years.

The analysis of processed signs found out that a large percentage of signs from all three classes average meet the minimum prescribed value of retroreflection within the warranty period. Of the total processed 8,473 traffic signs of class I, the results show that 73.9% of signs meets the minimums, 3,743 traffic signs of Class II (87.2%) meet the minimum requirements of retroreflection while in Class III 1,171 traffic signs (88.7%) corresponds to the requirements.

The results lead to the conclusion that the average age of traffic signs of all classes that meet minimum retroreflection requirements is about 11 years and thereafter the traffic signs should be examined and measured in order to determine if the signs meet legal requirements.

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MULTI-ECHELON INVENTORY OPTIMIZATION

ABSTRACT

Optimizing inventory in the supply chain is a very important goal in the logistic business process, considering that optimized inventory directly affects the efficiency and profitability of the process. The aim of manufacturing, distribution and trading companies and also companies that provide complete logistical support is maximization of reducing inventory, while maintaining a certain level of services they provide for their own customers to become and remain competitive in the market. For this reason, different models and methods used in inventory optimization today are increasingly developing in order to achieve better and more efficient results. Considering the increasing demands of the market, companies are forced to turn to new and better ways of doing business. For this purpose this paper presents multi-echelon inventory optimization method, which provide highly efficient inventory management and may increase the optimization opportunities within the supply chain.

KEY WORDS:

Multi echelon, inventory optimization, supply chain, inventory management.

1. INTRODUCTION

The main issue that arises in supply chain inventory management is to coordinate logistics activities and the amount of stock while the service level is set highest as possible. Managing inventory can be a daunting task for an enterprise with tens of thousands of products that are located in hundreds of locations. The challenge is even greater when the locations are situated in different tiers or echelons of the enterprise's distribution network. In such multi-echelon networks, new product shipments are first stored at a regional or central facility. These central facilities are the internal suppliers to the customer-facing locations. This is a common distribution model for many retail chains as well as for large distributors and manufacturers [1]. Single echelon inventory optimization is relatively well and quite easily feasible using certain methods that provide optimum solution for each level. Multi stage optimization is more complex than single stage so it is necessary to use multi echelon inventory optimization methods. In the next few chapters it will be represented main differences between multi-echelon or multi-stage optimization and single-echelon optimization and true benefits in the supply chain [2].

2. SINGLE-ECHELON VS. MULTI-ECHELON OPTIMIZATION

Single-echelon inventory system is one wherein a single Distribution Center (DC) acts as a central repository between the supplier of the inventory and the customer-facing outlets.

In a single-echelon network, an individual material-location combination is not affected by any other material or location. If a business was selling products from a single location, then it would be categorized as a single-echelon system. The DC is under the control of a single enterprise.

A multi-echelon inventory system is one that relies heavily on layers of suppliers distributed across multiple distribution centers and that is based on outsourced manufacturing. In such a system, new inventory shipments are first stored at a central or regional distribution center (RDC). These central facilities are the internal suppliers to the customer-facing outlets, also called forward distribution centers (DCs). Multi-echelon inventory optimization (MEIO) right-sizes safety stock buffers across the entire supply chain, taking into account the complex interdependencies between stages, as well as variables that cause chronic excess inventory, such as long lead times, demand uncertainty, and supply volatility [3]. Inventory optimization releases millions in trapped working capital and moves the supply chain to an entirely new trade-off curve between inventory cost and service level performance [4]. The difference in optimization can be seen in Figure 1.

There are some significant issues in optimizing a multi-echelon inventory system [4]:

- Demand variations measure for the RDC
- Demand measure for the RDC, and how to forecast this demand
- Defining optimal service level goals between the RDC and its "customers"- the DCs.
- Allocation of inventory down to the DCs when faced with limited supply situation at the RDC.

The key difference between single and multi-echelon inventory optimization is that traditional single-echelon inventory planning optimizes safety stock locally at each stage or location of the supply chain and the required amount of inventory is determined by applying appropriate inventory models. Single-echelon optimization models do not take into account the dependencies between the stages of the supply chain. In contrast, multi-echelon optimization approaches simultaneously optimize the placement and sizing of inventories within the entire supply chain, while considering all dependencies of the material flow between the stages. [5]

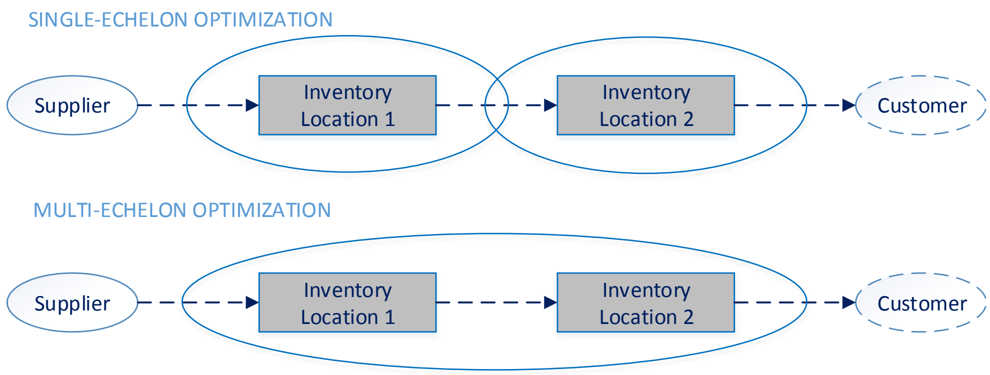

Figure 1 - Single vs. Multi-Echelon Optimization
Source: [4]

3. MANAGING INVENTORY IN MULTI-ECHELON NETWORKS

3.1 Network Topology

Multi-echelon supply chain or system is composed of stages (nodes, items, sites) that are grouped into echelons. Echelon inventory is defined as the inventory between a stage in the supply chain and the final customer. This helps when we are determining the safety inventories at an individual stage in the supply chain because it will depend not on the local inventory but it will depend on the inventory that is available at the previous and next stages too and will help in minimizing the safety inventories for the individual stages. [6] Stages can represent physical locations, items in BOM and processing activities. Stages can be defined as upstream and downstream stages. Usually stages to the left are upstream and those to the right are downstream as it can be seen in Figure 2.

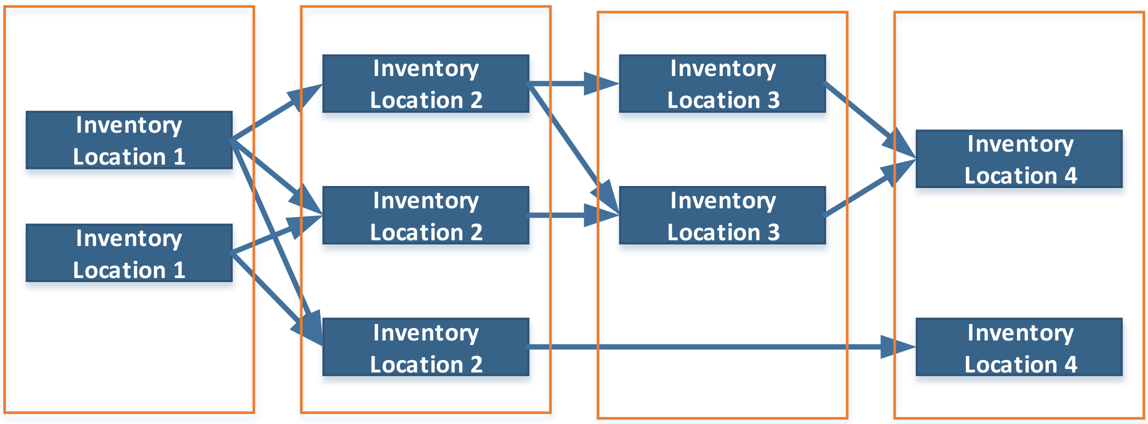

Figure 2 – Supply chain stages and echelons
Source: [7]

Network topologies, in increasing order of complexity can be defined as: serial system that each stage has at most one predecessor and the most one successor shown in Figure 3.

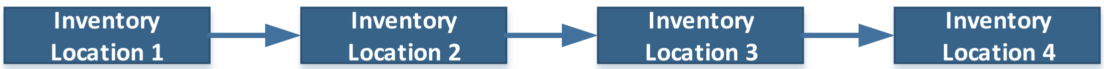

Figure 3 – Serial system
Source: [7]

Assembly system that each stage has at most one successor as it can be seen in Figure 4.

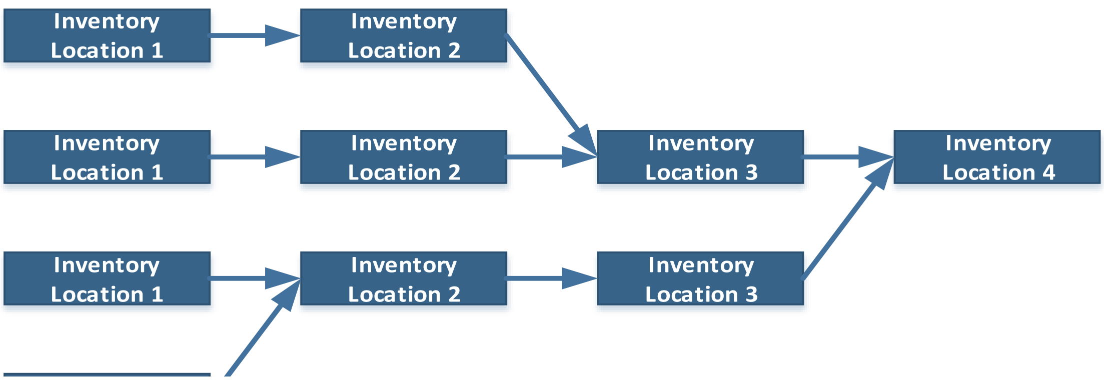

Figure 4 – Assembly system
Source: [7]

Distribution system that each stage has at most one predecessor as it can be seen in Figure 5.

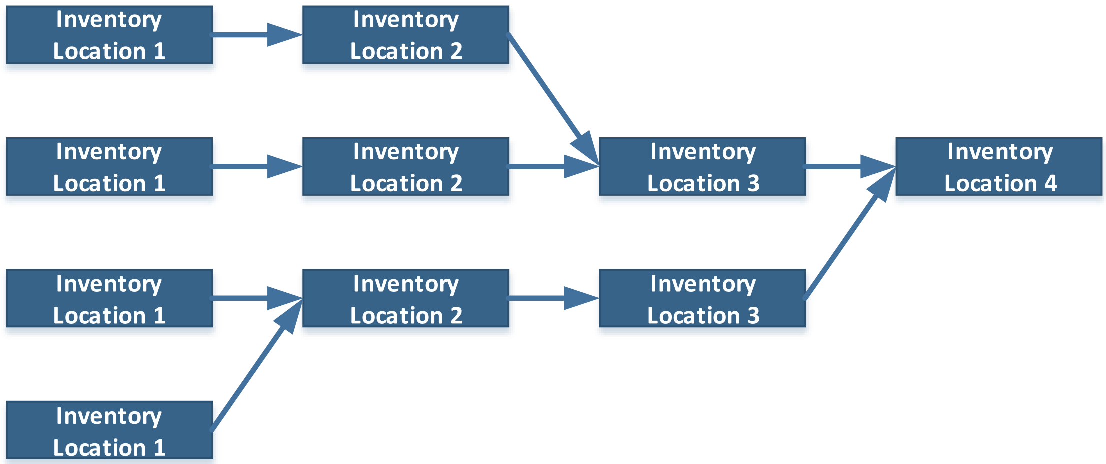

Figure 5 – Distribution system
Source: [7]

Tree system that has not restriction on neighbors but no cycles shown in Figure 6.

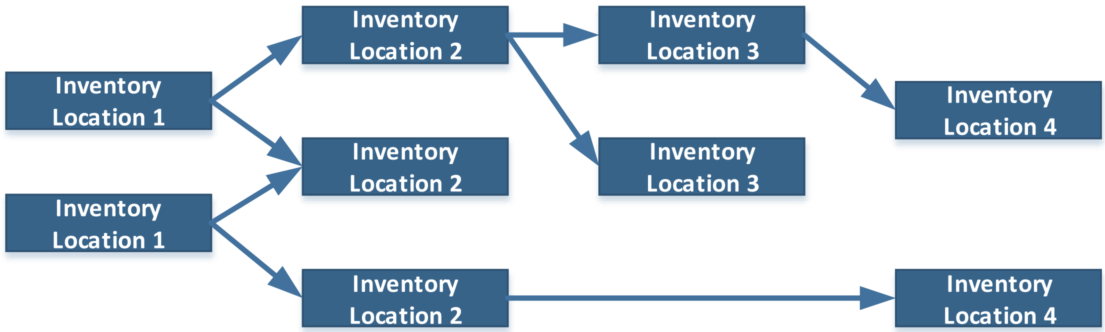

Figure 6 – Tree system
Source: [7]

3.2 Using a Sequential Approach

Choosing this approach you take the established approach used in the single-echelon case and apply it twice - once to replenish the DCs based on their inventory drivers and then again to replenish RDC, based on its inventory drivers. The lead times for the RDC are clear, they are lead times to the supplier. Sequential approach splits multi-echelon into two separate challenges – one for the DC and one for RDC. This approach may cause many problems [4]:

- Lack of visibility up the demand chain because when DC replenish itself, it is oblivious to suppliers beyond the RDC. DC ignores any lead times except the lead time from the RDC.
- Lack of visibility down the demand chain because when RDC replenish itself, it is oblivious to customer beyond those of the DCs. RDC has no visibility into DCs balances and demands.
- Demand distortion from bullwhip effect. Because the RDC and the DCs develop independent demand forecasts, the bullwhip effect causes increased demand variation between the RDC and the DCs.

- Total network cost remain unevaluated. When the RDCs or the DCs replenishment strategy changes, the cost implications of the new strategy on the other echelon are not considered.

3.3 True Multi-Echelon Approach

The objective of multi-stage inventory optimization is to determine the allocation of safety stocks within a supply chain that guarantees a high customer service level at the lowest cost possible [6]. The primary objective is to minimize the total inventory in all echelons while meeting service commitments to end customers. Transportation and warehouse operations are also kept in line, because their costs are part of optimization. With a multi-echelon approach, demand forecasting and inventory replenishment decisions are made at the enterprise level in a single optimization rather than in sequence for each echelon. This type of optimization should [4]:

- Avoid multiple independent forecast in each echelon because the demand signal and the other information at the DCs drive the forecasts in all echelons.
- Account for all lead times and lead time variations because in each echelon replenishment decisions account for lead times and lead time variations of all upstream suppliers.
- Monitor and manage the bullwhip effect and determine the root causes of demand distortion.
- Enable visibility up and down the demand chain – enable visibility what is on hand, on order, committed and back ordered.
- Synchronize order strategies reduces lead times and lead time variations between echelons.
- Offer differentiated service levels so each echelon can provide different service levels for the same product. It makes possible, because enterprise controls how and when product enters and leaves echelon.

4. EXAMPLES OF USING MULTI-ECHELON INVENTORY OPTIMIZATION

In this section will be illustrated two examples of multi-echelon inventory optimization. First example is based on supply chain optimization and will be showing principal advantages of using this type of optimization Second example is two-echelon optimization based on distribution center and retailers. In this case is used mathematical formulations to calculate minimum costs of running this type of system.

4.1 Multi-Stage Inventory Optimization in the Pharmaceutical Industry

The following case illustrates the multi-stage inventory optimization of a pharmaceutical supply chain of one of the world's top-selling branded pharmaceuticals, with multi-billion annual revenue figures.

Supply chain stretches over several countries: Japan, Italy, France, US to the packing sites in North America, Asia Pacific and Western Europe. Main production site is located in France called active pharmaceutical ingredient (API) of the drug is synthesized from a chemical precursor. This precursor is produced by two different subcontractors located in Japan and Italy. Raw materials required for the precursor production are obtained from external suppliers. When main process is done in France, API is brought to drug formulation site in US info different pharmaceutical forms, e.g. into tablets of different dosages. This bulk drugs are then shipped to a number of packaging sites around the world, when they are bundled to sales units of different types and sizes and sold to pharmaceutical distributors, hospitals, and other external consumers.

Lead time to raw materials is being delivered to precursor production is 6 months. Lead time of precursor production to API production is 10 weeks, API to drug formulation is 2 weeks and from drug formulation to packaging is 7 weeks.

Stock keeping units are 4 at precursor production, 2 at API production, 11 at drug formulation and 519 SKU at packaging. Cumulated value added is 10% at precursor production, 70% at API production, 85% at drug formulation and 100% at packaging process. Supply chain characteristics are shown in Figure 7.

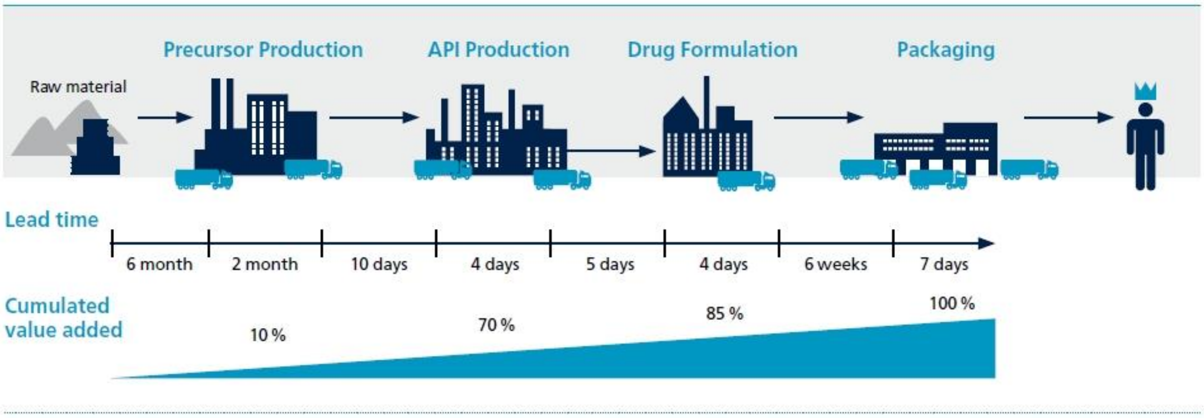

Figure 7 – Supply chain characteristics

Source: [8]

The optimization project was divided to into two parts. In the first phase the most important inventory locations were analyzed and optimized individually. The second phase of project was about developing new common process and platform for inventory and replenishment planning of all stages in the supply chain. The main part of this project was to optimize safety stock allocation within the supply chain using an advance multi-stage optimization tool. [5]

The main objective was to retain service level up to 99% but decrease stock levels. The analysis of optimization showed the total amount of buffering stock could be significantly reduced through the inventory consolidation. Working capital was reduced by 100% in precursor production, increased in API production by 48%, decreased in drug formulation by 64% and decreased in packaging by 6% as it can be seen in Figure 8. The total working capital through multi-stage optimization was reduced for 19%. Considering all optimization processes, such as reducing lead times, reducing safety stock and refining inventory management, the capital tied up in inventories was decreased by 27.3%.

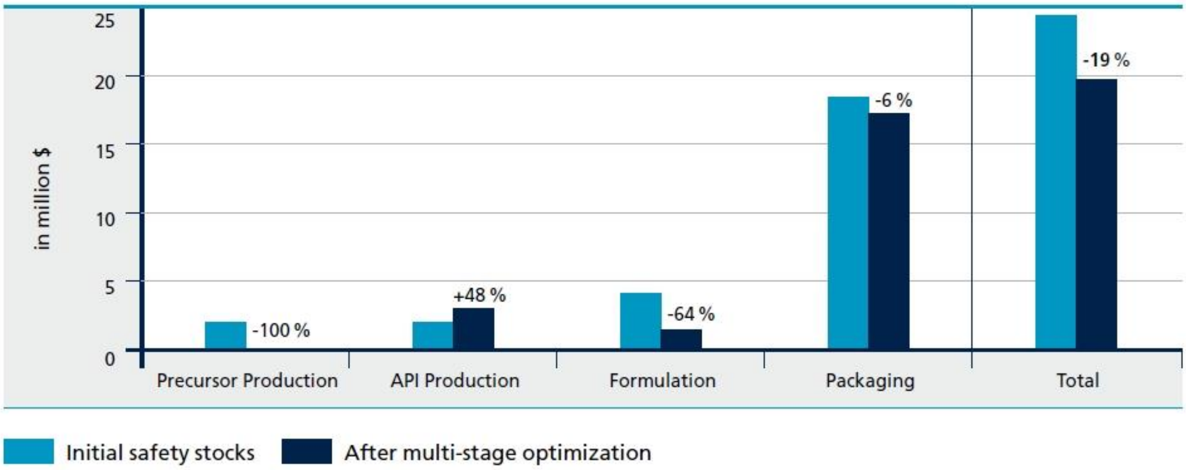

Figure 8 – Working capital reduction through multi-stage optimization
Source: [8]

4.2 Multi-Echelon Inventory Controling in Two-Echelon System Based on Stochastic Demand

Multi-echelon inventory optimization can also be used in distribution supply chain systems based on stochastic demand. As example it will be shown two-echelon model consisted of one distribution center and three retailers. Based on the objective of minimizing total cost, the model determines optimal order point and safety stock of retailers in the system.

In order to simplify the model conditions are proposed as following [9].

- Inventory cost of distribution center is lower comparing with manufacturers and retailers because of using centralization inventory control strategy;
- Distribution center orders from manufacturer, retailers order from distribution center and there is only one core product. Manufacturer supply ability is infinite so it is impossible distribution center will appear out of stock;
- The lead time of distribution center is constant and far less than average lead time of retailers;
- The demand *r* of retailers in *t* range is stochastic, the probability is known and obeys Poisson distribution;
- Lead time of retailers is stochastic, the probability is known and obeys Normal distribution, average lead time in unit time and variance are also known;
- Retailers should have safety stock to avoid stock out because demand and lead time are both stochastic.

Because model includes two parts, retailers inventory and distribution center inventory it must be analyzed separately and the sum objective functions of them is final objective function. Initial parameters are shown in table 1.

Table 1 – Initial Parameters

Place/Parameter	D_i	c_i	h_i	k_i	ρ_i	μ_i	σ_i^2	L_0
Retailer 1	365	1500	50	5000	1	15	1	-
Retailer 2	365	1600	45	6000	1	14	1	-
Retailer 3	730	1400	45	5500	2	16	1	-
Distribution center	1460	2000	30	10000	-	-	-	1

Source: [9]

As first step it should be calculated economic ordering quantity Q_i and optimal period n_i using EOQ formula:

$$Q_i = EOQ = \sqrt{\frac{2c_iD_i}{h_i}};\ n_i = \frac{D_i}{Q_i} \quad (i = 1,2,3) \qquad (1)$$

where:

- Q_i – optimal order quantity of retailers i;
- c_i – order cost of retailers i;
- D_i – annual average demand of retailers i;
- h_i – the unit inventory cost of retailers i;
- n_i – optimal period of retailer i;

Order point R_i includes average demand $D_i$and safety stock S_i, because lead time $L_i$obeys Normal distribution, average lead time is μ_i:

$$R_i = D_i + S_i = \mu_i\rho_i + S_i \quad (i = 1,2,3) \qquad (2)$$

where:

- R_i – reorder point of retailers i;
- S_i – safety stock of retailers i;
- ρ_i – average demand in unit of retailers i;

When inventory amount drop to R_i, retailers will order from distribution center, P_{iR} is probability of inventory shortage caused delay of delivery or demand increasing

$$P_{iR} = \sum_x P_i(x)F_{ix}(R) \quad (i = 1,2,3) \qquad (3)$$

where: $P_i(x)$ – probability of lead time.

If order point is R_i but the demand $r > R_i$ in x days, the probability is

$$F_i(x) = \sum_{r>R_i} \frac{e^{\rho_i x}(\rho_i x)^r}{r!}$$

The expectation of cost in inventory shortage is $n_ik_iP_{iR}$, inventory cost in every year is $\left(\frac{1}{2}Q_i + S_i\right)h_i$. In order Q_i is fixed after giving parameters, it is only need to minimize the sum of safety stock cost and expectation of cost in shortage, the function:

$$\min n_ik_iP_{iR} + h_iS_i \qquad (4)$$

$$st\ R_i = \mu_i\rho_i + S_i \quad (i = 1,2,3)$$

where: k_i – shortage penalty cost of retailers$i$.

Distribution center inventory optimization is much simpler than retailers. First step is to calculate economic ordering quantity Q_o using formula and optimal period n_o:

$$Q_0 = EOQ = \sqrt{\frac{2c_0D_0}{h_0}};\ n_0 = \frac{D_0}{Q_0} \qquad (5)$$

where:

- Q_0 – optimal order quantity of distribution center;
- c_0 – order cost of distribution center;
- D_0 – annual average demand of distribution center;
- h_0 – the unit inventory cost of distribution center;
- n_0 – optimal period of distribution center;

Order point R_0 includes average demand D_0 and safety stock S_0. Lead time of distribution center is a constant, so P_0 obeys between 0 and 1 distribution, $P_0 = \begin{cases} 1 & x = L_0 \\ 0 & x \neq L_0 \end{cases}$ Discussed earlier it is impossible distribution center appear out of stock, so it can be obtained that $P_{0R} = 0$ function is:

$$\min h_0\, S_0 + \frac{1}{2} Q_0 h_0 \tag{6}$$

where: S_0- safety stock of distribution center.

After all, two-echelon inventory in distribution model is built as following.

$$\min n_i k_i P_{iR} + h_i S_i + h_0 S_0 + \frac{1}{2} Q_0 h_0 \tag{7}$$
$$st\ R_i = \mu_i \rho_i + S_i \quad (i = 1,2,3)$$

Table 2 – Calculation Results

Place/Parameter	Q_i	R_i	n_i	S_i	Minimum cost
Retailer 1	148	25	2.5	10	588
Retailer 2	148	24	2.3	10	532
Retailer 3	213	52	3.4	22	1143
Distribution center	441	0	3.3	0	6615

Source: [9]

This inventory model research possibilities of minimizing cost caused by holding stocks in distribution center and retailers using multi-echelon inventory approach. Comprehensive analysis was made and evaluated by authors [9] and obtained optimal solution using Mathlab. Retailers are more important in this model because of stochastic demand and lead time so it is very important to keep stock optimal level. It is important to maintain service level at the same time with minimal costs. This model could involve additional parameters such as limited lifetime of perishable goods and might be researched in the future.

5. CONCLUSION

Inventory management is necessary work of any manufacturing, distribution and trading organization. It is necessary for several reasons: cost reductions, sales improving, increasing profitability, etc. Inventory management processes can be assumed in various ways but not every method is effective and applicable in all cases.

Because inventories are a major driver of working capital it should be well monitored and safety stocks are one of the most significant part to attain customer service and to enable well organized material flows through supply chain.

Multi-echelon or multi-stage inventory planning and optimization provide efficient measure to optimize all parts of supply chain such as: safety stocks, transportation processes, lead time variations, supply and demand uncertainty. By optimizing all of these, high service levels should be kept intact and customer must be highly satisfied with logistic service.

Using modern technology and IT services multi-echelon inventory optimization could be applicable to the complex and global supply chains and can integrated in existing distribution supply chains. High cost reductions and service improvements should stimulate companies worldwide to start implementing and using multi-echelon inventory planning and optimization.

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ANALYSIS OF TRANSPORT INSURANCE MARKET IN REPUBLIC OF CROATIA

ABSTRACT

Insurance is an important element of economic activity of each country. Economic activity today is almost inconceivable without insurance because of the value of material goods and the potential damage associated with them. The basic function of insurance includes preventive measures and indirect protection that are achieved through compensation of damage. Transport insurance of goods in transport is designed for people who have interest in the transported goods which are usually the owners of the goods. The basic principle of the insurance is the principles of reciprocity and solidarity, according to which the large number of insured, with the payment of the insurance premiums, allows the insurer to advance accumulates funds for the payment of future damages.

The aim of this paper is to present the contract of transport insurance, the way in which it is concluded, what types of damages can occur in transport insurance and to analyze the transport insurance market in the Republic of Croatia based on the data of the Croatian Financial Services Supervisory Agency and the Croatian Insurance Bureau.

KEY WORDS:

transport insurance, insurance contract, damages, insurance premium

1. INTRODUCTION

Transport insurance is insurance against damages in which contract of insurance, types of damages and its compensation need to be accounted for. The most important document in the transport insurance is the contract of transport insurance of goods which must be double-sided and mandatory and shall be concluded between the insurer and the insured.

Insurer's liability can be divided into those that should be fulfilled at the time of conclusion of the contract, the ones that need to be fulfilled during the duration of the contract and the ones that need to be fulfilled when the insured event is realized (payment of damages or compensation payments from insurance). Important characteristic of the transport insurance is the compensation for damages. Insurance claim is the amount that insurer pays to the insured after the occurrence of the insured event. An insured event is an accidental, unexpected or unforeseen event whose realization occurs in the damage to the case of insurance. At the same time this event creates an obligation of the insurer to compensate for the damages done to the insured. The fee charged by the insurer on behalf of his liability to pay damages to the insured if the damage occurs to the insured goods is called insurance claim. The insured assumes responsibility to pay premiums to the insurer with conclusion of the insurance contract. After concluding the insurance contract, the insurance is valid [1].

In this paper the analysis of the transport insurance market in the Republic of Croatia will be made, including the analysis of insurance claims during the past ten years. Within the initial analysis of the insurance market, analysis of the insurance premium, according to the division of insurance within the past five years, is presented.

2. CONTRACT OF TRANSPORT INSURANCE

The parties participating in contract of insurance are the insurer, which takes over the obligation to pay compensation from insurance (in the case of occurred events i.e. risks specified in the contract) and the insured person, which on the basis of the insurance contract shall be paid off in case of the insured event [2].

The contract of insurance is concluded between insurer and the insured person and he can make a contract for his own account or for the account of a third party. When concluding the insurance contract, the insurer is obliged to provide the insurer with all the information relevant to assessing the gravity of the risk. For the duration of insurance contract, the insurance beneficiary needs to take care of the insured assets, and notify the insurer about changes that could affect the severity of the risk (for example, changes in travel times, changing means of transport, changing the place of destination, etc.) [3]. In case that insured risks and the damages occur, the insured must immediately notify the insurer or its proxy of the place where the damage has occurred and take measures to prevent further damage of the insured object [4].

Typical way of concluding the insurance contract for transportation starts with the application for the insurance by insured or his attorney. The insurer shall issue an insurance policy, which confirms that the insurance contract is concluded [5]. On that basis and with the indemnity claim of the insured, the insurer carries out the process of liquidation of damages which determines whether all conditions for realization of the insurance rights in relation to claims for damages are present [6]. The insurer is bound to pay indemnity when following conditions are met [7]:

- there is a causal link between the insured risks and the resulting damage, i.e. the damage is due to the realization of some of the risks covered by insurance;
- the insured is not to blame for the damage, i.e. to damage not occurred intentionally or through gross negligence of the insured;
- fulfilled all the conditions set forth in the contract of insurance.

3. TYPES OF DAMAGES IN TRANSPORT

Damage is actual loss when insured risk occurs. Performance of the insured event in the transport of goods causes two types of damage. Those are the loss or damage of the goods. Types of damage in transport may be classified as follows [8]:

- **actual total loss** represents a material loss which occurred due to the collapse, disappearance, destruction or damage causing the goods have ceased to exist as such. If the damage happened due to the realization of insured risks, the insurer is required to reimburse the full insured value under the provisions of the insurance contract.

- **implemented complete loss of the goods** includes economically insured goods that as such physically exist, but given the purpose of the insured goods do not represent any value.
- **general or common disasters** are the types of damages which are divided as an disaster damage and a disaster cost. Disaster damage is caused by sacrificing a part or parts of the ship / cargo for the purposes of the common salvation. Disaster expenses consist of costs incurred for saving the ship and cargo and expenses incurred in connection with extraordinary measures in this regard.
- **individual disaster** represents damage or loss that occurred on ship or cargo in the case of event that has a detrimental effect on the ship or cargo. Damage is paid by those whose goods are damaged in occurred event.
- **reward for rescuing** is rescuing action in order to save the insured goods from the dangers of damage or collapse leading to cost. It is in the interest of the insured and the insurer, and the reward for saving should compensate the insurer who assumed the risk.
- **private costs** are the special costs that the insured had in the interest of the insured goods. This includes the cost of separating the damaged goods, the costs of cleaning and drying goods, goods re-sorting and packing, storage, unloading, reloading and re-boarding, further movement of goods, the costs of legal proceedings and the measures needed to store goods and expenses incurred in order to avoid the risk consequence.
- **obligation to compensate third parties**, is the obligation of giving which the insured person is required to pay, the owner of the goods is not covered by the insurance policy. For example, if due to improper packaging of goods the damage to other goods or ship is occurred, obligations of the owner of the goods to pay for damage to third parties are not covered by insurance, unless such damages are covered by the liability insurance for damages caused to third parties.

4. MARKET TRANSPORT INSURANCE IN CROATIA

Croatia has after six years finally emerged from recession during 2015. Potential positive contribution of foreign demand is expected due to a strong recovery in exports of service goods. Possible slowing of recovery in the EU would constitute a potential risk to continue speeding up the recovery of the domestic economy based on foreign demand [9].

If we examine the trend of exports in the past five years (from 2011 to 2015), it can be concluded that exports grew continuously except for negligible fall in 2013, and according to preliminary data for 2015 reached 11.47 billion euros. On the other hand, total imports shows an upward trend, although this growth rate is lower than the growth rate of exports, total imports in 2015 increased by 18 billion as shown in Table 1. The positive fact is that the coverage of imports of goods exports exceeded 62 % [10].

Table 1 - Trade balance

Year	*Export*	*Import*	*Export changes*	*Import changes*
2015	11.470.951	18.313.790	⇧ 111%	⇧ 107%
2014	10.324.296	17.055.889	⇧ 108%	⇨ 103%
2013	9.589.448	16.527.900	⇨ 100%	⇨ 102%
2012	9.628.468	16.215.896	⇨ 100%	⇨ 100%
2011	9.582.161	16.281.147	⇧ 108%	⇧ 108%

Source: [10]

From Table 2. it can be seen that the growth of transported goods is not sufficient to stop negative downward trend in insurance premiums of goods in transit. Except for 2013, the trend is downward since 2009. Total insurance premium of goods in transit for 2015, including all means of transport, is only 39 284 thousand HRK, which is compared to the peak in 2008, a drop greater than 55% [9].

Table 2 - Insurance of goods in transit

Year	Policies		Claims		Index premium	Average premium	Index average premium	Average settled claim	Index settled claims gross amount	Claim ratio
	Number of policies	Gross written premium in THRK	Number of Claims	Settled Claims Gross Amount in THRK						
2015	16.761	39.284	6.079	19.637	92%	2.344	94%	3.230	169%	50%
2014	18.234	45.266	4.568	11.621	94%	2.483	86%	2.544	81%	26%
2013	19.311	55.488	4.735	14.299	92%	2.873	117%	3.020	69%	26%
2012	20.934	51.601	4.490	20.620	100%	2.465	83%	4.592	102%	40%
2011	20.971	62.065	4.869	20.285	90%	2.960	103%	4.166	47%	33%
2010	23.401	66.951	6.330	42.907	123%	2.861	80%	6.778	94%	64%
2009	18.955	68.072	8.769	45.731	83%	3.591	93%	5.215	105%	67%
2008	22.746	88.033	9.343	43.381	104%	3.870	110%	4.643	181%	49%
2007	21.863	77.043	8.732	23.967	109%	3.524	100%	2.745	117%	31%
2006	19.990	70.557	6.220	20.529		3.530		3.300		29%

Source: [9]

If the above statistical data are plotted (picture 1.), we can see that in the period from 2006 to 2009, the number of insurances increase, while increasing the number of claims. In 2009 there was a sharp decline in the number of insurances, while the number of claims has stagnated. In 2010, the number of insurance had risen sharply and then came to the continuous decline until 2015, while the number of claims at the same time begins to fall until 2014, when a rise in the number of damage recorded. The technical result for the insurance of goods in transit for 2015 is 50% [9].

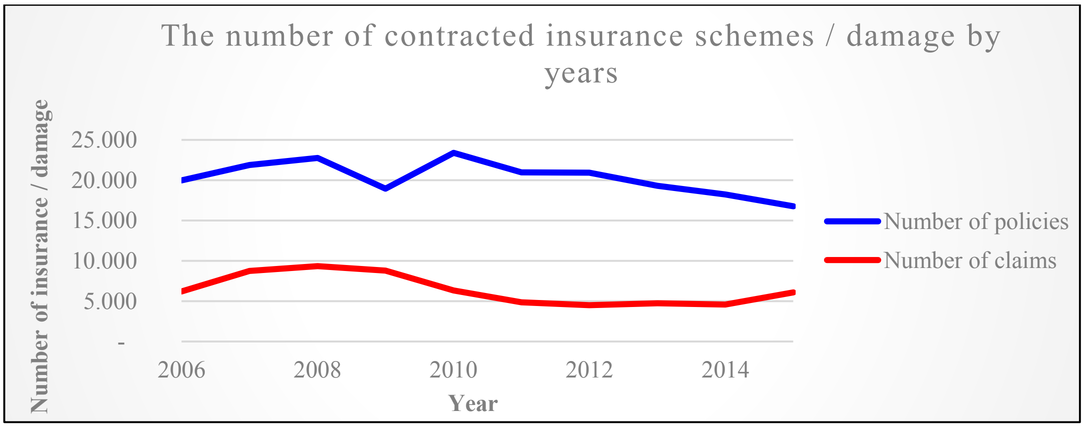

Figure 1 - The number of contracted insurance in relation to the number of reported claims
Source: Authors

As for the liquidation of the damages as shown in Table 3, in maritime transport since 2012 are on the decline until 2015 when a significant growth was registered. In aviation traffic in 2012 there was a dramatic increase in claims paid compared to 2011. In 2013 there was a decline of liquidation damages until 2015, when a new growth was recorded. In land transport, following an increase of claims paid in 2012 comes to a sharp decline in 2013 and stagnation in 2014 that continues in 2015. The total amount of claims paid in land transport was 5.3

million HRK. For the insurance of goods during the storage time there is no real data about the damages [11].

In the period from January to December 2015, 106.5 million tons of cargo was transported, which is 2.2% more than in the same period in 2014. The increase in the transport of goods was recorded in road transport (0.5%), in transport on inland waterways (15.2%), in maritime and coastal transport (5.1%) and pipeline transport (18.0%), and decrease was recorded in railway transport (by 4.3%) and air transport (11.7%) [10].

Table 3 - Insurance premiums and claims paid by type of

Types of insurance	Year	Gross written premium in THRK	Settled Claims Gross Amount in THRK	Index premiums written	The average premium per policy	The index of average premiums	The average damage	The index of average damage
INSURANCE GOODS IN SEA TRANSPOR	2015	7.805.450	2.025.269	95%	5.342.539	99%	50.631.715	728%
	2014	8.228.236	292.181	54%	5.381.449	48%	6.956.695	31%
	2013	15.272.649	952.037	136%	11.313.074	151%	22.667.554	67%
	2012	11.268.949	1.701.555	90%	7.507.628	181%	34.031.094	51%
	2011	12.466.870	2.933.308		4.150.090		66.666.096	
INSURANCE GOODS IN AIR TRANSPORT	2015	1.423.756	147.181	136%	1.324.424	136%	16.353.433	222%
	2014	1.044.734	29.429	91%	972.751	119%	7.357.210	66%
	2013	1.151.650	156.483	87%	816.194	78%	11.177.383	20%
	2012	1.326.138	792.950	99%	1.046.676	121%	56.639.294	446%
	2011	1.333.489	139.843		865.340		12.713.021	
INSURANCE OF GOODS IN LAND TRANSPORT	2015	14.500.678	5.318.833	92%	1.679.680	112%	4.839.702	67%
	2014	15.767.382	5.350.627	98%	1.496.240	104%	7.269.874	117%
	2013	16.028.886	4.009.844	88%	1.436.924	98%	6.216.812	28%
	2012	18.157.139	13.264.614	87%	1.462.281	92%	22.070.906	127%
	2011	20.814.277	8.886.246		1.585.367		17.389.915	
INSURANCE OF GOODS DURING STORAGE	2015	905	-	87%	181.058	35%		
	2014	1.038	-	1875%	519.140	1875%		
	2013	55	-	9%	27.690	22%		
	2012	636	-	173%	127.230	208%		
	2011	367	-		61.130			
OTHER INSURANCE GOODS IN TRANSIT	2015	15.574.374	12.143.439	77%	2.787.610	70%	2.462.673	156%
	2014	20.228.480	5.986.611	88%	3.973.380	93%	1.581.250	69%
	2013	23.076.977	9.206.255	111%	4.276.682	118%	2.282.165	179%
	2012	20.863.392	4.868.690	76%	3.630.942	76%	1.272.860	66%
	2011	27.504.691	8.320.421		4.807.672		1.933.632	

Source: [11]

Looking at the insurance premium by individual insurance according to picture 2, the expected fall in insurance premiums of goods in all types of transport is noticeable, except in the air transport. The cause of the fall of insurance premiums is a small number of insurance when Croatia in 2006 entered the recession. In air transport insurance premiums decrease was not recorded because of the increased risk in air transport [11].

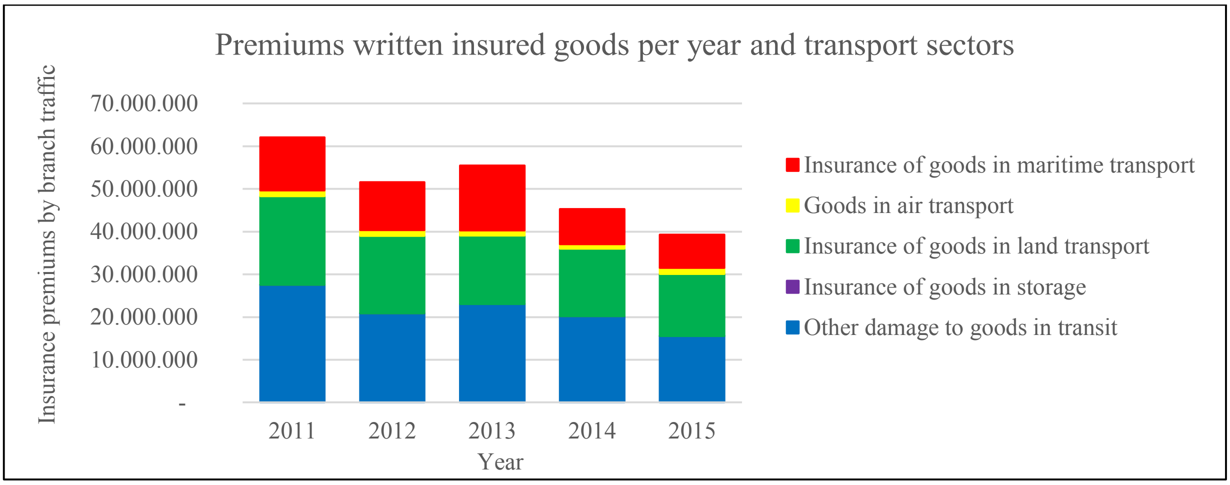

Figure 2 - Chart of written premiums per year
Source: Authors

According to picture 3, the most common type of insurance in 2015 is still the insurance of goods in land transport, which recorded the decline of 8% and premium about 14.5 million after the stagnation of the premium. Insurance in land transport prevailed in 2011 while other types of transport insurance prevailed in 2011, 2013, 2014 [9].

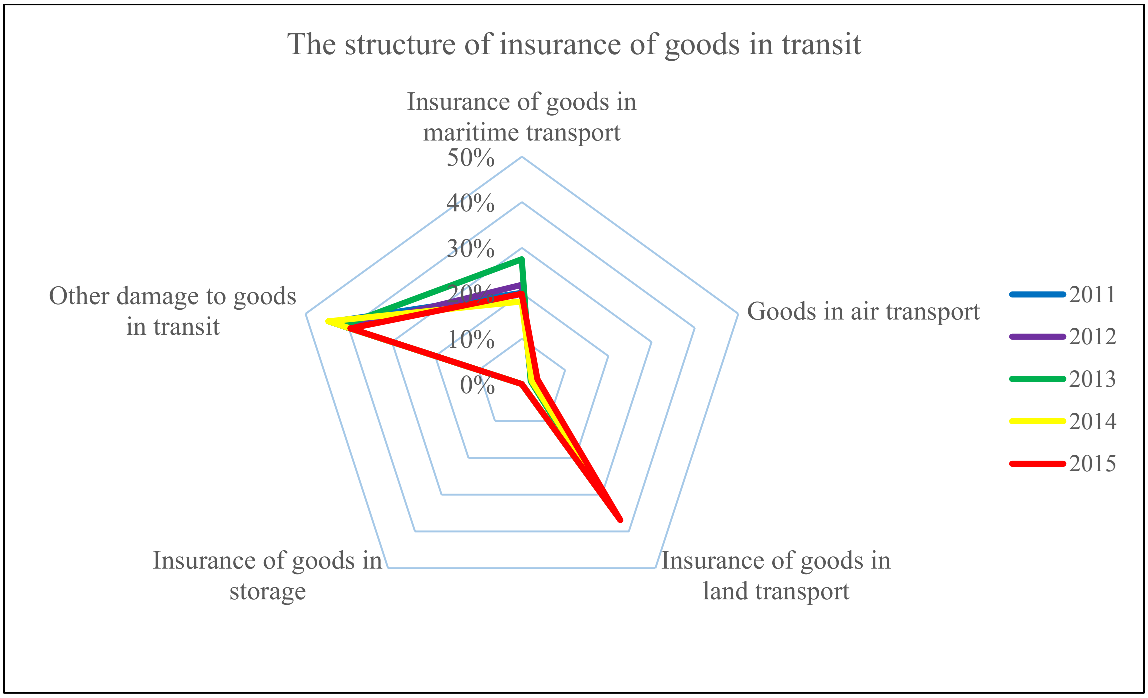

Figure 3 - The graph showing the goods insurance structure in the process of transportation
Source: Authors

5. CONCLUSION

Given the macroeconomic situation in the Republic of Croatia and the insecure political situation and the fact that transport cargo insurance is not mandatory, the negative trend of continuous decline in written premium is continuing and at the same time the growth in the liquidation of the damage continues. This leads to the negative performance of the Insurer, and because of this Insurers are slowly giving up the development of the insurance of goods in transit.

Based on collected data, it can be concluded that trade balance, which depends on import and export of goods, in the period from 2011 till 2015 was an upward trend which leads to the fact that the coverage of imports by exports exceeds 62 %. While imports and exports of goods recorded a positive trend, this time in the insurance of goods in transit government's negative trend of declining premiums of goods in 2015, including all means of transport, achieved a decrease greater than 55 %. As for the number of contracted insurance in relation to the number of reported claims in 2015 recorded the increase in damages, while a decline in insurance. In observation of the insurance premium for each type of insurance, there is an insurance premiums decrease in all types of transport except in air transport. On the other hand, there is a risk increase in transport, especially in air transport.

It can be concluded that the most common type of insurance is insurance of goods in land transport at a stagnant premium of 8 %. One of the main causes of the negative trend in transport insurance is the Croatian entry into recession in 2006.

With the awareness development of increasing risk in the transport of goods which is reflected in the decline of the premium and the simultaneous growth of the amount of damages, after exiting the recession, growth in the number of newly contracted insurance of goods in transit can be expected.

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ANALYSIS OF THE NORM HRN EN 1317-3: 2011 FOCUSING ON TRAFFIC SIGNALIZATION WITH THE PURPOSE OF PASSIVE PROTECTION OF ROAD USERS

ABSTRACT

The construction of modern roads that allow the circulation of large volumes of vehicles and also develop increasingly higher speeds, the requirements for adequate protection of participants in traffic are being set. In order to improve and enhance safety on motorways and other fast or potentially dangerous roads, it is necessary to build elements of passive protection of road users. In order to achieve greater security in the troubled parts of the road, many experts who care about security tried to install various security systems, from the simplest obstacle to modern road safety systems, protective cushions, etc.

In this work closely will be processed Croatian standard EN 1317-3: 2011 concerning the criteria for the testing of protective systems. Also, special emphasis will be on traffic safety marking system as an element of road transport equipment, which could greatly increase the level of protection and better recognition of protection systems.

KEY WORDS:

traffic safety, protective systems, normisation, traffic signalization

1. INTRODUCTION

Road safety is based on a three pillar approach by focusing on the vehicle, the driver and last but not least, the infrastructure. In turn, infrastructure safety [1] can be separated into active safety measures, whose role is to ensure as far as possible that the driver maintains control of his vehicle through appropriate guidance (e.g. road markings and signs) and passive safety measures, whose role is to protect drivers once they have lost control of their vehicle and, in the end, to protect drivers from their own human mistakes.

With the development of the road network, especially the construction of new highways in Croatia and a growing number of modern (and fast) vehicles in the last decade, there is a need for systematic improvement of safety of traffic participants. Motorways and modern cars enable quality traffic flow and reduction of traveling time, but they do not ensure the maximum safety of all passengers. In order to achieve greater security, security systems which task is to mitigate adverse consequences of traffic accidents as more possible are installed.

Various experts in technical disciplines approach in different ways to the issue of finding appropriate safety system, and according to this a range of successful and less successful protection systems are developed. For this reason, it was necessary to adopt norms to regulate this area and for this purpose the Croatian Standards Institute adopted EN 1317 [3] and all its parts as Croatian standard.

Road restraint systems [2] have the aim to prevent vehicles from leaving the road, thus to elude obstacles (lightening posts etc.), to protect the environment (water protection areas etc.) or to prevent fall hazards at bridges (protecting people and housing underneath bridges).

According to [3] protection systems according to their applications are divided into the safety systems for vehicles and protective systems intended for pedestrians. The safety systems [3] include endings and transitions, guard rails, low driving fence, protective cushions and stopping beds. The protective system for pedestrians [3] includes pedestrian fence and pedestrian low fence.

As previously stated, this paper put the emphasis on testing the protective crash cushion and the traffic marking of protective systems as elements of road traffic equipment.

2. TECHNICAL - TECHNOLOGICAL ANALYSIS OF THE HRN EN 1317-3: 2011 NORM

To an average user it is impossible to assess the level of security that a particular product provides, and consequently it was not easy to decide which system is better for the individual locations. For this purpose, the Croatian standard HRN EN 1317-3 was adopted, which determines the type of implementation, crash tests eligibility and methods for testing protective cushion, as protection of road system. Norm is a clear indication of the application scope of the tested protective cushion.

In accordance with HRN EN 1317-3, testing is carried out according to three criteria: the approach (angle), the mass of the test vehicle and the speed of impact. The test is marked as shown in Figure 1, where from the example can be seen that the disclosed test is used for front access of a 1,300 kg heavy vehicle at 100 km/h.

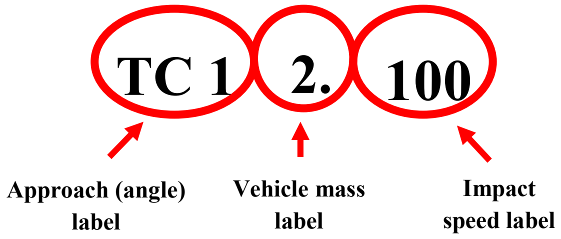

Figure 1 - An example of test marking
Source: Made by the authors according to [4]

2.1 Criteria for testing vehicle impacts

In order to evaluate the quality of the protection system, it is necessary to test it. Determining the quality in accordance with the access angle is conducted based on five different criteria [4], as shown in Figure 1:

- TC1 Frontal impact in the middle point on the top of the protective cushion,
- TC2 Frontal impact on the top of the protective cushion with vehicle displacement by ¼ width,
- TC3 Impact in the top (center) of the protective cushion at an angle of 15˚,
- TC4 Impact at an angle of 15˚ in the side of the protective cushion,

- TC5 Impact at an angle of 165˚ in the side of the protective cushion.

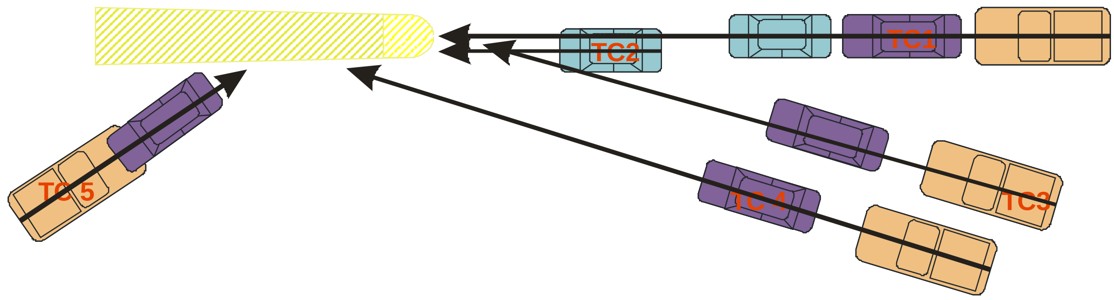

Figure 2 - The criteria for determining the quality of protective system according to the access angle
Source: Made by the authors according to [4]

Based on the weight of the test vehicle, testing is performed with three different vehicle types [4] as shown in Figure 3. Vehicles with total mass greater than 1500 kg are not used in crash cushion tests and there are not provided any tests for them.

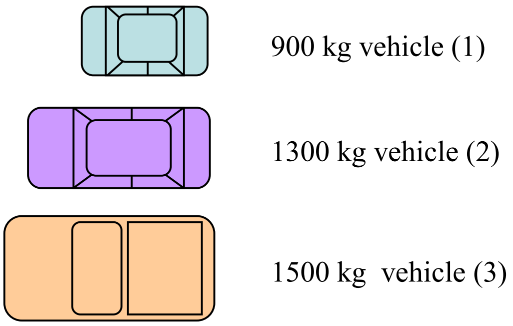

Figure 3 - Test vehicle types
Source: Made by the authors according to [4]

Speeds of test vehicles when hitting a crash cushion determine the level of protection, and during the test four different values are used [4]: 50 km/h, 80 km/h, 100 km/h and 110 km/h, where the maximum test speed of impact represents value of 110 km/h. For speeds greater than 110 km/h tests are not provided.

In accordance with the action mode, the design and application, crash cushions or bumper pads can be divided according to the method of [4] action into redirective and non-directive. According to the structure, they can be narrow and wide type (Figure 4), while according to the field of application can be divided into one-way and two-way type.

Redirective cushion type [4] allows the slowing or stopping of the vehicle hitting it and / or diverts the vehicle into the correct or preferred path to continue the vehicle movement. Unlike the directive type, non-directive crash cushion type [4] just slows down and stops the vehicle safely.

Narrow type crash cushion [5] throughout its length is of the same width, with parallel-mounted side walls, while its width usually does not exceed 1000 mm. Wide crash cushion generally is shaped trapezoidal , and is narrower at the front and wider at the rear. The front of the wide cushion [5] usually has a width between 1400 and 2200 mm, while the so-called back-up has a width between 2500 and 3200 mm, depending on the intended prescribed speed on the road part on which mentioned crash cushions are installed.

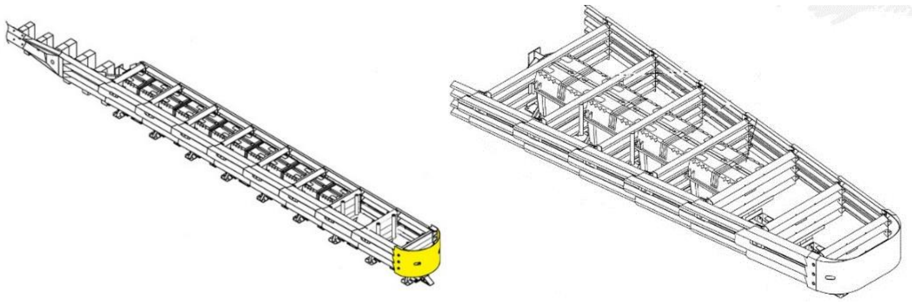

Figure 4 - Narrow and wide type of protective cushion
Source: [6]

2.2 Eligibility criteria of crash tests

In order to quality and responsible evaluate the appropriateness and safety of the use of a test crash cushion, when studying the test results, it is necessary to identify the type of protective device that has been tested and which test had satisfied. It is possible that it happens that one system cushion passes the test as wide crash protective system or fails the test as narrow type and other way around. To determine which level of qualification crash cushion system reached, it is necessary to identify exactly which tests it passed and whether it was used narrow or wide. It is also necessary to assess whether the product has been tested and passed the tests as a two-way or one-way crash pad, in order to be safe in what cases it is possible to use it. The protective pad which did not pass the tests marked TC5 cannot be used as a two-way safety cushion.

In accordance with HRN EN 1317-3, Table 1 shows the types of tests used in testing of vehicle hitting the crash protective system. The table defines the terms of execution of each test.

Table 1 - Criteria of vehicle impacts for each test

Test	Vehicle approach	Total vehicle mass (kg)	Speed (km/h)	Test no.
TC 1.1.50 TC 1.1.80 TC 1.1.100	Vertical in the center	900 900 900	50 80 100	1
TC 1.2.80 TC 1.2.100		1300	80 100	1
TC 1.3.110		1500	110	1
TC 2.1.80 TC 2.1.100	Vertical ¼ vehicle outside the cushion	900	80 100	2
TC 3.2.80 TC 3.2.100 TC 3.3.110	The central at an angle of 15°	1300 1300 1500	80 100 110	3
TC 4.2.50 TC 4.2.80 TC 4.2.100 TC 4.3.110	Side impact at an angle of 15°	1300 1300 1300 1500	50 80 100 110	4
TC 5.2.80 TC 5.2.100 TC 5.3.110	Side impact at an angle of 165°	1300 1300 1500	80 100 110	5

Source: Made by the authors according to [4]

Crash cushion can be tested as an individual product like non-directive or redirective type and as a system type of protective cushion. If the product is tested as an individual type tables 2 and 3 are used, and if is tested as a system type tables 5, 6, 7, 8, 9 and 10 are used.

Table 2 is used when testing the directive individual type of protective crash cushion and shows all the tests that must be conducted in order to qualify the product for the required level.

Table 2 - Vehicle impact criteria for an individual redirective crash cushion

Level	**Eligibility test**					
50	TC 1.1.50	-	-	-	TC 4.2.50	-
80/1	-	TC 1.2.80	TC 2.1.80	-	TC 4.2.80	-
80	TC 1.1.80	TC 1.2.80	TC 2.1.80	TC 3.2.80	TC 4.2.80	TC 5.2.80*
100	TC 1.1.100	TC 1.2.100	TC 2.1.100	TC 3.2.100	TC 4.2.100	TC5.2.100*
110	TC 1.1.100	TC 1.3.110	TC 2.1.100	TC 3.3.110	TC 4.3.110	TC5.3.110*
Note 1. (*)it is not necessary for a place where vehicle cannot come (one-way street, thoroughfare) Note 2. For the class 80/1 number of tests has been reduced by the volume index of acceleration, deformation of the safety crash cushion and the vehicle's behavior is not comparable with the class of 80						

Source: Made by the authors according to [4]

Table 3 is used to test the non-directive protective crash cushion, a single type. Tests TC 4 and TC 5 are not included in this table because non-directive protective cushions are not suitable for the location through which a two-way traffic flow occurs.

Table 3 - Criteria of vehicle impact for individual redirective safety cushion

Level	**Eligibility test**			
50	TC 1.1.50	-	-	-
80/1	-	TC 1.2.80	TC 2.1.80	-
80	TC 1.1.80	TC 1.2.80	TC 2.1.80	TC 3.2.80
100	TC 1.1.100	TC 2.1.100	TC 2.1.100	TC 3.2.100
110	TC 1.1.100	TC 2.1.100	TC 2.1.100	TC 3.3.110
Note – For the class 80/1 number of tests has been reduced by the volume index of acceleration, deformation of the safety crash cushion and the vehicle's behavior is not comparable with the class of 80				

Source: Made by the authors according to [4]

Table 4 contains the levels of impact intensity used in conducting the tests of eligibility. All the results of the impact force when conducting the tests must be documented in the final report testing.

Table 4 - The values of intensity of hitting crash cushion

Level of impact intensity	**Maximum permissible values**		
A	ASI ≤ 1.0	THIV ≤ 44 km/h in tests 1,2 and 3 THIV ≤ 33 km/h in tests 4 and 5	PHD ≤ 20 g
B	1.0 < ASI ≤ 1.4	THIV ≤ 44 km/h in tests 1,2 and 3 THIV ≤ 33 km/h in tests 4 and 5	PHD ≤ 20 g
Note 1: The impact strength A provides a higher level of protection for drivers of a traveling vehicle impact than level B and was given a priority Note 2: The limit value for THIV has been higher in the test 1, 2, 3 because experience has shown greater value that can be tolerated in a frontal collision (because the better passive safety in this direction). The difference in tolerance between the frontal and side impact has been considered in the ASI parameters so no changes are required *ASI – acceleration severity index **THIV – theoretical head impact velocity *** PHD – post-impact head deceleration			

Source: Made by the authors according to [4]

In practice, very often there is a need for using a system protective cushions that are made of the same parts with the same operating mechanism of the same name and tested in accordance with HRN EN 1317-3. System protection cushions are tested according to the tables 5-10 with regard to the initial model tested.

If the initial tested safety cushion is narrow and belongs to the highest speed level (110 km/h) in order to qualify a group of products as system crash cushions, tests shown in Table 5 must be successfully carried out.

Table 5 - Tests for system crash cushions, narrow 110 km/h

Speed class Km/h	**Narrowing / width**		
	Minimal	**Medium**	**Maximum**
110	All tests	-	TC 1.1.100 TC 4.3.110**
100	TC 1.2.100	-	TC 4.2.100**
80	TC 1.2.80	-	TC 4.2.80**
50	TC 1.1.50	-	TC 4.2.50**
Note: test labeled with ** is not necessary for non-directive safety cushions.			

Source: Made by the authors according to [4]

If the initial tested safety cushion is narrow and belongs to speed level of 100 km/h in order to qualify a group of products as system crash cushion it is necessary to successfully carry out the tests shown in Table 6.

Table 6 - Tests for system crash cushions, narrow 100 km/h

Speed class Km/h	**Narrowing / width**		
	Minimal	**Medium**	**Maximum**
100	All tests	-	TC 1.1.100 TC 4.2.100**
80	TC 1.2.80	-	TC 4.2.80**
50	TC 1.1.50	-	TC 4.2.50**
Note: test labeled with ** is not necessary for non-directive safety cushions.			

Source: Made by the authors according to [4]

The protective system to be tested with a narrow initial protective cushion that belongs to speed level of 80 km/h must pass additional tests as shown in Table 7.

Table 7 - Tests for system crash cushions, narrow 80 km/h

Speed class Km/h	**Narrowing / width**		
	Minimal	**Medium**	**Maximum**
80	All tests	-	TC 1.1.80 TC 4.2.80**
50	TC 1.1.50	-	TC 4.2.50**
Note: test labeled with ** is not necessary for non-directive safety cushions.			

Source: Made by the authors according to [4]

The protective system to be tested with a narrow initial protective cushion that belongs to speed level of 50 km/h must pass additional tests as shown in Table 8.

Table 8 - Tests for system crash cushions, narrow 50 km/h

Speed class Km/h	**Narrowing / width**		
	Minimal	**Medium**	**Maximum**
50	All tests	-	TC 1.1.50 TC 4.2.50**
Note: test labeled with ** is not necessary for non-directive safety cushions.			

Source: Made by the authors according to [4]

If the initial tested safety cushion is narrow and belongs to speed level of 100 km/h and 110 km/h, it must pass additional tests such as shown in Table 9 in order to qualify as a system crash cushion.

Table 9 - Tests for system crash cushions, narrow 100 km/h and 110 km7h

Speed class Km/h	**Narrowing / width**		
	Minimal		**Minimal**
110	TC 1.3.110 TC 3.3.110	-	TC 4.3.110**
100	All tests	-	TC 1.1.100** TC 4.2.100**
80	TC 1.2.80	-	TC 4.2.80**
50	TC 1.1.50	-	TC 4.2.50**
Note : : test labeled with ** is not necessary for non-directive safety cushions			

Source: Made by the authors according to [4]

If the initial tested safety cushion is wide and belongs to speed level of 100 km/h, it must pass additional tests such as shown in Table 10 in order to qualify as a system crash cushion.

Table 10 - Tests for system crash cushions, wide 100 km/h

Speed class Km/h	**Narrowing / width**		
	Minimal	**Medium**	**Maximum**
110	TC 1.3.110 TC 3.3.110	-	TC 4.3.110**
100	TC 1.2.100 TC 4.2.100** TC 5.2.100*	-	All tests
80	TC 1.2.80	-	TC 4.2.80**
50	TC 1.1.50	-	TC 4.2.50**
Note 1: test labeled with ** is not necessary for non-directive safety cushions Note 2: test labeled with * is not necessary in places where a vehicle cannot come (traffic in one direction, the passage)			

Source: Made by the authors according to [4]

Road safety systems which are designed, manufactured and tested, with documented processes of formation and testing devices in accordance with HRN EN 1317-3 ensure a high level of protection of road users. In order to achieve even greater level of protection, given protective systems should be properly labeled with recognizable traffic signalization.

3. CRASH CUSHION MARKING WITH TRAFFIC SIGNS

Crash cushion marking is not standardized and clearly defined, not in terms of the pictograms use, nor the quality and type of material. Since this equipment is located on the road, mostly at the most dangerous places in all weather conditions (darkness, glare, rain, snow and similar), the proper and visible marking is necessary.

Road markings at locations where the protective crash cushions are installed usually are not conditioned by crash cushion but certain configuration and direction of road and regardless of the security system itself were drawn and placed in a similar way.

The main tasks of road markings are to warn of the situation in the area in front of the vehicle and lead traffic through optimal and safe path. Road markings in locations with installed protective cushions need to ensure that drivers at the time they notice a stationary obstacle on the road and lead traffic at a sufficient distance from the crush cushion to avoid unnecessary hitting the protective system.

Road markings on location with integrated protective cushion usually consist of lateral guiding lines and of the traffic island lined with cross oblique lines, as shown in Figure 5.

Figure 4 - Horizontal road marking in a place where crash cushion is installed
Source: [8]

It is necessary to keep in mind two safety aspects of this element of traffic road equipment when marking crush cushion with traffic signs. The first aspect is the labeling of crush cushion, which itself is a certain stationary obstacle on the road, and as such must be properly labeled so the drivers could notice it at the time and all in order to prevent an unwanted impact. As marking of crash cushion as an element of traffic equipment is not standardized nor covered by Regulations on traffic signs, signalization and equipment on the road (Official Gazette 33/05) [7], thus only front frontal visible cushion parts (crush cushion nose) (Figure 6) and turn (bend) as such are marked, or protective systems are not marked with traffic signs at all (Figure 7).

Figure 5 - Traffic marking of crash cushion in Republic of Croatia
Source: [9]

Figure 6 - An unmarked crash cushion in Republic of Croatia
Source: By authors

In Figure 7, it can also be seen a shortage at the set of crush cushion, because, not only that is not associated in an adequate and safe way with repulsive elastic protective fence which should be built on a safety cushion, but the repulsive elastic fence is placed parallel to single protective bag. Crash cushion set up and traffic marked like this can never provide a satisfactory level of protection and the funds invested are nearly wasted.

Another aspect, which is equally important to consider, is the case when the driver loses control of the vehicle. For this reason, traffic signalization should not lead to the drivers attempt to avoids a safety cushion, because it could lead to more dangerous consequences, such as the impact in another vehicle or in the exposed parts of the road. The purpose of crush cushion is to assume and to mitigate the impact energy of vehicles, so it is advisable that in the event of an accident vehicle hits exactly the crush cushion.

4. POSSIBILITY FOR IMPROVING ROAD SAFETY SYSTEM

Road safety systems are very effective in raising the level of passive protection on roads and saving lives, so it is necessary to work continuously to improve the efficiency and development of these devices. Possibilities of improving road safety systems are very large, and can be viewed from the aspect of increasing the use of the same, in terms of technical and technological improvements or of reducing the price and the cost of installing and upgrading the transport labeling.

Possible technical and technological improvements represent great opportunity for improving road safety systems. We are witnessing daily promotion and finding of new materials and technology that very quickly find its place in the production of new and improvement of existing devices.

The use of new information led to the new forms of folding side panels, which resulted in greater strength and durability of the same. Furthermore, the current protective systems are manufactured exclusively from steel profiles, protected by hot dip galvanizing, so are very heavy and are expensive to produce, transport and setup, and after that to maintain. The use of new composite materials should reduce the overall weight of the system and cheapen their production. Reducing the weight of the individual components could improve the relatively poor side of the protective cushion, which is the risk of parts which can be separated from the system during the impact. The big disadvantage of some types of product is the possibility that during the vehicle impact a relatively heavy piece of equipment separates from the safety device, which due to the speed and uncontrolled movement represents an additional risk for road users. Although HRN EN 1317-3 norm says that from the protective crash systems must not separate any part weighing more than 2 kg, because it is already more than enough that combined with high speeds could cause serious consequences on vehicles or passengers. Using modern equally solid but lighter materials, this greatly disadvantage could be avoided.

One of the important reasons for not using these products is relatively high cost of their construction and installation, very often more than ten thousand Euros. Therefore, the widespread use of road protection systems can be realized by reducing the prices of these products. Reducing the cost of protective system could be realized through the use of new materials for producing protective crash cushions and new cheaper and more effective technical solutions. The initial price reduction could cause greater use of these systems which could lead to mass production and thus further costs reducing and the reducing the final price of the product.

Better road safety labeling system would contribute to the improvement of safety of participants in traffic, since so far installed devices are very poor or no marked. Such deficiencies should be corrected by better and above all uniform marked traffic safety equipment. When we talk about a better labeling of road safety systems, it primarily concerns the additional labeling that could on time warn of approaching a stationary obstacle on the road and of the presence of the road protective system. It is desirable to mark the side of the protective cushions with signs K10 and K11 "The panel to mark obstacles on the road to the left and to the right". It is preferably that the sign is not made on an aluminum sheet substrate, but to glue the minimum class II retroreflective foil directly to the side panels of the protective crash cushions (Figure 8).

Figure 7 - Additional traffic marking of the crash cushions by signs K10 and K11
Source: By authors

Improvements in the traffic road marking of protection system in Figure 9 are achieved by placing additional traffic sign K08 "The panel to indicate a traffic island" made with foil class II, basic color white, then sign K09 (the nose of crash cushion) "Traffic island marking panel" made using foil class II, basic colors yellow-green and side mounted signs K14 "The panel to indicate the bend on the road", made with class II foil, basic colors yellow and green. Oversite the sites of the protective crash cushion only foil with a sign K14 pictogram is applied.

Figure 8 - The additional traffic labeling protective with cushions K8 and K14
Source: By authors

Traffic signalization, especially traffic signs, shouldn't lead to a situation where the driver tries to avoid impact in the road safety system and after that hits another vehicle or an unprotected part of the road or road shoulder. On the contrary, drivers should on a simple and universal way be informed of the installed protective device that can help to stop the vehicle with minimal consequences. A special way of marking road protection system would be of great help in this kind of situations. Since there are signs that mark obstacles on the road with codes K6 - K18 already defined and drivers know them well, it would be good to use but change the base color of sign. One of the suitable color may be fluorescent green, while the orienting fields could be white, as shown in Figure 10. This combination of colors is not used anywhere else in the traffic signs, so would undoubtedly indicate the existence of specially installed equipment to cushion vehicles.

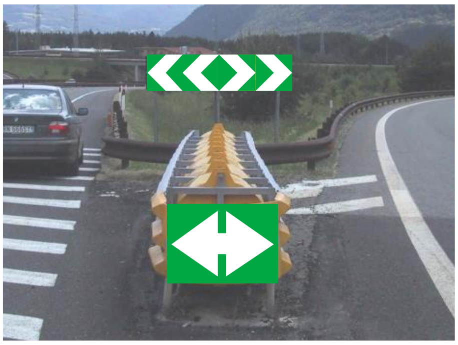

Figure 9 - Crash cushion marking with fluorescent green and white foil
Source: By authors

5. CONCLUSION

According to [10] and [11], in the period between 2005 and 2016 on Croatian roads happened 503,245 accidents in which the 216,550 people were affected: 5,303 died and 211,247 injured. Since then, in 2015 happened 32,571 accidents, in which 348 people died, 2,822 people were seriously injured and 12,202 persons were slightly injured. Furthermore, according to data from [10], an important indicator of road safety, the number of deaths per hundred thousand inhabitants, in the Republic of Croatia amounted to 7.2

Increased need for an appropriate road safety system has resulted in the creation and production of a large number of various systems that are different from each other by the mode of action, but also by the level of care they provided in case of impact. In order to facilitate efforts to the producers of the mentioned equipment and traffic experts who deal with traffic safety, to produce and select the appropriate equipment, the authorities introduced norms regulating this area.

HRN EN 1317 standard was created as a response to the need of regulating the production and use of road protection systems. This paper elaborates the part that refers to the type of implementation, crash tests eligibility and methods for testing crash cushions, or standard HRN EN 1317-3: 2011. Since the norm is little known to a wider circle of traffic experts and is highly complex, and it can seem incomprehensible to less experienced professional, in this paper was attempted to point out the most important parts of the norm that the person responsible for traffic safety should keep in mind while designing, construction and exploitation of roads. First of all, they need to know to decide whether they need sufficient individual crash cushion or tested protection system (product groups). Furthermore, responsible professionals for any potential application of this features need to select appropriate, between one-way or two-way, redirective or non-redirective and wide or narrow protective systems (crash cushions).

Special emphasis in this paper was on marking the road traffic safety systems. The existing method of marking is insufficient, and sometimes crash cushions are not marked at all, so some aspects of the road safety systems markings were described, in accordance with the Regulative on traffic signs, signalization and equipment on the road (NN 33/05) and some new ways of marking were proposed. A marking with new materials of retroreflection class III was suggested, which would be more noticeable at night and in low visibility. The basic foil color could be fluorescent green, which would contribute to a better visibility during the day and give uniform message to road users that they are approaching the installed equipment of road protection system.

Knowing HRN EN 1317-3 norm, installation of road safety systems that are manufactured and tested in accordance with this standard and their consistent and uniform road marking, can greatly contribute to the increase of passive safety on our roads and save many human lives.

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SHORT REVIEW OF APPROACHES FOR VARIABLE SPEED LIMIT CONTROL

ABSTRACT

Urban motorways serve the traffic demand from adjacent dense populated urban regions and transit traffic. Combinations of these two traffic demand types generate periodically traffic congestions during the peak hours. The capacity drop effect is the most common cause of congestions. It occurs when the current traffic flow reached its maximal capacity of the observed urban motorway section. In order to alleviate the capacity drop effect and enable better level of service on motorways new traffic control methods are introduced. One of the used traffic control methods is variable speed limit control (VSLC). VSLC conducts homogenization and reduction of vehicle speeds what consequently decreases time needed to create a critical shockwave, which will induce the capacity drop. This paper presents a short overview of the latest VSLC algorithms originally designed for mitigation of traffic congestions and their effects on the motorway mainline. Firstly, simple reactive VSLC algorithms are introduced. Then approaches based on model based optimization are described. Possible coordination between VSLC and other motorway management strategies is also described in this paper.

KEY WORDS

Variable speed limit control, coordination, traffic control, fundamental diagram, motorways

1. INTRODUCTION

Originally, motorways are designed to provide larger maximal traffic capacity, which consequentially enables their higher Level of Service (LoS), compared to other types of roads. LoS is defined as a group of qualitative measures, which characterize operational conditions within the traffic flow and their perception by motorists and drivers [1]. Even though motorways are designed to serve higher traffic load in some cases they can be overloaded. Such situation is known under the term congestion. It is characterized by low speed and high traffic density what consequently reduces the motorway LoS. Congestions on motorways are most common on motorways with a larger number of adjacent on- and off-ramps. If those ramps are connected with a nearby dense urban area, they can be generators of high traffic demand for the motorway mainline capacity. Traffic demand originating from the urban area combined with transit traffic, which is also commonly served by motorways, can create good predispositions for congestion built up. If the spatial and temporal synchronisation between different types of traffic demands on motorways occurs, and if they are all intense enough, congestion will start. Place on motorway where congestion starts is usually known under the term bottleneck. In shockwave theory within moving congestions, this place is called "head of the shockwave". Static congestions are usually present near on-ramps or near places of traffic incidents.

One of the control strategies used for congestion mitigation on motorways is variable speed limit control (VSLC). VSLC systems display speed limit information on appropriate variable message signs (VMSs). Therefore, speed limit values can be set according to the current traffic unlike fixed speed limit values. VSLC is a system that was first introduced in Germany more than three decades ago. Two main approaches can be found for VSLC implementation aiming at flow improvement. The first emphasizes the homogenization effect while the second approach is focused on preventing traffic breakdown or resolving existing jams by reducing the flow by means of speed limits [3]. Homogenization of vehicle speed reduces the speed difference between vehicles and consequently induces much stable and safer traffic flow. Mean speed of vehicles is reduced under the values that can cause occurrence of critical traffic density and consequently traffic congestion [2]. Flow reduction approaches focus more on preventing or resolving too large densities (including jams) by limiting the inflow to bottleneck places [3]. This paper presents a short overview of several commonly used and researched VSLC control strategies oriented on the flow reduction approach.

This paper is organized as follows. Section 2 describes the influence of VSLC on motorway traffic. In section 3 commonly used VSLC reactive controllers are presented. Section 4 presents VSLC approaches implemented using model based optimization. In section 5 an overview of possible coordination between VSLC and several other motorway management strategies is given. Paper ends with a conclusion section.

2. INFLUENCE OF VSLC ON MOTORWAY TRAFFIC

Because of the traffic's nature, traffic jams are present even when the current traffic flow is below the maximum flow value. There are three types of traffic jams and they can be characterized as follows. First type is congested flow characterized by strong interactions between the vehicle-driver elements and nonlinear dynamic phenomena like jams and stop-and-go waves [4]. Second type is the classic traffic jam where in the first case speed approaches zero and density increases to its maximal or above the maximal value. In the second case, there are stop-and-go situations in which the flow, density and speed vary considerably. Third type of congested traffic is given by standing waves in which the flow along a motorway section is almost constant, but still the speed and the density changes considerably [4]. Main impact of VSLC, which aims to improve the performance of traffic flow, is deemed to be [2, 5]:

- Reduction of the mean speed at under critical densities;
- Homogenization of speeds, that is, reduction of speed differences among vehicles and of mean speed differences among lanes.

This means that VSLC can stabilize and homogenize the traffic flow thus reducing traffic jams, air pollution and road noise, and minimize the number of accidents. When applied, VSLC changes the fundamental diagram of the corresponding motorway section. The changes of the slopes in the fundamental diagram with variable speed limits (VSL) and without VSL applied can be seen in Fig. 1.

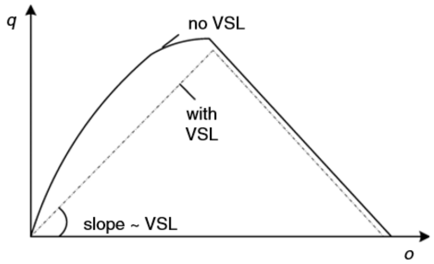

Figure 1 - Slope for traffic flow diagram without VSL and with VSL [2]

As mentioned before, one of the targeted impacts of VSLCs is enhanced traffic safety. When motorway stretches are selected for installation of VSLC, one of the main indicators of selection should be the frequency of registered accidents. Positive impact, which VSLC has on traffic safety, is a result of speed reduction and speed homogenization. Thus, the probability of accidents is reduced. Evaluations done on motorways with VSLC show a positive impact on traffic safety. Reduction in accident numbers can reach up to 30% [5].

Studies made in Finland showed that motorways with VSLC, even though it was firstly used to improve the fluency of the traffic flow, have increased traffic security in cases of bad weather conditions [5]. The positive effects are based first, on the efficient recognition of hazardous weather and road conditions, second, on the use of variable slippery road signs to support the VSLC system, and third, on the moderate use of the highest speed limit. In Finland, speed limits are lowered during winter time on most two-lane roads, but with VSLC it is possible to show higher speed limits under good conditions than it is with fixed signs.

3. SIMPLE REACTIVE CONTROLLERS

VSLC can be divided in two implementations groups. First group of implementations changes the speed limits based upon the decision of motorway operational staff. This type of VSLC implementations is mainly used in case of safety hazards such as traffic incidents, dense fog, wet road surface, etc. and it is not in the scope of this paper. Second group involves reactive VSLC controllers, which change the speed limit upon sensed traffic situation on the controlled motorway section. Based on the sensed data, the VSLC algorithm computes adequate speed limits. This type of VSLC implementations is mainly used in order to improve traffic flow characteristics. Simple reactive controllers are based on the classical negative feedback loop control framework. In continuation, reactive controllers for VSLC are described. First two are based on the fundamental flow-density relationship mapped to speed values given in Fig. 3 [6] and third one uses fuzzy logic rules to compute the speed limit value.

3.1 Mainline virtual metering

The mainline virtual metering approach is based on the concept of ramp metering [9]. Ramp metering reduces congestion on the motorway by limiting the inflow coming from an on-ramp. One of the often used ramp metering approaches is ALINEA. It is a local ramp metering approach, easy to implement and based on a pure integral control action represented as [9]:

$$R(kT_1) = R\big((k-1)T_1\big) + K_r[O_d - O(kT_1)], \tag{1}$$

where k is the time step, $R(kT_1)$ is ramp flow command, $R\big((k-1)T_1\big)$ is the ramp metering command at the previous cycle, K_r is a control parameter, $O(kT_1)$ is the measured downstream occupancy at the current cycle, and O_d is the desired value for the downstream occupancy that is typically chosen close to the critical occupancy O_c. This ramp metering approach can be generalized to a simple speed limit control algorithm based on the fundamental flow-density relationship. For this generalization the section i of the controlled motorway is regarded as a virtual on-ramp of section $i+1$ as shown in Fig. 2.

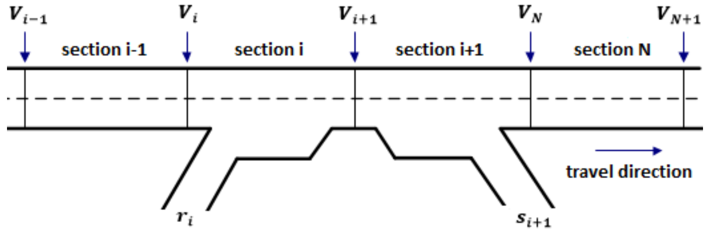

Figure 2 - Illustration of a uni-directional motorway stretch divided into N sections

The same integral control strategy as in the case of ramp metering is applied to regulate the metered flow rate Q_i from section i to section $i+1$. Equations that represent the flow rate Q_i are determined on inequalities below:

$$Q_i(kT_1) = \begin{cases} Q_{max}\ , if\ \bar{Q}_i(kT_1) \geq Q_{max} \\ Q_{min}\ , if\ \bar{Q}_i(kT_1) \leq Q_{min} \\ \bar{Q}_i(kT_1)\ , otherwise \end{cases} . \tag{2}$$

Equation (3) provides the regulation of the flow at a particular section of the motorway, where k_v is a controller parameter, ρ_i is the density of the particular motorway section and ρ_d is desired density.

$$\bar{Q}_i(kT_1) = Q_i\big((k-1)T_1\big) + k_v \sum_{m=1}^{N_c} [\rho_d - \rho_{i+1}((k-1)N_cT_0 + mT_0] \tag{3}$$

The flow rate control described by equations (2) and (3) cannot be implemented as in the case of ramp metering, because in this case the control variable is the speed limit. Therefore, in order to regulate the traffic speed instead of the traffic flow rate, the flow command has to be mapped into a speed limit command using the flow-speed relationship shown in Fig. 3. The speed of the traffic flow in each section i has to be bounded as follows:

$$V_{min} \leq V_i(kT_i) \leq V_{max}, \tag{4}$$

where V_{max} is the maximum speed limit allowed (often set to be the default speed limit), and V_{min} is the lowest speed limit we want to apply. Hence, Q_{min} is set as the flow corresponding to V_{min}, and Q_{max} is the flow corresponding to the critical density (capacity flow). The capacity flow is usually not achieved at the maximal allowed speed [6, 7, 9].

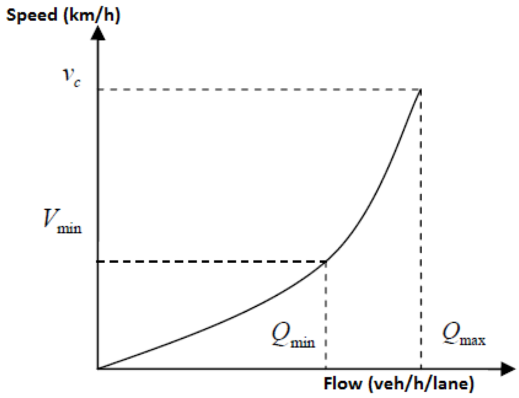

Figure 3 - Strictly increasing function f(Q) from [Qmin,Qmax] to [Vmin,Vc] [6]

The mapping $f(Q)$ is based on the estimated flow-density relationship that is assumed to be:

$$q = \rho V_f \exp\left[-\frac{1}{\alpha}\left(\frac{\rho}{\rho_c}\right)^{\alpha}\right], \tag{5}$$

where V_f is the free flow speed, ρ_c is the critical density, and the exponent α is estimated online or offline using real traffic data. When C_i (control variable of each controlled motorway section) is inactive, the desired speed limit is the default speed limit of the i^{th} freeway section. If C_i is active, section i requires calculation of a new speed limit. The new value of the speed limit can be determined by the function:

$$\bar{V}_i(kT_i) = f(Q_i(kT_i))\ . \tag{6}$$

However, $\bar{V}_i$ generated by (6) may lead to unsafe changes of speed limits. For practical purposes, the following speed limit V_i is used:

$$V_i(kT_1) = \begin{cases} V_i\big((k-1)T_1\big) - C_v\ , & if\ \bar{V}_i(kT_1) \le V_i\big((k-1)T_1\big) - C_v \\ V_{i+1}(kT_1) + C_v\ , & if\ \bar{V}_i(kT_1) \ge V_{i+1}(kT_1) + C_v \\ \bar{V}_i(kT_1)\ , & otherwise \end{cases}, \tag{7}$$

where C_v is a positive constant which represent the maximal allowed change of the speed limit (usually $10[\frac{km}{h}]$) and $\bar{V}_i(kT_1)$ is the current space mean speed of traffic flow in section i [6].

3.2 Proportional speed controller

The proportional speed limit controller was developed to further simplify the mainline virtual metering speed controller described above. Ramp metering is usually active when the mainline traffic volume is high. Accordingly, the fixed chosen desired occupancy makes sense. Moreover, the dynamic variable speed limit is only necessary when a disturbance happens, such as an accident or a wave with increased traffic density. The desired density in such a situation is usually difficult to predict, because of adduced problems such as traffic volume (capacity drop), and freeway geometry [7]. For this reason it is advisable to have a speed controller that appropriately responses to the changes in downstream density instead of a fixed desired density.

Assume there is a motorway segment divided into *N* sections, as shown in Fig. 2 and a disturbance happened in the most downstream section *N*. The speed controller of sections that are upstream of section N would be active and response to their downstream density changes [8]. Therefore, the speed controller makes decisions based on activities of the control variable C_i and calculates the new speed limit value [6]. Aggregated traffic state variables are collected from traffic surveillance systems. The traffic state variables can be also estimated. The controller generates command signals every T_1 seconds, where $T_1 = N_c T_0$, T_0 is discretization time and N_c is a positive design integer. Let I_v signify the set of road section indices in which speed limits are controlled. Let C_i denote a control variable of each section $(i \in I_v)$. The controller generates the desired speed limit $\bar{V}_i$ for section i as presented in Fig. 3. To determine when C_i is active or not, density in the following section ρ_{i+1} for the particular moment nT_1 has to be measured. The following decisions observe three cases:

- S1. If $\rho_{i+1}(kT_1) \geq (1 + \Delta_+)\rho_c$, where Δ_+ is a positive design parameter and ρ_c is the critical density, then C_i is active;
- S2. If $\rho_{i+1}(nk) \leq (1 + \Delta_-)\rho_c$, where Δ_- is a positive design parameter, then C_i is inactive;
- S3. If neither of the two inequalities are not satisfied, C_i maintains its status as in the previous control time interval.

The speed of the traffic flow in each motorway section i is bounded with (4). As already mentioned, if C_i is inactive the speed limit in each section remains identical to the default speed limit. Active state of C_i requires calculation of the new speed limit value. In that case, equation (7) is used to determine the new speed limit value. If C_i is inactive at time $(k-1)T_1$ and becomes active at time T_1, the speed limit is given as:

$$V_i(kT_1) = \begin{cases} V_{i+1}(kT_1) + C_v\,, & if\ \bar{V}_i(kT_1) \geq V_{i+1}(kT_1) + C_v \\ \bar{V}_i(kT_1) = f\big(\rho_{i+1}(kT_1)v_{i+1}(knT_1)\big)\,, & otherwhise \end{cases}. \tag{9}$$

By using the fundamental equation of traffic flow $Q = \rho v$, $f\big(\rho_{i+1}(kT_1)v_{i+1}(kT_1)\big)$ in (9) can be expressed as a function of $f(Q)$. Then $\bar{V}_i(kT_1)$ can be determined with the relationship $V = f(Q)$ shown in Fig. 3 [6].

3.3 Fuzzy logic based controllers

Rule-based algorithms are widely used in VSLC applications because of their comprehensibility and ease of application [23]. In rule-based algorithms, speed limits are determined based on some pre-specified rules. Main problem is that the most algorithms proposed in the literature under this category are rather rough for speed control. Rough nature of these algorithms is induced by using crisp sets bases on which control rules are created. Crisp sets cannot adequately present traffic situations due to the non-linear and non-stationary nature of traffic flows. Fuzzy logic-based VSLC uses fuzzy sets, which conducts separation of attribute domains into several overlapping intervals. The discretization using fuzzy sets can help to overcome the sensitivity problem caused by crisp discretization used in the existing VSLC algorithms [23].

Whole VSLC control system is designed in the form of a fuzzy inference system. This type of control system is based upon three major steps. In the first step, crisp input values are accepted and converted into a set of fuzzy variables defined by membership functions. Second step is named inference engine. It evaluates all rules in parallel based on the fuzzy set theory that describes the interpretation of the logical operations. Output of this step is a combination of inference results of these rules through the aggregation process. Final step conducts defuzzification of the aggregation product into a crisp output. In Fig. 5 schematic example of a fuzzy inference system for VSLC proposed in [23] is presented.

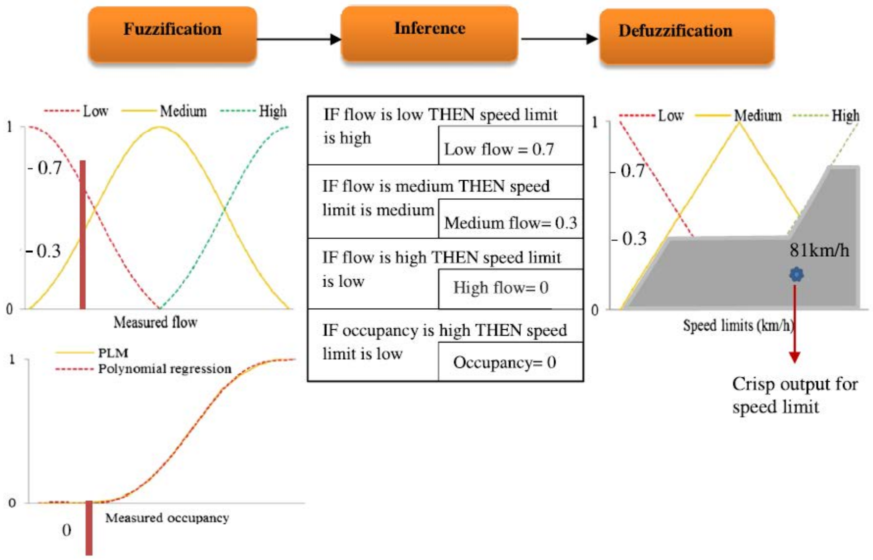

Figure 5 - Schematic example of fuzzy inference system for VSLC proposed in [23]

4. MODEL BASED OPTIMIZATION

VSLC algorithms created using model based optimization are also reactive but they control law is more complex. Currently they represent the most advanced approach for mitigation of congestions on motorways using VLSC. Model-based optimization methods construct a regression model that predicts performance of the controlled system and then use this model for optimization. Mentioned type of optimization is often used for very complex dynamical systems. Accurate modelling of such systems is connected with significant challenges. Example of such a system is the motorway traffic system with its numerous entities (vehicles) and their complex interactions (driver behaviours) in traffic flows.

Often used model based optimization in VSLC is model predictive control (MPC). The main advantage of MPC is the fact that it enables optimization of the control action in the current time step, while taking information about future time steps into account [10]. This is achieved by optimizing a finite time-horizon, but only implementing the obtained optimized control action into the current time step. In another words, MPC has the ability to anticipate future events and can take control actions accordingly. Additionally, MPC based controller has the ability to change the used prediction model what is critical in traffic scenarios when traffic conditions have suddenly and significantly changed (e.g. incidents, weather conditions, lane closures for maintenance, etc.) [11].

MPC is applied within a rolling or moving time horizon. At each time step k a new optimization process is conducted. Optimization is conducted over the prediction horizon $\{k, \dots, k + N_p - 1\}$ where N_p is the number of time steps in the prediction horizon [11]. Only the first of the resulting N_p control values derived from the moving horizon is applied as the control signal for VSLC. This procedure is repeated in the next time step [10] and it present the first feedback control loop in the MPC structure. Second feedback control loop is related to the optimization process for every time instant k in the rolling horizon. The MPC algorithm must find a suboptimal speed limit value in order to minimize the chosen objective function as subject to the model of the system (which can be considered as a system of equality constraints) and as subject to the safety constraint (MPC-based optimal coordination of variable speed limits to suppress shock waves in freeway traffic) [12]. The usual objective function of the MPC controller is to minimize the Total Time Spent (TTS) by all vehicles on the motorway [13]. This is done by changing the speed limit value over the moving horizon from *k + 1* until $k + N_C$. In order to improve stability and resilience to the frequently changing traffic situation it is possible to introduce a control rolling horizon with N_C number of time steps. The control rolling horizon must have fewer time instants than the original rolling horizon [16]. Optimal control signals (computed control outputs) obtained according to the predictive rolling horizon are applied in the motorway system only if they are within the trend of data from the controlling horizon. Based on heuristic reasoning it is possible to determine an initial guess for the size of the control and prediction horizons [10]. The second loop, which connects the controller based on MPC and motorway traffic system, is performed once for each time step *k* and provides the state feedback to the controller. This feedback corrects prediction errors and enables on-line adaptive control. In Fig. 6 schematic view of the described MPC structure is shown.

Implementation of VSLC on a motorway system is in this case considered as a nonlinear, nonconvex optimization problem, which can be solved using Sequential Quadratic Programming (SQP), the genetic algorithm and the pattern search algorithm [11]. All mentioned methodologies can be used in the optimization process in the second control loop of the described MPC structure. To determine the solution of the VSLC optimization problem is very difficult, thus, only an approximate solution can be sought. Problem is in the heavy computational burden of the optimization based approaches. In practice, it is usual to provide a synthesis of a suboptimal controller by designing an estimator of traffic conditions and a controller, which relies on the estimator for determining the control actions [15]. Example of such a suboptimal controller is the described MPC. The most widespread state estimator for nonlinear systems is the extended Kalman filter (EKF), which has been used for many applications in traffic monitoring and for incident detection [15]. To sum up, an EKF estimator computes an estimate of the traffic dynamics, which are used during computation of speed limits as the needed control output.

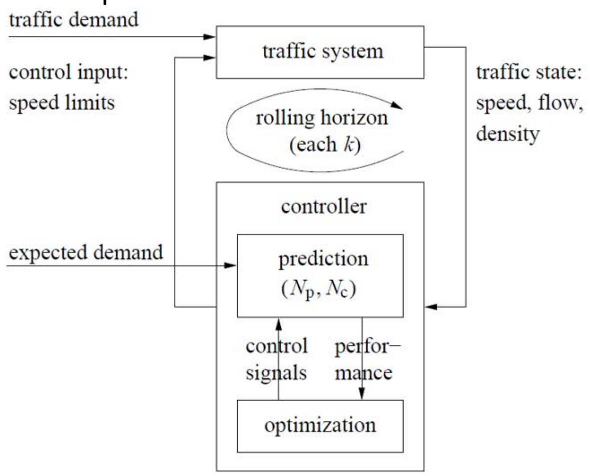

Figure 6 - Schematic view of the MPC structure [11]

5. COORDINATION WITH OTHER TRAFFIC CONTROL SYSTEMS

VSLC systems can be used in a standalone mode or in coordination with other traffic control systems. Coordination in this case means that the traffic control systems in coordination interchange traffic and control data, and use these data to improve the overall LoS on the motorway. To establish such a coordination, cooperation (communication link for data interchange) between different traffic control systems has to be established first. When

VSLC is used in coordination with other traffic control systems, better LoS on the motorway can be expected. Mostly used traffic control systems for coordination with VSLC are ramp metering and the lane change system. Additionally, today new emerging technology of connected vehicles and automated driving is being examined.

5.1 Coordination with ramp metering

Ramp metering controls the input flow from on-ramps entering the motorway mainline by the means of a traffic light mounted at the end of the on-ramp [9]. Idea is to reduce the traffic inflow if a potential congestion build-up or a congestion on the motorway is detected. The on-ramp serves as a temporally storage place for vehicles. Problems can occur when the on-ramp has to be emptied to prevent a congestion spillback into the adjacent urban road network. The vehicles from the on-ramp have in this case difficulties in merging with the motorway mainline traffic flow. VSLC can in this case reduce the speed of the vehicles on the mainline alleviating the merging process. Additionally, speed reduction by the VSLC system can also delay the mainline inflow to the merging area of an on-ramp if a congestion build-up is detected. Congestion build-up starts with a congestion pre-phase and if it can be prolonged there is a good chance that congestion can be even prevented.

To establish coordination between VSLC and ramp metering different approaches can be used. Mostly used approaches are based on fuzzy rules tuned by a genetic algorithm [16] or a neural network [19], optimal control [17] and algorithms based on the shock-wave theory [18]. In order to use one control structure for VSLC and ramp metering a cost function able to evaluate the overall LoS on the controlled motorway segment is defined. VSLC and ramp metering contribute both to this cost function and often the measure TTS is used. In this way influence of vehicles on the mainline and on the on-ramps are included in the cost function. Minimizing TTS results with maximization of the motorway throughput. Control parameters corresponding to the VLSC and ramp metering controllers are tuned based on the obtained value of the cost function. Additional variables can be also included in the cost function like on-ramp queue length, risk of traffic accidents, vehicle emissions, etc.

5.2 Coordination with the lane change system

The lane change system provides recommendations to upstream vehicles to change their lane on time before reaching a work zone, on-ramp merging point, closed lane, incident or a similar traffic situation. It is one of the most restrictive traffic control approaches but it can increase traffic safety and network throughput when combined with other traffic control systems. In [20] a combined VLSC and lane change control was tested on a truck dominant motorway segment with a closed lane. A set of rules for the lane change controller and the virtual ramp metering for VSLC were used. Simulation results showed an improvement in travel time, fuel consumption and vehicle emission values.

5.3 Coordination with automated driving

To effectively use a VLSC system an adequate percentage of driver compliance to the imposed speed limits is an important prerequisite. In some countries, this can be an issue since drivers do not comply with speed limits [22]. From this reason today vehicle control approaches based on automated and connected driving are being investigated. An on-board unit (OBU) is integrated into the vehicle enabling selected control commands to be imposed on the vehicle by overriding the driver's commands [19]. To improve the effectiveness of VSLC, automatic reduction of the vehicle's speed when it enters a zone under VSLC is needed as one of the OBU's functionalities. The vehicle obtains the information about the imposed speed limit from the traffic control system by the means of vehicle to infrastructure communication. Using this communication channel and the OBU the compliance to the imposed speed limit can be increased, especially in countries with a lower speed limit compliance rate. In [21] the approach of connected driving was implemented to harmonize the traffic speed in a work zone. The penetration rate of vehicles equipped with an OBU was also examined. Achieved results confirm that a larger penetration rate of connected vehicles, i.e. vehicles that comply with the imposed speed limit increases the effectiveness of VSLC, reduces total travel time and shortens the duration of congestions.

6. CONCLUSION AND FUTURE WORK

VSLC systems on motorways reduce the mean speed and homogenize the speeds on the mainline lanes. The results are reduced traffic jams, less air pollution, smaller possibility of traffic accidents and decreased fuel consumption. In order to achieve these effects, speed limit values have to be computed according to the current traffic situation. Therefore, a closed negative feedback control loop structure is used in which the applied control law is crucial. Appropriate control law can increase the LoS of the controlled motorway segment by affecting the fundamental diagram of the controlled motorway segment.

In this paper a short review of approaches for VSLC that are actual today is given. Simple reactive speed limit controllers are described in detail including implementation aspects. Additionally, a more complex optimization based controller based on MPC is explained. Such approach enables definition of a cost function for optimization that can contain additional quality measures related to risk of incidents, pollution, etc. For optimization, methods from the domain of artificial intelligence can be used enabling the controller to adapt itself to new traffic situations. Possibility of coordination other traffic control systems with VSLC is also examined. A description how the effectiveness of VSLC can be increased in countries with low compliance to speed limit is included. This concept is based on automated driving and a broader implementation of it can be expected in the future.

There exist also other approaches to VSLC and future work on this topic will continue with the development of a simulation framework to test the described approaches using realistic traffic data. The simulation framework will contain a module for implementation of complex control laws based on optimal control and machine learning.

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ANALYSIS OF HUMAN RESOURCES STRUCTURE IN THE SEGMENT OF TRANSPORT

ABSTRACT

In the global environment activity companies use different means of transportation with transport process intermissions in ports, terminals and logistics distribution centers which to achieve a certain level of service quality within the supply chain requires professional and educated workforce.

Human resources management, according to referential author's researches, using different methods result in reducing the number of manipulations, fast and safe transportation of goods, reducing costs and optimizing the organizational aspect.

This paper provides recent research in the field, specified methods of human resource management, enhanced impact on the efficiency of the supply chain, and describes the analysis of the structure of human resources in the storage and transport segment.

KEY WORDS

human resources, supply chain management, human resources management, transport

1. INTRODUCTION

Human resources management in the supply chain represents commonly significant factor in the success of business companies. Competence and quality structure of employees directly influences the increased competitiveness of business, reduces costs and achieves lower price levels for services provided within the supply chain [1].

Successful and competitive qualified companies in the global environment give the increasing importance to human resources management with a variety of methods including the selection of employees, continuing education and training, professional seminars, training courses, team building and other forms of raising the level of knowledge and motivation of employees. From the foregoing it follows that the essential function of human resources in the supply chain is to quickly and efficiently find optimal solutions for connecting different transport modes in a continuous process of transport, storage and other operations from the initial to the final point of goods delivery [1].

Human resources management as a category in company's business gets more important because it encourages the development of production, distribution and marketing activities. Existing and planned level of employment should be managed in a way to achieve maximum effect in the business with minimum cost and a high level of satisfaction of all participants in the production, transport and distribution process as well as meeting the needs and desires of consumers [2].

The aim of this paper is to review recent research of reference authors in the field of human resources management and models that are applied in this area at the global level. A review of research will include the territory of the Republic of Croatia, overview of terms and settings related to the specific characteristics and problems of managing supply chains primarily with technical and technological and organizational point of view, and will state the final guidelines for further research areas.

2. KEY FUNCTIONS OF HUMAN RESOURCES IN THE SUPPLY CHAIN

For the concept of human resource management authors in [4] used different terms, such as human capital, intellectual capital etc. According to [2] the link between human resources management and transport in the supply chain system, reflects in order to increase the total created value of the product or service while success in achieving this goal is the difference between the value that the product or service has to the customer and the value of resources spent.

Authors [3] state that in the supply chain system and connecting all its components and elements, human resources have one of the key roles because they realize the set tasks, and this affects the organization of the process, uniformity of procedures, level of education, motivation, teamwork, and a host of other factors. According to [5] and [6] in Republic of Croatia many companies give the increasing importance to human resources management because in line with scientific and technical research the quality staff contributes competitiveness and business performance.

The key functions of human resources in the supply chain according to [1] and [3] can be divided into several stages where in each of them the human factor affects the dynamics and the way the logistic processes work:

- Collection and processing of offers for transportation represents the administrative tasks of communication with various operators at local, regional or national level.
- Organization of transport requires knowledge of the capacity and performance of vehicles, and the choice of transport routes.
- Transport process requires highly qualified and trained staff for handling and managing the transport vehicles.
- Delivery or goods to the end user represents administrative chores and physical delivery of goods.

3. FACTORS OF HUMAN RESOURCES MANAGEMENT IN THE SUPPLY CHAIN

According to [1] and [4] one of the key factors for optimal performance of the transport operations, transshipment, storage and delivery of goods to the consumer are the employees who carry out these operations. The fundamentals of the management and planning of human resources are:

- well-organized supply chain
- uniformity of procedures
- recruitment
- level of education
- motivation

- remuneration for work.

3.1. Business Management in the Supply Chain System

Human resources planning in the supply chain is a complex process due to the dynamic and spatial dimension realization of transport process. In [7] it is stated that planning is an integral part of the overall business of the company, and it can be seen as a long-term (strategic), medium term (tactical) and short term (operational planning).

According to the same source on the basis of well-designed strategies and plans (Figure 1), human resource management in modern business is an imperative for managers in transport. In transport activities there is a high turnover of staff, occupational diseases are very common and legislative regulations, international conventions and EU directives as well as a number of other limiting factors have significant effect.

In order to obtain benefits in the supply chain process such as:

- transport rationalization,
- reducing the cost of transshipment and labor cost,
- better utilization of transport equipment and employees in transport,
- usage of standardized transport units (pallets, containers),
- in [7] and [9] it is stated that it takes a systematic approach to the management and optimization of the supply chain as a whole to realize plans and strategic goals of the company.

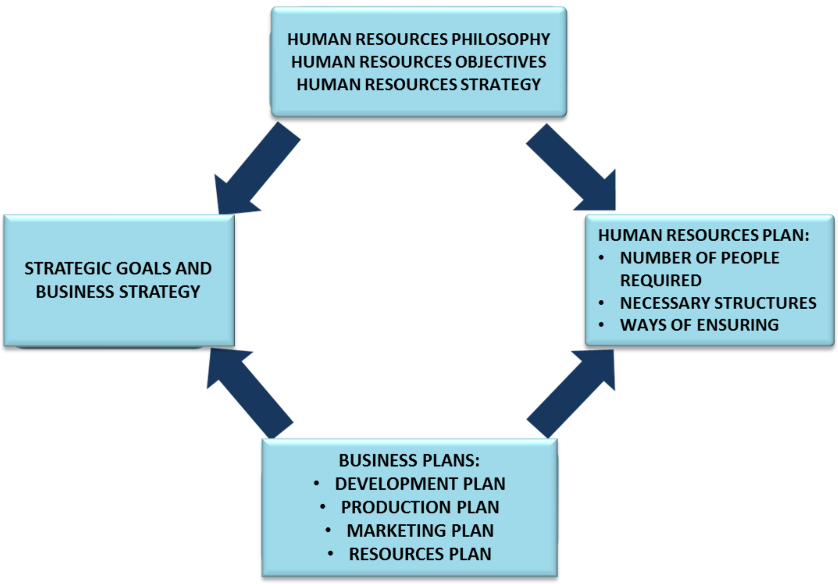

Figure 1 - The correlation between strategy and planning of human resources
Source: [7]

3.2. Analysis of the Role and Importance of Human Resources in Logistics Systems

Transport companies today have access to modern means of transport, loading and unloading equipment use or own warehouses, logistics and distribution centers, which requires a large number of operational workers of different professions and skills. The above shows and is stated in [9] that human resources must be satisfactory from quantitative and qualitative aspects. Because of the relevance and definition of employees involved in the supply chain processes research was carried out, and some of the data collected are shown in this paper. According to Croatian Bureau of Statistics [8] until the date 31st March, 2014 in the Republic of Croatia in the sector of transportation and storage the number of employees was:

- in crafts and trades and free lances in transportation and storage: 13.295
- in legal entities in transportation and storage: 57.981.

These data show that the ratio of employees in crafts and employees in legal entities is about 1:5, while the structure of the employees shown in Chart 1 shows that the largest proportion of employment is in legal entities of private, then state ownership.

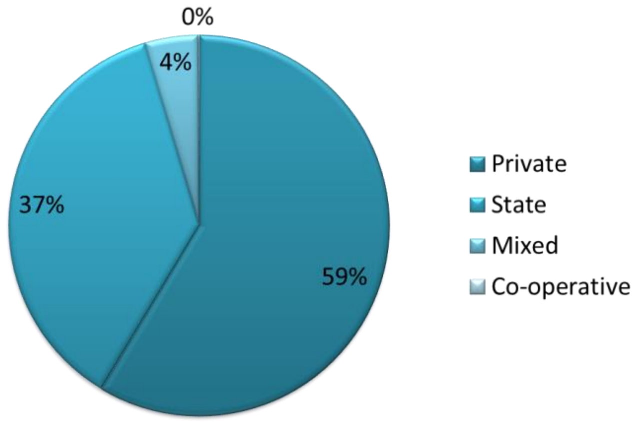

Chart 1 - Structure of persons employed in legal entities, by types of ownership, situation on March 31, 2014.
Source: [8]

According to the Statistical Yearbook of the Croatian Bureau of Statistics, made in 2015 in legal entities by educational attainment 53,645 employees were processed and the following structure is shown in Table 1:

Table 1 - The share of employment in the sector of transportation and storage after the qualification structure in relation to the number of employees in Republic of Croatia.

Educational attainment	Persons in paid employment in legal entities in Croatia	Persons in paid employment in legal entities in the sector of transportation and storage	Share of employment in the sector of transportation and storage in Croatia in %
University degree	223.427	4.979	2,2
Non-university college degree	87.446	4.185	4,8
Secondary school education	499.738	32.904	6,6
Basic school education	26.560	2.265	8,5
Highly skilled	14.212	1.101	7,7
Skilled	79.564	6.322	7,9
Semi-skilled	17.603	486	2,8
Unskilled	58.906	1.403	2,4
Total	1.007.465	53.645	5,3

Source: [8]

These data show that employees with a university degree, college and secondary school education participate in the total number of 53,645 employees with 78.42%, respectively with this degree there are 42,068 employees. It is also evident from the presented indicators that there is a relatively small proportion of employees with higher (7.8%) and high (9.3%) education. But from these data the structure of employees by occupation within the transport sector is not visible, which is necessary to thoroughly investigate and demonstrate because precisely the structure by profession is the basis for creating models of human resources management in the supply chain.

3.3. Human Resources Management

In modern business systems according to [4], [7] and [9] attention of management structures is focused on the creative potential of individuals who by solving problems and introducing changes and innovations directly affect the efficiency of resources, operating results and companies competitive position. In addition to encouraging creativity in human resources management, an important segment according to [7] is the construction of motivational methods and techniques, which adds to tangible and intangible compensation or remuneration as a result of work performance as a product of work activities (Figure 2).

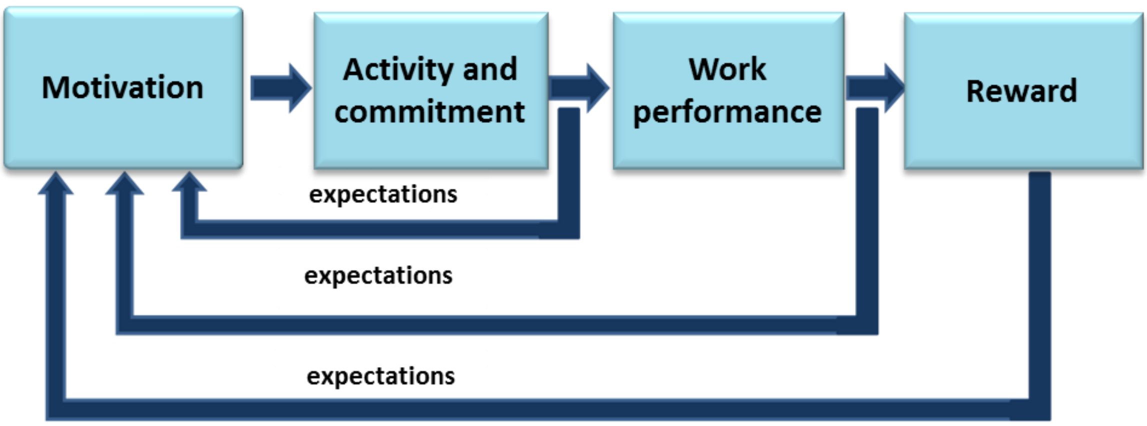

Figure 2 - General process model for work motivation
Source: [7]

4. APPLICATION OF METHODS FOR HUMAN RESOURCES MANAGEMENT IN THE SUPPLY CHAIN

At the global level specific research in field of human resources were carried out mainly in the industrial sector, while the research of these issues in the transport field were carried out as part of general research. For the research of the human resources problem different methods and models are structured with the largest portion oriented towards top management and managers. The authors in [13] describe the possible application of mathematical methods in companies human resources management. They propose business analysis based on the analysis of the dynamics and the existing procedures, and environment dynamic that continuously affects the business flow. The choice of mathematical models essentially depends on the input parameters and the narrow field of research and includes Markov chains, stochastic, linear and goal programming. Unlike purely mathematical modeling approach, the authors in [14] describe that human resources management should be observed from an organizational aspect, segmented into modules, and suggest the need for measuring the outcomes in the various systems on the market. The proposed model of human resource management is viewed from two aspects, unique and pluralistic approach defined by interest groups.

Further studies included the proposal of the authors in [15] for the implementation of information systems for human resources management in the supply chain in the form of modules ERP (*Enterprise Resource Planning*) information system. ERP systems are information systems that consist of integrated software applications and include modules for planning, sales and production.

Research related to human resources management in businesses that are participants in supply chains include those of the authors in [11], which highlight the need for the identification and selection of qualified professionals in supply chain managing. They propose different methods of evaluating competence, optimization possibilities in organizing their own business structure and function within the supply chain, creating procedures, and development of criteria based on the analysis of the observed business structure.

Authors in [12] examine market changes in terms of the demand increase, and the impact and uncertainty of goods delivery from the suppliers. They expand the issues of responsibility of certain functions within the supply chain, and propose strategic and long-term relationships with subjects within the supply chain. The paper presents four case studies with the benefits of the application of human resource management on four levels, including the utilization of resources.

By using a comparative method, the authors in [16] represent the specificity of differently successful supply chains in different markets in terms of resource planning. Detailed studies were conducted with 913 business subjects within the supply chain and data used include data of qualitative and quantitative nature. Also, the authors pointed out the ways and the need for continuous measurement of logistics performances.

In addition, research was carried out in the form of professional studies such as research from 2005, ordered by the government of Canada, called The Study of Human Resources Strategy in the Supply Chain Field [17]. The modules processed: economic development, business and regulatory environment; the impact of technology on business; employment analysis; skills demand and prognosis; recruitment, training, development and retention; recommendations.

This Study processed the sector of transport and storage in the supply chain system, starting from the number of employees and their functions and duties. The main conclusions and recommendations of the Study are that in the structure of the supply chain it is necessary to define the skills and knowledge of employees, the ways of employment, training and advancement of human resources as well as their retention on their jobs in order to avoid excessive fluctuations. The findings of this Study suggest that this segment should also be further explored.

5. ANALYSIS OF THE HUMAN RESOURCES STRUCTURE IN THE SEGMENT OF STORAGE AND TRANSPORT IN CROATIA

Studies of human resources in Croatia, in particular those related to transportation systems exist, but they are made for individual companies or interest groups such as clusters in road transport. One of the largest studies which also processed the transport sector was conducted by The Institute of Economics, Zagreb in cooperation with the Croatian Chamber of Economy, and was associated with greater project on the competitiveness of the Croatian economy [18].

Research goals of the segment of Republic of Croatia (the research was expanded to several countries of the European Union) were:

- to determine the status and development of certain functions (activities) and sub-functions of human resources in Croatian companies, and possible differences in the representation due to the size of the company, regional affiliation and activities branch;
- to record the heads of personnel departments opinion on the general meaning of each process;
- development of human resources activities for the near future.

The chart below indicates results obtained by companies in Republic of Croatia, divided into nine most important functions of human resources where the evaluation data of individual functions by the heads of the department of human resources were compared with the current state evaluated by expert evaluators.

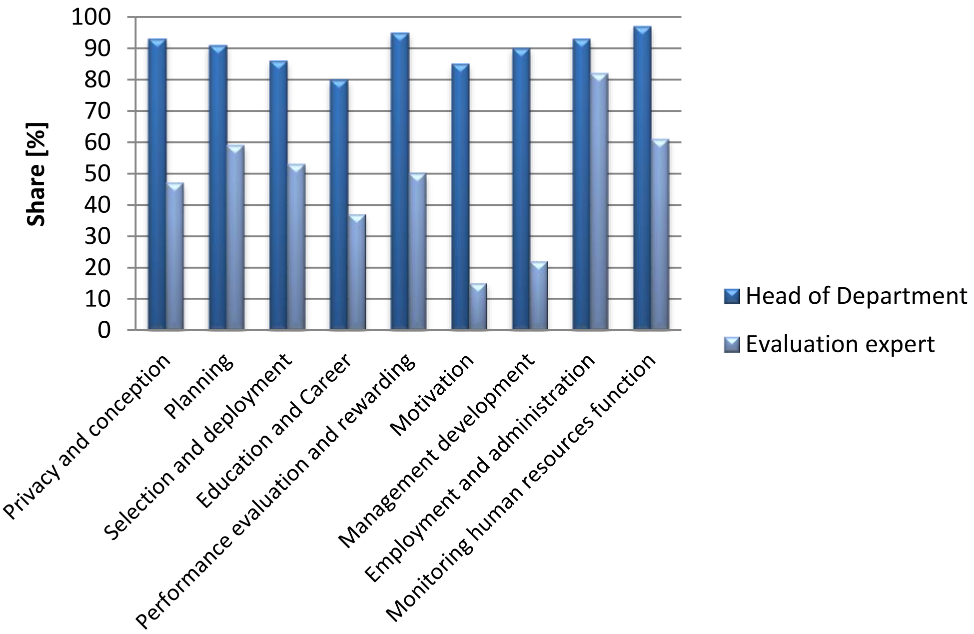

Chart 2 - The overall results by the group functions
Source: [18]

This extensive research of the human resource management is a basis for further studies that haven't been conducted since the global crisis occurred.

The issue of human resources management in Republic of Croatia is presented in several articles and book chapters, with the author's focus in [5], [6] and [19] placed on supply chains and logistics and distribution centers.

Further studies were carried out in January 2014 and included data collected by survey method, where the first part of the questionnaire was related to the activity of the company, organizational position of transportation, number of employees, staff qualifications in transport and the structure of the professions in transport. The second part of the questionnaire is related to the application of motivational methods, encouraging creativity and evaluating work performance of employees in transport. The questionnaire was sent to seven companies with a significant market share in Republic of Croatia[1]. Four companies responded to the questionnaire, which employ a total of more than 500 employees. In the first part of the questionnaire qualification structure in transport was analyzed where it is evident that the transport employs a total of 662 employees in all four companies out of which 478 or 72% are secondary school education and 104 or 16% are skilled workers, as shown in Chart 3.

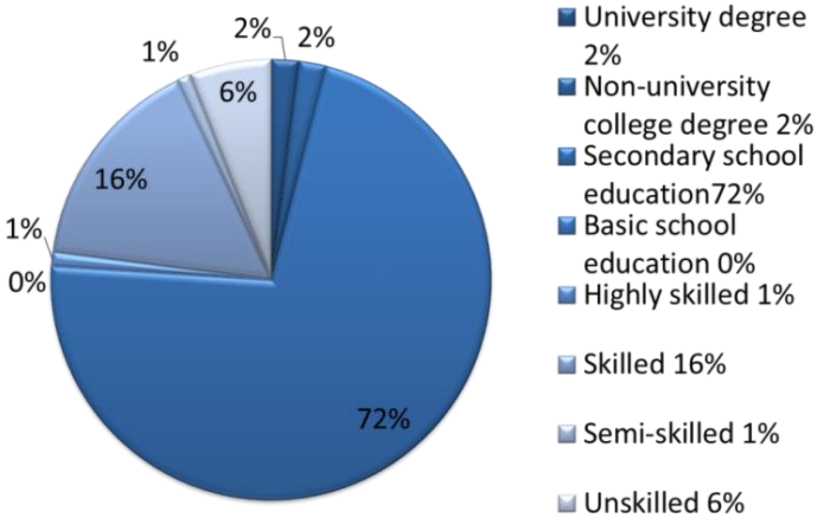

Chart 3 - Qualification structure in transport

By analyzing the structure of the professions in transport in Croatia predominant number of employees is of the transport profession and highly skilled and skilled drivers 44%. Also a significant proportion of employees occupy secondary school education technicians or 34%, while traffic engineers make up only 1% of the total number of employees, so it is necessary to investigate whether it would improve flow of the transport process and service levels in the supply chain by increasing the number of employees with university or college degree in traffic sciences as shown in Chart 4.

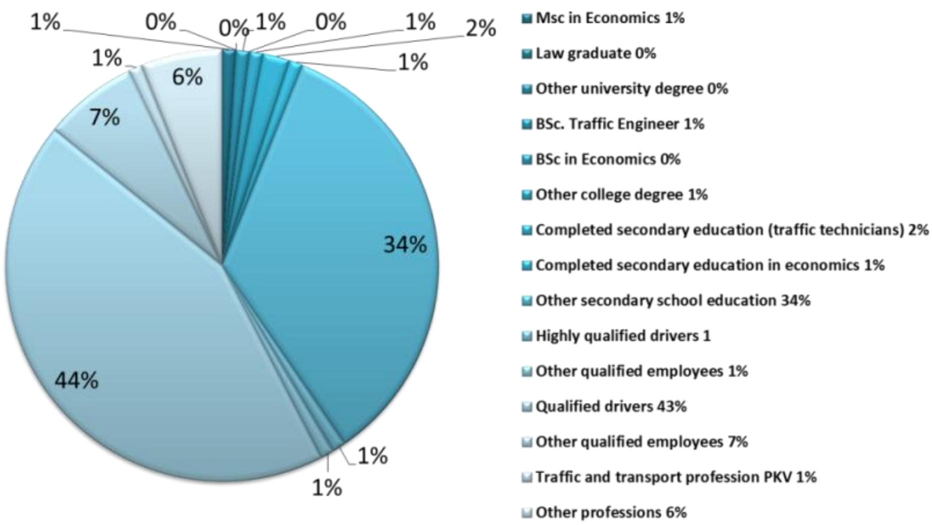

Chart 4 - The structure by occupations in transport

[1] Due to the signed non-disclosure agreement on data confidentiality obtained by the survey, the names of the companies are not included

These data show that the predominant number of employees in the surveyed companies make employees of transport profession, where secondary school education, highly skilled and skilled prevails, while there is a smaller proportion of graduate engineers and traffic engineers.

The second part of the questionnaire obtained data on the application of motivational methods, encouraging creativity and evaluation of work performance, which show that despite the fact that all four companies are privately owned, there are rules and regulations to encourage these activities.

6. CONCLUSION

In the global environment the business of the company requires certain approaches to management of processes in the supply chain, starting with the planning of each step in the transport realization of certain cargo to human resources management. Modern technologies condition the highest level of communication and implementation of information systems for the preparation and realization of transport in the supply chain, and this requires teamwork between experts and participants with the highest levels of education and acquired knowledge.

Research of human resources management in transport, with particular emphasis on supply chains were carried out mainly in the context of general studies in industrial and service sectors of the economy in Republic of Croatia. In order to achieve greater competitiveness and profitability of companies in the supply chain it is necessary to develop a strategic research demonstrating the adoption of development strategies and operational plans in the transport activities of the Croatian economy.

The general methodological approaches and methodologies that are accepted for research of human resources is necessary to adapt to the needs of the supply chain which features a number of different participants and where transportation can be realized with more transportation means of different modes of transportation.

Detailed analysis of the current situation in Republic of Croatia refers to the research of structures, level of equipment of transport and transshipment means, degree of organization, existing processes, uniformity of procedures, and measurement of the impact and engagement of employees in the supply chain flow. With systematic research it is necessary to separate the key parameters that directly affect the flow of the supply chain with the technological and organizational point of view, where technical and technological aspect includes establishing procedures and flows within the supply chains, processes and operations, employee involvement, transportation and manipulative means, and measurement of periods related to processing.

The organizational aspect involves defining the existing procedures, documentation, supporting information systems, and the level of employees education. In two of these aspects it is necessary to establish a direct and measurable impact of human resource management at the efficiency of supply chains.

Further research should include:

- Time intervals for the flow of goods in the supply chain
- Defining the procedures and operations and the division of labor of employees in the supply chain
- Defining the total cost of the transport process

- Availability of employees in the process of transport and capacity of transport equipment
- Measuring the impact of human factors on transport damages and losses
- The impact of human resource management practices to businesses related to supply chains.

Training of personnel involved in the supply chain primarily results with the optimal organization of the flow of goods and reduces the number of working operations, thus achieving efficiency of the chain system directly increasing profits.

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IDENTIFICATION AND MONITORING OF THE CONTAINER AT THE POSTAL OPERATOR

ABSTRACT

Article provides research in field of automatic identification of container through radio-frequency identification technology (RFID) in terms of supply chain of particular postal-logistics operators. In this article we would like to share knowledge of testing and the results that we found during the test in laboratory and also real conditions in conjunction with selected postal operator. The ambition of this work is selection of appropriate identifier type and its placement on a container. A special section is dedicated to description of the technical equipment used during measurements as well as their results from MySQL database. At the end of article is described pilot, where the selected area at the selected postal operator and its processing centers were equipped with RFID readers that were connect over a network to the central database server. At intervals of a few days we monitored movement of objects equipped with RFID tag in real time. The captured data form this testing were used as a basis of evaluating the feasibility of deploying RFID technology at the selected postal operator.

KEY WORDS

RFID, container, transport unit, monitoring, logistics, identification

1. INTRODUCTION

Smart identification by automatic identification technologies currently plays an important role in all areas of the national economy. In terms of optimization of logistic processes, barcode technology is used. However, radio frequency identification technology brings lot of advantages to the table, therefore it is expected that its involvement will significantly expand into all areas of the national economy. The article focuses on research of RFID technology in the process of smart identification of containers trough RFID technology. It also talks about software support for RFID technology, mainly about creation and configuration of RFID middleware – specialized software tool allowing mutual communication between two or several applications; also known as connector between various application components. The article talks about RFID technology as well as about the completed study of readability of RFID identifiers placed on metal container. Among the results of the readability, the dependency of tags on the metal parts of the container has been studied. Based on the results of the research, a recommendation for tags positioning on container was published.

2. THE MAIN PRECONDITIONS AND TEHEORETICALLY BACKGROUND

The main precondition in conjunction with monitoring and identification of containers by passive RFID tags was, how the metal construction can interference readability of RFID tags and how it will change the value of RSSI. One of the other problems in dealing with projects related to the monitoring and control of containers, it is necessary to clarify and streamline the respective asset management. Other requirement is to ensure that the required amount of containers was always available at the right time and the right place [1]. All this plays an important role not only in the mass submitter that their shipments are inserted into a container in their own areas, but also for the processing and distribution centers of different levels where containers fulfills its fundamental role as a transportation unit. Monitoring and controlling the flow of containers should lead to the planned accumulation of containers for specific uses and preventing unplanned accumulation, which can lead to a shortage of containers in sorting and processing of the top resorts in the framework of processing postal operator. Besides this problem can insufficient monitoring (visibility) of containers cause of their loss and the subsequent cost of providing new containers [2], [3], [4]. Before starting our research, we were passed following the requirements of the proposed testing system:

- must provide an overview of used and underutilized postal containers,
- must provide an overview of the currently used postal containers (in terms of time and place),
- must provide an overview of the postal containers provided by the customer and returned to the top, of the top customers [5].

In general, our authority is assumed that the eventual implementation gains a tool that he will provide information for:

- preventing the accumulation mailing containers,
- minimize loss of postal containers,
- improving the accessibility of postal containers and ensuring the overall balance of the entire logistics chain,
- checking the contents of the mail containers,
- improving the postal service and maintenance of containers.

Of course, all these assumptions RFID technology can bring to incorrect implementation, which precedes the start of testing.

A. RFID Architecture

RFID technology is complex, combining a number of different computing and communications technologies to achieve desired objectives. Each object which has to be identified has a small object called a RFID tag stuck to it. Each RFID tag has a unique identifier that enables additional information about each object to be stored. Devices known as RFID readers wirelessly communicate with RFID tags, with a view to identifying the attached RFID tags, as well as enabling information stored in the RFID label to be read and updated.

Every RFID system contains an RF subsystem, and most RFID systems also contain an enterprise subsystem. An RFID systems supporting a supply chain is a common example of an

RFID system with an inter-enterprise. In a supply chain application, a tagged product is tracked throughout its life cycle, from manufacture to final purchase, and sometimes even afterwards (e.g., to support service agreements or specialized user applications). Radio frequency identification is a wireless data collection technology that uses electronic tags which store data, and tag readers which remotely retrieve data. It is a method of identifying objects and transferring information about the object's status via radio frequency waves to a host database. RFID represents a significant technological advancement in AIDC because it offers advantages that are not available in other AIDC systems such as barcodes. RFID offers these advantages because it relies on radio frequencies to transmit information rather than light, which is required for optical AIDC technologies. [4]

There are three basic components of RFID system: RFID tags, RFID readers and Middleware, which is responsible for all data transaction in the system.

An RFID tag (figure 1) is a small device that can be attached to an item, case, container, or pallet, so it can be identified and tracked. It is also called a transponder. The tag is composed of microchip and antenna. These elements are attached to a material called a substrate in order to create an inlay. Tags are categorized into three types based on the power source for communication and other functionality: active, passive, semi-passive and semi – active.

Figure 1 - RFID passive tag

The second component in a basic RFID system is the interrogator or reader (figure 2). Readers can have an integrated antenna, or the antenna can be separate. The antenna can be an integral part of the reader, or it can be a separate device. Handheld units are a combination reader/antenna, while larger systems usually separate the antennae from the readers. The reader retrieves the information from the RFID tag. [4]

Figure 2 - RFID reader

There is also Middleware, software that controls the reader and the data coming from the tags and moves them to other database systems. It carries out basic functions, such as filtering, integration and control of the reader. RFID systems work, if the reader antenna transmits radio signals. These signals are captured tag, which corresponds to the corresponding radio signal. [6]

B. Container monitoring

One of the main issues being addressed by the container tracking and managing project is need to take control of and better manage transportation assets. Another primary project requirement is to ensure that the required containers will be always available at the customers' premises and within postal operator facilities. This should overcome the tendency for planned or unplanned hoarding of containers that causes shortages elsewhere, especially at peak times. Additionally, the lack of visibility of container where about led to unnecessary loss since it was not possible to identify where the containers disappeared and hence forced expensive purchase of new containers to meet the customer service level agreements. [1],[2]

When a container is ready for dispatch, the container is scanned for destination and product type. If the container is lead through a gate not matching the destination, an alert will immediately help correct the mistake. Solution must include Asset Management software platform enabling full, real-time transparency of the location of each container and can be also used to track specific mail and parcel transports. [7]

Implementing this system offers unique values. Examples of benefits:

- improves availability and load balance throughout the logistics chain,
- prevents hoarding of containers,
- minimizes losses,
- helps to improve supply chain efficiency,
- provides the ability to monitor the transported delivery time of goods and
- helps to improve service and maintenance.

a. Postal transport network

Postal transportation network an operator is comprised of the following entities:

- the main processing centers,
- the local processing centers and
- the processing nodes.

The principle of distribution of postal containers is illustrated in figure 3.

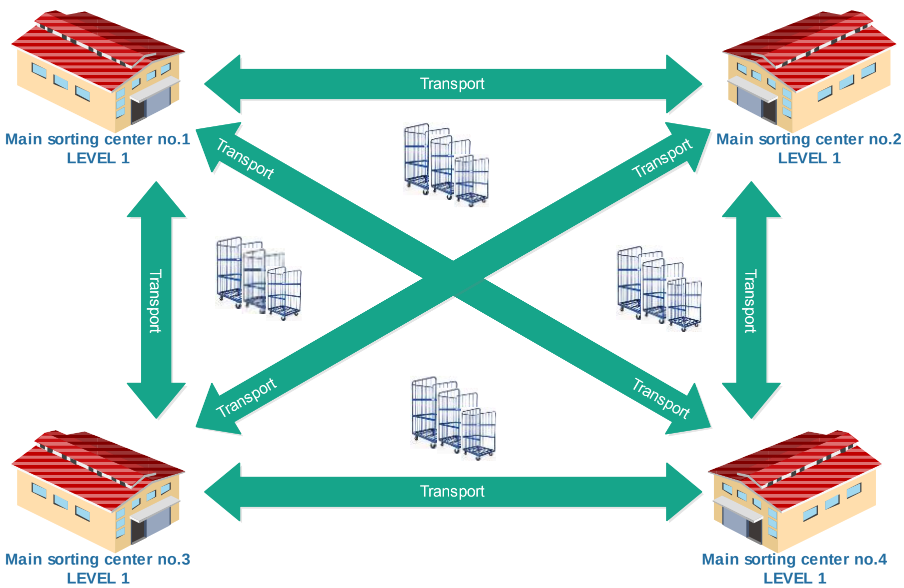

Figure 3 - The structure of postal transportation network

The main processing center performs sorting and processing mail, local processing center serves as front handlers for the main processing center and processing node acts as contact with top customers. Within the assigned area has always one main processing center, along with several local processing centers and processing nodes [5].

3. MEASUREMENT IN LABORATORY AND REAL CONDITIONS

In order to achieve relevant outcomes, it was inevitable at first to design functional system enabling realization of single measurements under laboratory conditions. In order to comprehend single measurements, we have to define the principle they operate under and what is being detected by them. We have to find out the readability of RFID tag placed on metal container at the moment of its passing through RFID gate with antennas. Considering the close collaboration of our department with company ATO spa. , we chose middleware OnID or AMP that actually made our work with collected date much easier.

A. Laboratory measurement

In the laboratory we conducted a series of tests on borrowed mail container from the postal operator. It was mainly a choice of RFID readers, RFID antennas, RFID tags and their placement on the mail container.

During the measurements were used omnidirectional antenna connected to the reader Motorolla FX 7400. RFID identifiers were scanned from above. The roll cage is made of steel and due to problems with loading the RFID identifier needs to be appropriate to the location of the antenna connected to the RFID reader. Equally important is also the location identifiers. Walls of the roll cage are formed by a metal grille which can have the effect of reducing the intensity of the signal reflected back from the identifier antenna. From many pre - tested RFID tags, we chose special encapsulated tags on metal (see Fig. 1).

The largest portion of the laboratory testing was devoted to placement of RFID antennas and RFID tag placement on the mail containers because these two parameters offered a fairly wide range of combinations. For the placement of RFID tags on the metal container we selected 25 positions (see Fig. 4) and these positions were tested laboratory condition. In terms of potential damage to the antenna by RFID containers, we finally chose the placement of antennas above the containers, as can be seen on the second part of Fig. 3. [7].

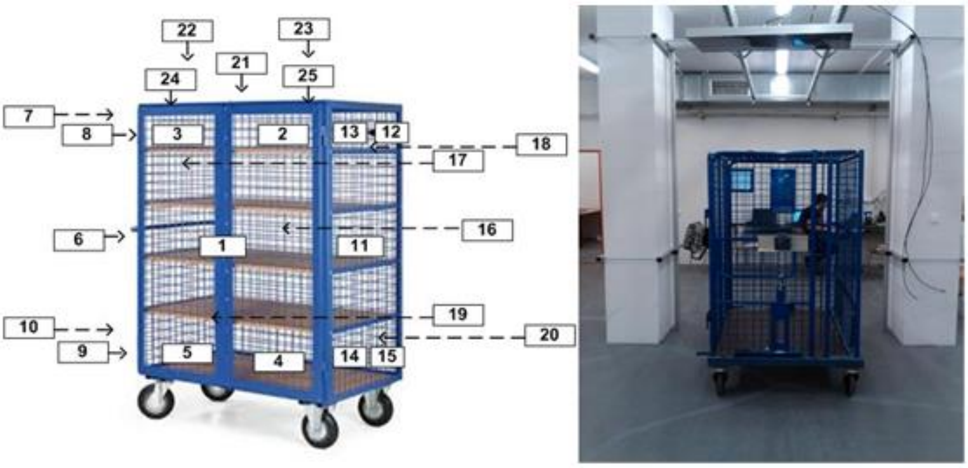

Figure 4 - Placement of RFID tags at postal container

3.1.1. AMP model configuration

Middleware AMP ensures communication between hardware and software part of our model. At the same time, it enables to set up the configuration itself, so by its use we define practically what, how and when should the particular hardware and software components operate.

Under the configuration shown in Figure 5 there are processors, including:

- LLRP reader - may represent a real goal sensing RFID identifiers or test goal, which only simulates loading identifiers.
- Whitelist - a list of ID individual identifiers, which are under testing process. Reader does not respond to identifiers that are not listed in the whitelist.
- DB - processor for recording information in the database.
- Test Device – Processor for simulation an RFID gate.
- EarlyDecoupler - this processor is used to filter the retrieved ID and avoids multiple load at the same identifier. The function of the processor includes a timing adjustment.
- Time formatter 1, 2 – this processors transforms timestamp coming from the RFID reader to selected format of the time, for example. YYYY-MM-DD or HH:MM:SS [5]

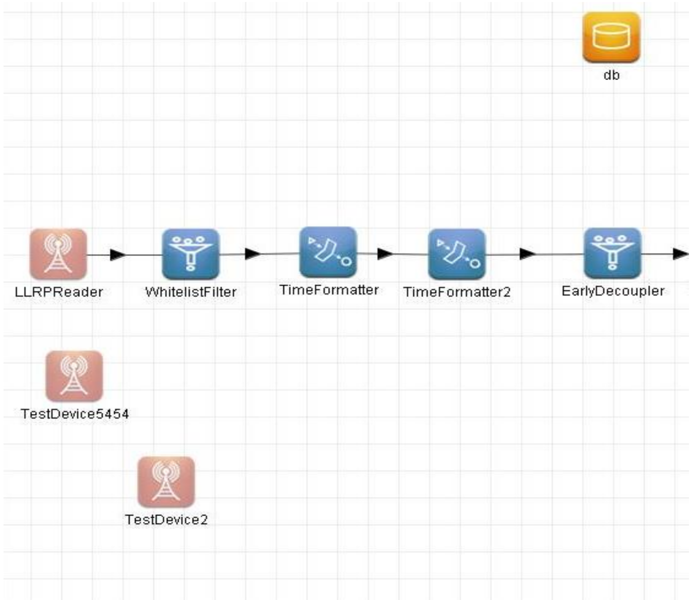

Figure 5 - AMP model configuration – first part [5]

The second part of the configuration see Figure 5, consists of processors to work with data that change the status of individual items in the database every time you load identifier. Other processors in the configuration of processors are used to format the dump to the console server java AMP:

- InlineSelectProcessor - It allows to load data from DB based on the input parameters for SQL demand.
- InsertProcessor – It allows to store data to the DB.
- XMLInjector (1, 2) – It allows to set constant to XML path.
- InsertProcessorJournal – It allows to store journal information from measurements.
- Logger – It allows to real time logging of measurement.
- Message morphing – It's used for transforming text to XML format.
- Message generator – It's used for generating XML messages.

Each processors have additional configuration parameters that can be set in conjunction with different purposes.

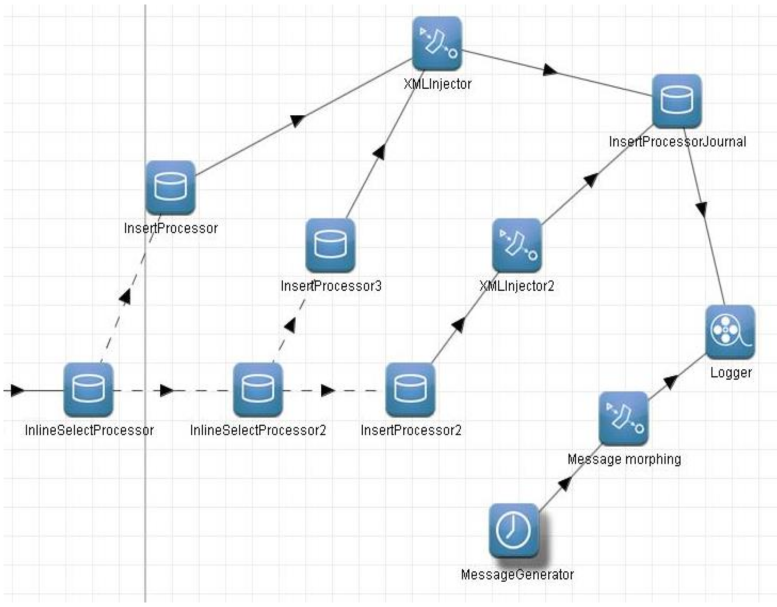

Figure 6 - AMP model configuration – second part [5]

3.1.2. Result of laboratory measurements

Selected RFID tag were measured on 25 different positions and we obtained not only values of readability of RFID tags but also strength of the backscattered signal value called RSSI. With this value (fig. 7) we were able to select right placement (fig. 8) of RFID tag on metal container.

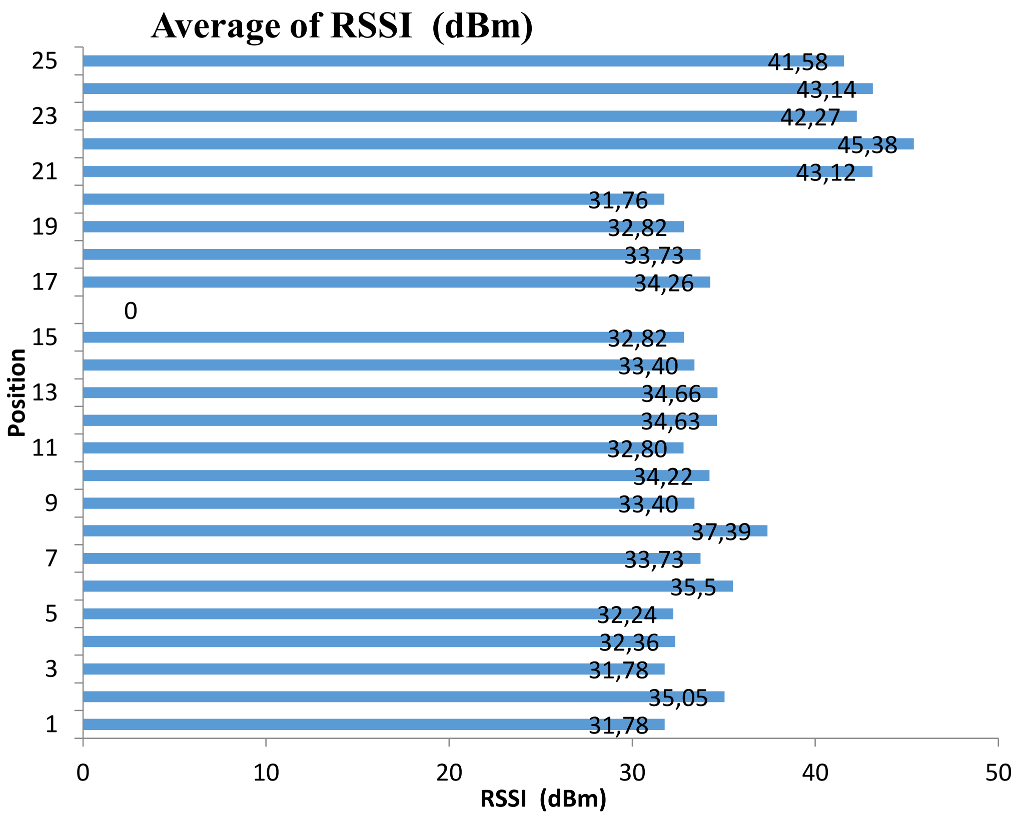

Figure 7 - Average of RSSI at selected placements of RFID tag [5]

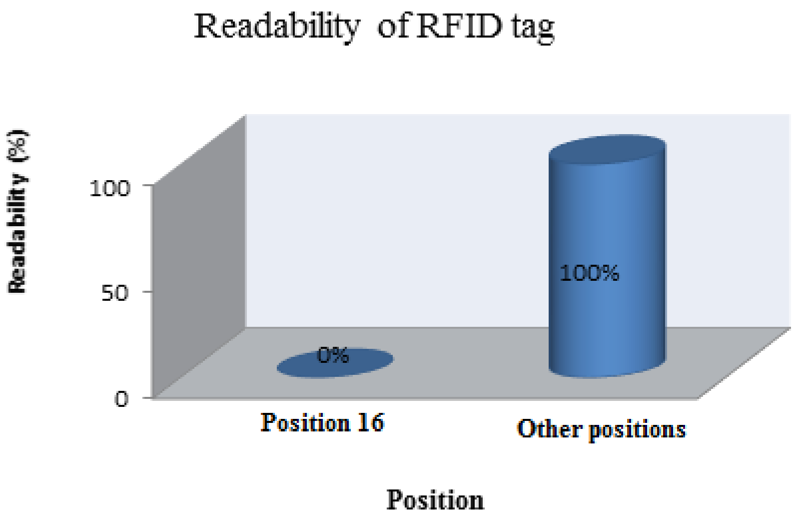

Figure 8 - Average of RSSI at selected placements of RFID tag [5]

From the result described on the figures above, we can see the value of RSSI by different position of RFID tag. Position 25- 21 achieved the best results. In relation to readability we can see that only position where the RFID tag was placed on position number 16 was not read by RFID reader. In terms of potential damage to the RFID tag antenna by units usually placed on the top of the RFID containers and other operational barriers we selected following position (fig. 9) and from this positions we chose position number 13, that obtained best RSSI value.

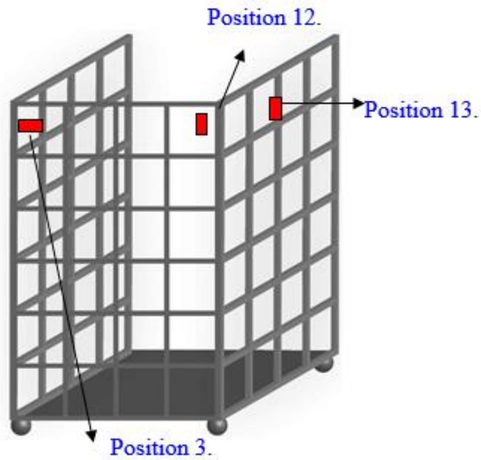

Figure 9 - Selected placement of RFID tags at postal container

a. Real testing

After we had finished a laboratory testing and evaluation, it was a time for real testing at condition in selected postal operator. Due to the nature postal transportation network it was decided that the testing will take place only on the part of postal transportation network. It was chosen the part of postal transportation network that meant in terms of RFID worst possible conditions. Every major, local processing center and processing segment are inherently different. This is due to the nature of the construction and processing area for loading and unloading. That is why we chose to test the worst possible conditions because it is more than likely that the same problem on other operations do not conflict. Overall, we are in the allocated area selected 3 Entities. These were main postal processing center, local processing center and processing node. Schema of transport between these entities are shown in Figure 10.

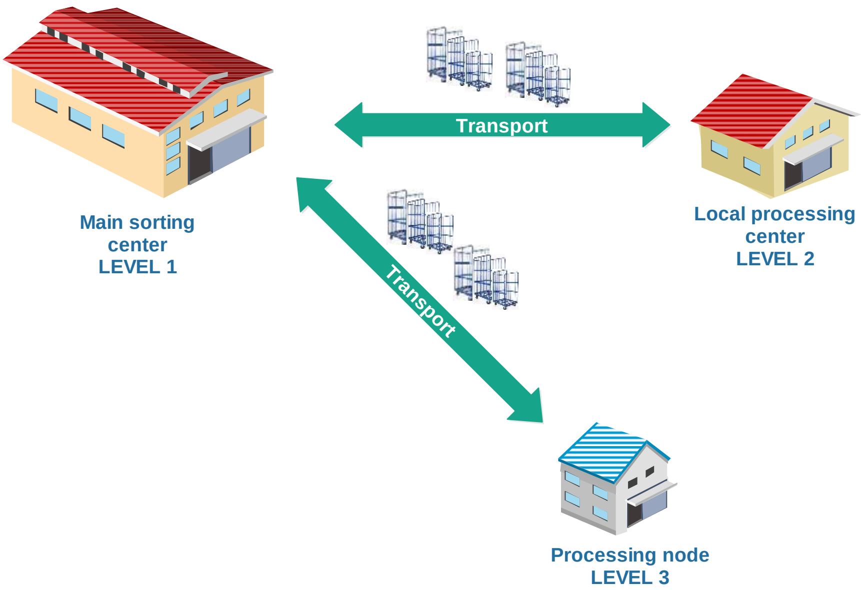

Figure 10 - The part of postal transport network

We have made a real application, which consists with web application that is shown on figure 6. Selected processing centers and nodes of postal operator were equipped with the aforementioned device. All readers are connected to the main database server via a mobile connection. RFID readers have been through middleware connected to a central database server and subsequently evaluated by means of web applications in real time.

The statistical web module has provided us with information about the length of time and transport time to stay on the individual processing centers for individual postal containers. Also, we monitored as individual sites provide postal containers and more.

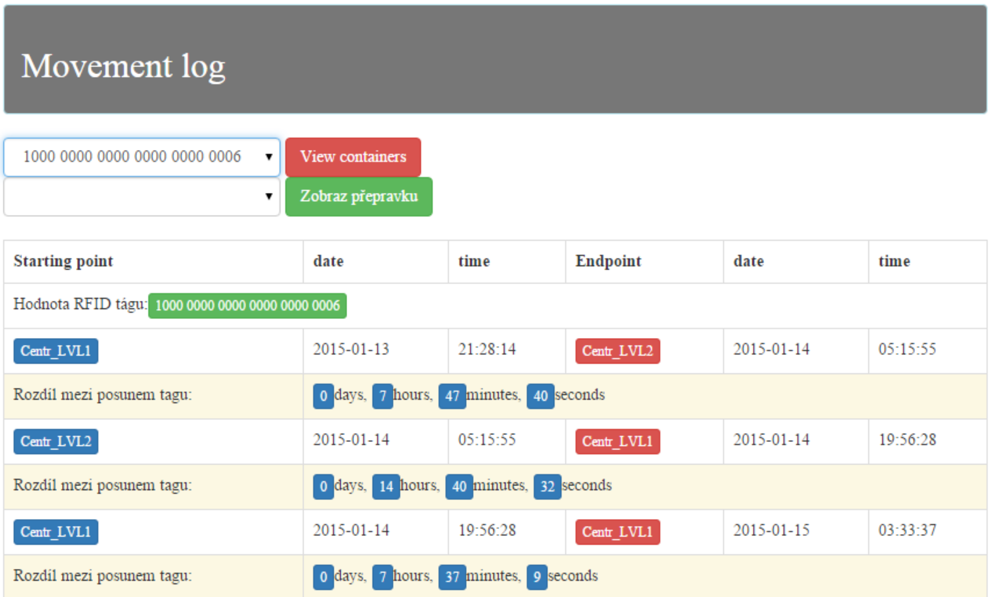

Figure 11 - Web application

The configuration implemented at one of the processing centers of postal operator can be seen in Fig. 12.

Figure 12 - Real configuration on postal operator

After installation of all modules in selected processing centers of postal operator, we placed RFID tags on all mail containers in selected mentioned processing centers. For several days the system record entries containers through our system. But after the interim and final evaluation of all the data collected, we were able to determine the exact results and opinion. We achieved 100% readability of all RFID tags, that were circulated around the selected processing centers.

4. CONCLUSION

We made a pilot in conjunction with postal operator and we got relevant information to designate a utilization of RFID implementation in postal environment in field of identification and monitoring postal containers and postal packages. We can say that our result in our configuration provide for postal operator a realistic view of the location of postal containers in real time.

This research represents another step towards the identification of the entire postal logistics chain and then connection to the concept internet of postal things (*IoPT*). In the implementation of RFID technology should take into account its advantages and disadvantages. The main advantage is the traceability of postal containers across the entire network. At disadvantages may be mentioned perhaps higher initial investment costs to build an RFID infrastructure. Each postal operator, after quantifying ROI must decide whether it pays to invest in this technology or not. The concept of IoPT is the basis for the implementation a whole range of new innovative next services and support process in postal market, for example, real time identification of packages and boxes.

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INNOVATIVE APPROACH TO INVENTORY MANAGEMENT AND WAREHOUSING: A REVIEW AND A CASE STUDY

ABSTRACT

Inventory management is a part of the enterprise procurement strategy, which is based on the relationship between the entity as a consumer of material inputs and their suppliers. The article contains a general definition of analysis and synthesis as scientific methods used in the field of inventory management. The aim of the main part of the paper is to justify the need of inventory management and the current analysis of existing models such as inventory management tools to optimize them. ABC analysis, XYZ analysis, Decision Cube and Economic Order Quantity are included in the article. The analysis deals mainly with the criteria on which they are optimized and inventory advantages and disadvantages of each method. The article outlined the proposal of innovative inventory management model usable in practice which is a synthesis of the existing used models. Inventory management is increasingly important and research shows potential for further improvement.

KEY WORDS

inventory management; logistics; ABC analysis; XYZ analysis; Economic Order Quantity

1. INTRODUCTION

Logistics is defined as a part of the supply chain process, which is engaged in transportation, storage, administration and management of commodities inventory between the place of origin and destination (place of consuming) [1]. In recent decades, there has been mentioned the logistical costs that affect the economic situation of enterprises. Costs associated with logistics can be divided into three groups, namely the transport, storage and material handling [2]. In recent years, the relevance of logistics services as a competitive weapon has increased significantly in several industrial sectors. Logistic services are a bundle of attributes, which mainly relate to speed, reliability and flexibility of supply and immediate availability of the items that the customer wants to acquire [3]. Sustainable management of logistics operations, particularly inventory management has become an essential element of business strategy and competitive advantage for organizations [4] [5].

The aim of this article is to outline the proposal of innovative inventory management model usable in practice (manufacturer of automotive parts) which is a synthesis of the existing used models.

2. INVENTORY MANAGEMENT

The role of inventory management is much discussed topic in the field of modern logistics in recent years. The success of a venture depends on its ability to provide services to customers or users and remain financially viable. For an organization supplying goods to its customers, the major activity is to have suitable products available at an acceptable price within a reasonable timescale [6]. Efficient and effective inventory management helps companies retain a competitive advantage, particularly at a time of accelerating globalization [7].

Supply activity is a part of the production planning and it is understood as a security of providing the inputs of the manufacturing process. It should be organized and managed well in order to guarantee a smooth and economical running of the production process. By this activity, an enterprise acquires tangible current assets in the amount, quality, range and time so that the costs associated with supplying are on the lowest level. Inventory management costs typically account for nearly half of total logistics costs [8]. The goal of inventory management is to determine when and how to order should be accomplished so that the inventory costs can be minimised. Every company is conducting a thorough record by monitoring the condition and movement of inventory. It concerns accounting, statistical and operational records of the inventory condition and movement in warehouses. If there is no timely and accurate recording, it is not possible to check inventory and it is not possible to monitor the efficiency of storage. The way of recording can be different it depends on the company size, the diversity of assortment, quantity of goods and the technical equipment of the company [9] [10].

It was noted that the proper operation of the warehouse has a significant impact on total costs generated by the company. The correct interpretation of the warehouse data is one of the key factors that decide about the financial results of the company [11]. The success of the policy depends on effective inventory management demand planning that begins with accurate forecasts [12]. During the replenishment period, inventory depletion occurs due to the combination of market demand and deterioration [13]. The inventory maintenance is currently conducted with the use of the computer technology. The evidence is done in order to determine the speed of inventory turnover, because that affects tying the funds in inventory [14].

Development of mathematical methods, particularly the operational research and statistics, together with the expansion of modern computer technology has enabled extremely fast development of modern methods of inventory control which are gradually adapting by application to the specific needs of managerial practice [15].

One of the models of supply is optimization model of inventory management. This model can have deterministic or stochastic character [16] [17], the deterministic model of inventory management must fulfil certain conditions:

- Demand for item must be known in advance;
- Potential deficit of inventory is not considered;
- Safety inventory is not considered;
- The model aims at minimizing the total cost of supply;
- Optimization means finding the optimal size of the order.

Modelling held by deterministic models is executed on the basis of a specific algorithm, whereas the most important decision variable is the ordered amount of inventory, or more precisely the optimal size of the order. It characterizes the amount of inventory that is supplied at once to the store from which it is gradually withdrew according to the manufacturing process and the intensity of withdrawing the inventory. The time between the arrival of orders to the warehouse and the moment of depletion of all inventories is characterized by a delivery cycle. It depends on the intensity of inventory drawdown and the size of order. The number of orders for a certain period of time is the inverse value of the replenishment cycle. The level of order is a variable that characterizes the height of the inventory of the material. If the inventory falls at this level, it is necessary to make a new order. The time between the moment of ordering the goods and the moment of arrival of the ordered goods to the warehouse is called a delivery time. Variable, which is crucial for the quantity of ordered goods, the level of ordering and moment of ordering, is the intensity of the inventory drawdown, or more precisely the consumption of inventory [18]. These indicators allow to quantify the optimal parameters of the deterministic model. For example, the consumption of semi-finished products in the manufacture is determined by the volume of production, which is determined in a volume per unit time. The deterministic model is used for the consumption of semi-finished products (production of the final product). This consumption is determined by the specific production volume [18].

3. METHODS APPLICABLE IN THE AREA OF THE INVENTORY MANAGEMENT

An important method is the exact analysis. The goal of the analysis is the breakdown of the whole unit on all its parts and their types. Based on what the analysis is focused on, there are several types of them. While the classification analysis involves sorting phenomena on parts, using a functional analysis it can be defined what is the relationships between parts of the whole and the mathematical dependencies. This means that in terms of the functional analysis it can be discovered which parts affect other parts of the whole unit and which parts are influenced by other parts of the whole unit. Parts of the whole unit are thus divided into dependent variables and independent variables. Independent variables influence the dependent variables, wherein one or more dependent variables may affect one or more independent variables [19].

Within the functional analysis may occur following four cases:

- One independent variable affects one dependent variable;
- One independent variable affects several dependent variables;
- Several variables affect a dependent variable;
- Several variables affect several dependent variables.

Another type of analysis is the causal analysis, which is used to define the causes of phenomena and searching for connections between them. In terms of a causal analysis, there can occur several cases of links between phenomena [19]:

- One phenomenon is the cause of the second;
- Two phenomena are interdependent;
- Two or more phenomena are a consequence of the third;
- One phenomenon is the cause of the activity of several other phenomena;
- The two phenomena are related only seemingly.

Comparative analysis is based on analogies, which are among the empirical methods, and therefore based on experience. Analogy is based on the correspondence of certain features of the object, focusing on their content and form. Subsequently, a comparison of these characters is made. Findings from the analysis can be used for conducting a synthesis of essential phenomena and links. On the basis of these, there can be submitted proposals of measures for further development of the analysed objects [20].

4. CLASSIFICATION ANALYSIS OF EXISTING MODELS OF THE INVENTORY MANAGEMENT

Inventory fulfils important functions in the company which are determined by the satisfactory level. On the other hand, their level influences the financial point of the enterprise. Thus the enterprise seeks for an optimal inventory level to ensure the continuity of the production, and at the same time to excessively draw the capital, taking into account different criteria [9] [19]. The current inventory management, aimed at determining the method of ordering individual inventory items, consider the influence of inventory on the financial aspects of the company and also the security of continuous production [20].

4.1 ABC analysis

ABC analysis means inventory planning and tracking according to their share of the value and number of inventory types. Purchased inventory assortment is divided into three groups - A, B, C, according to their share in the total value of purchased materials [21]. Inventory with the highest value represents in most cases the lowest number of material types [22] [23].

Group A - contains the types of materials of a high value (75-80 % of the total value) and a low percentage of all types of materials (approximately 10-20 %). The company makes detailed calculations of their consumption for these materials.

Group B - contains a large number of different types of materials, which comprises about 15-20 % of the total value of a 20-40 % of the total number of material types.

For these materials, the company pre-determine the minimal amount of inventory. After the inventory drop below this value, it is the followed by the material ordering and delivery.

Group C - contains materials which are purchased on the basis of an estimate. They represent approximately 5-15 % of the total value of a 50-70 % of the total number of material types. This group includes the largest number of materials, but their share of the value represents the slightest importance for the enterprise [24].

Inventory management differentiated by the ABC method proceeds from the Pareto principle 80:20, this means that 20 % of items is 80 % of the turnover of the particular product [25]. Graphical presentation of the ABC analysis is performed using the Lorenz curve, which is shown in Figure 1 [26].

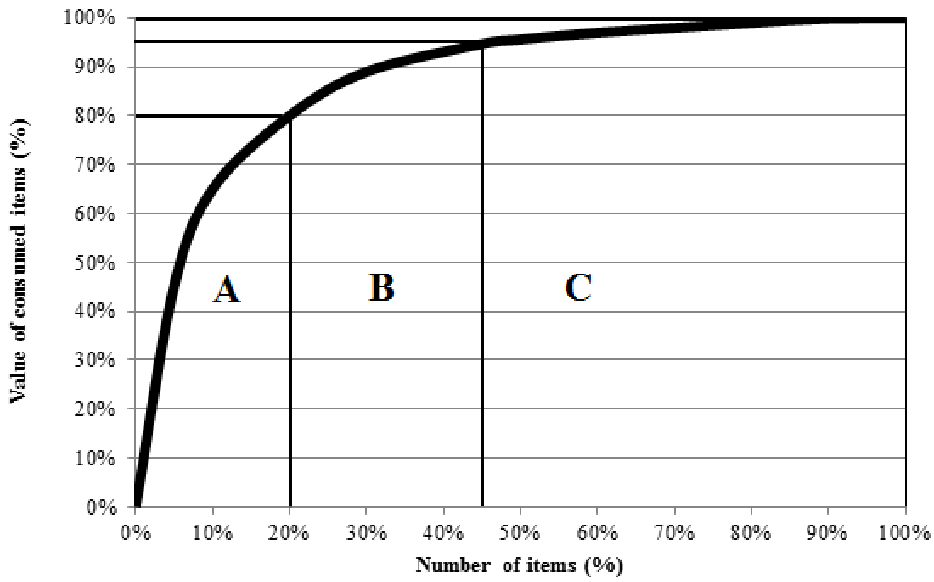

Figure 1 – ABC analysis – graphical representation
Source: Based on [26]

Monitoring the condition and movement of inventory

Method MINI - MAXI = Two-level methods:

- MIN = safety + technical supplies;
- MAX = conventional + insurance + technical supplies. If supply drops to a minimum, the supply will issue an order to a maximum.

The main advantages of ABC analysis include:

- Simplicity of making the analysis;
- Speed calculations;
- Clearness in the chart using a curve;
- Saving significant costs for inventory holding;
- Reducing the storage costs;
- Improving the profitability of the company;
- Reducing the errors in the process of ordering.

The basic disadvantages of ABC analysis include only the fact that it can be time-consuming and there is a necessity to provide sufficient data for calculations and for conducting a graphic part. There may be other criteria that represent additional important information concerning inventory management. Criticality expedition, the rate of obsolescence, the lack of substitutability, the demand for goods and the size of the order execution time deliveries are examples of such considerations [12] [27] [28]. However, the advantages outweigh the disadvantages of using the ABC analysis.

4.2 XYZ analysis

For more comprehensive information required to make decisions on how to purchase the material, the XYZ analysis is used. This analysis is a supplement to the ABC analysis and it also classifies inventory into three groups, but the standard for sorting them is the character of inventory consumption [22] [29].

Materials with the constant consumption and therefore high accuracy of consumption predictions are classified in group X. A concurrent method of acquisition is possible with these requirements.

In case the consumption succumbs to greater fluctuations, caused for example by seasonality, and thus it is not possible to make an accurate consumption, then the material is classified into the group Y. Such material is obtained to an inventory.

The group Z consists of materials with irregular occasional consumption. Their consumption can be predicted only with low accuracy. It is used a random method of ordering according to the current need [22]. Table 1 shows the properties of individual groups within the XYZ analysis.

Table 1 – Characteristics of individual inventory items by XYZ analysis

	X	**Y**	**Z**
Consumption	Constant	With fluctuations	Irregular
Accuracy of predictions	High	Medium	Low
The way of ordering	Synchronous	To stockpile	Randomly as needed

Source: Authors, based on [29]

4.3 ABC/XYZ analysis

When choosing a suitable method for the acquisition, it is used a combination of ABC and XYZ analysis. This combination results in nine groups of inventory. These groups are shown in Table 2.

Table 2 – ABC/XYZ analysis

Classification criteria and groups		**The value of the material**		
		A	**B**	**C**
Features material consumption and the prediction accuracy	**X**	High value, high prediction accuracy, smooth consumption	Medium value, high prediction accuracy, smooth consumption	Low value, high prediction accuracy, smooth consumption
	Y	High value, median prediction accuracy, polo smooth consumption	Medium value, median prediction accuracy, polo smooth consumption	Low value, medium prediction accuracy, polo smooth consumption
	Z	High value, low prediction accuracy, stochastic consumption	Medium value, low prediction accuracy, stochastic consumption	Low value, low prediction accuracy, stochastic consumption

Source: Authors, based on [26] [29]

Groups of inventory items AX, AY and BX are the items suitable for synchronous supply. On account of their high value, they significantly bind funds, require a high cost, and therefore it is necessary to minimize them. Their consumption is constant, and therefore it can be accurately determined what is the amount and the time needed for the item.

On the basis of this model, it is suitable to choose inventory items of the group CY when ordering to a stockpile. For inventory groups BY CX it is not clearly determined the way of ordering inventory. Those groups may be suitable for ordering to a stockpile, but also for synchronous supply. Equally the items AZ, BZ and CZ are at the interface between two types of supply, and that is the ordering to a stockpile and ordering randomly.

The advantage of this model is its simplicity and clarity. Based on this model we can determine the method of acquisition for all inventory items. The disadvantage is the ambiguity of determining the acquisition of most groups, which can lead to incorrect decisions of the company about the acquisition of them, resulting in a lack of inventory or unnecessarily utilized funds and incurring storage costs.

4.4 Decision Cube

For evaluating the suitability of individual inventory items for synchronous supply there is another important factor and that is the delivery reliability. This criterion is taken into account by the Decision Cube [26].

Decision Cube divides inventory into three groups: a group suitable for synchronous supply, a group partially suitable for synchronous supply and a group of inventory that is unsuitable for synchronous supply. Delivery reliability is divided into time reliability, delivery precision and delivery quality [26].

The advantage of this model is the consideration of delivery reliability, which is important for a synchronous way of supply in terms of ensuring the continuity of production, which has an impact on the costs from the lack of supplies and also on the customer service.

The disadvantage of the model is undefined items for other ways of supply and ambiguity of determining the suitability of certain inventory items for synchronous supply.

Except for the time reliability and meeting the delivery deadlines, delivery reliability may include accuracy (completeness) in supplied quantities and meeting the required delivery parameters.

4.5 Economic Order Quantity

The basic idea of determining the optimal inventory level in the logistics process is finding the greatness of inventory whereas the company achieves minimal costs associated with the acquisition and maintaining of inventory [30]. Thus it is a decision whether there should be an order of large quantities at lower supply costs or an order of small quantities at short time intervals and thereby reducing the storage costs. It is obvious that both of these tendencies are completely contradictory and it is necessary to find a suitable compromise and that is the Economic Order Quantity (EOQ) [31]. Graphical presentation of Economic Order Quantity is shown in Figure 2. EOQ is the amount which minimizes the cost balance between the ordering and storage costs.

The Economic Order Quantity model has been further extended to include transport costs, production costs, quantity discounts, qualitative restrictions and possible stochastic environment [6] [32] [33] [34] [35].

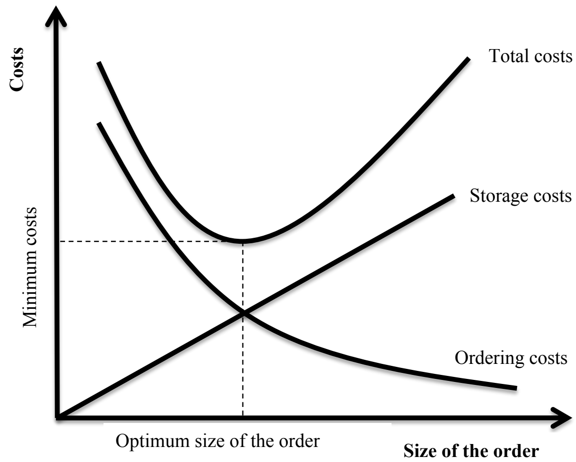

Figure 2 – The course of the ordering and storage costs
Source: Based on [31]

5. RESEARCH RESULTS AS A SYNTHESIS OF EXISTING MODELS OF THE INVENTORY MANAGEMENT

Based on the classification analysis of existing models of inventory management, it is possible to synthesize the considered factors of various models of inventory management.

It concerns the following factors:

- The value and the character of inventory consumption from ABC and XYZ analysis;
- Delivery reliability, which has been further divided into time reliability, delivery precision and delivery quality of Decision Dice in terms of the analysis;
- Total costs, supply costs, storage costs from EOQ.

Innovative model of inventory management (see Table 3) can be created by the synthesis of existing models of inventory management. This created model takes into account the factors influencing the inventory management.

Table 3 – Synthesis of the factors taken into consideration the different inventory models

<table>
<tr><th>Model</th><th>ABC/XYZ</th><th>Decision Cube</th><th>Synthesis models</th><th>EOQ</th></tr>
<tr><td rowspan="8">Respecting criteria</td><td colspan="3">Value inventory</td><td rowspan="5"></td></tr>
<tr><td colspan="3">Features power supplies</td></tr>
<tr><td rowspan="6"></td><td rowspan="3">Delivery reliability</td><td>Time reliability</td></tr>
<tr><td>Delivery precision</td></tr>
<tr><td>Delivery quality</td></tr>
<tr><td rowspan="3"></td><td colspan="2">Delivery costs</td></tr>
<tr><td colspan="2">Costs of storage</td></tr>
<tr><td colspan="2">Total costs</td></tr>
</table>

Source: Authors

Economic Wizard Matrix

Economic Wizard Matrix (EW Matrix) is used to control inventories of large numbers of inventory items with a minimum cost of holding and securing the required level. EW Matrix method is suitable for a clear segmentation of inventory items.

EW Matrix is an improvement of ABC analysis, created by combining the analysis of XYZ, and it is used when it is necessary to differentiate a large number of items. Taking ABC analysis can be differentiated for example by:

- Quantity (volume, frequency of collection);
- Book value (in store prices, costs or sales prices);
- Value added margins.

The EW Matrix consists of nine rows and three columns. EW Matrix is further illustrated in Table 4 and used in a case study from company that produces automotive parts.

EW Matrix was created based on:

- ABC analysis by revenues;
- ABC analysis according to sales volume analysis;
- XYZ according to turnover.

The EW Matrix gives a comprehensive view of the range of goods on inventory as a proportion of sales, quantity sold and regularity of demand. Extremely important group consists of manufacture for items organized into sectors AAX, which contributes 58.94 percent of sales from inventory. This group must carefully consider and plan to prevent scarcity of goods in inventory. Above all, those items should be included in all orders of manufacturing automotive parts. Given the regularity of demand and standard delivery time it would be appropriate to determine the optimal tracking and minimal amounts, in order to ensure continuity of supply.

Table 4 – EW Matrix as a case study in a chosen company

EW Matrix						
Group	AAX		AAY		AAZ	
Number of items	20		5		1	
Total	45,000,000	350,000	1,500,000	15,000	25,000	2,000
Share %	58.94 %	70.06 %	1.96 %	3.00 %	0.03 %	0.40 %
Group	ABX		ABY		ABZ	
Number of items	5		5		0	
Total	1,500,000	15,000	800,000	8,000	0	0
Share %	1.96 %	3.00 %	1.05 %	1.60 %	0.00 %	0.00 %
Group	ACX		ACY		ACZ	
Number of items	15		15		0	
Total	5,000,000	4,000	3,500,000	2,500	0	0
Share %	6.55 %	0.80 %	4.58 %	0.50 %	0.00 %	0.00 %
Group	BAX		BAY		BAZ	
Number of items	10		0		1	
Total	4,500,000	10,000	0	0	1,000	6,000
Share %	5.89 %	2.00 %	0.00 %	0.00 %	0.00 %	1.20 %
Group	BBX		BBY		BBZ	
Number of items	15		20		0	
Total	8,000,000	20,000	2,500,000	25,000	0	0
Share %	10.48 %	4.00 %	3.27 %	5.00 %	0.00 %	0.00 %
Group	BCX		BCY		BCZ	
Number of items	10		5		0	
Total	200,000	5,000	100,000	2,000	0	0
Share %	0.26 %	1.00 %	0.13 %	0.40 %	0.00 %	0.00 %
Group	CAX		CAY		CAZ	
Number of items	10		0		5	
Total	120,000	10,000	0	0	800,000	100
Share %	0.16 %	2.00 %	0.00 %	0.00 %	1.05 %	0.02 %
Group	CBX		CBY		CBZ	
Number of items	0		20		0	
Total	0	0	2,000,000	3,000	0	0
Share %	0.00 %	0.00 %	2.62 %	0.60 %	0.00 %	0.00 %
Group	CCX		CCY		CCZ	
Number of items	0		25		30	
Total	0	0	300,000	2,000	500,000	20,000
Share %	0.00 %	0.00 %	0.39 %	0.40 %	0.65 %	4.00 %

Source: Authors, based on [36]

Analyses which are preferred in a practice

From a financial point of view it is preferable to use the analysis determining the time and the speed of inventory turnover – it means turnover rate, binding the inventory and profitability. This should be used for inventory management in practice. In terms of the statistical approach some of the statistical characteristics are used in the field of inventory management such as the average inventory level, inventory standard deviation, minimal inventory, maximal inventory, the variation range of inventory and the modal value of the inventory [37].

One of the possible tools of inventory management is considered to be the system called Supply chain management, the logistics concept of managing the supply chain, which can contribute to clarify the decision-making and to increase the fluency of material flows in the enterprise which relate to the supply [38] [39] [40].

All of these tools are considered to be suitable prerequisites for the efficient inventory management. Supply and optimal delivery of inventory represent a problem and in practice this problem can be handled by the quantitative methods of inventory management.

6. CONCLUSION

The quality of inventory management has a major impact on the profitability of the company, which is expressed by the important indicators, it is meant to be the profit and largeness of inventory. Supply management is largely based on the cost function of inventory, focused on the analysis of the supply costs and determination of the optimal inventory and risk management in supply. The role of the inventory management is an optimal control of their condition and movements on the inventory. In addition to that, it is necessary to distinguish the materials which bind the significant funds from those that do not have a great impact on the structure of costs despite the amount.

According to the above analysis of inventory management, it is obvious that during their optimization two or three criteria are taken into, while in more cases the exact way of management is not determined. For reliable and unambiguous decisions about inventory it is necessary to take into account many criteria. There is a possible solution to create a model of inventory management that takes into account the entire system of criteria. Using the synthesis of various factors taken into consideration inventory management model is designed innovative inventory management.

This paper presents review of literature of inventory management and an application where new EW model is used to achieve a significant better inventory management at a company focused on manufacture automotive parts. With the results obtained, authors were able to show to the company that scientific methods for solving inventory problems are now more effective.

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THE ROLE OF INTEGRATED LOGISTICS SUPPORT IN ENHANCING THE RELIABILITY OF LNG IMPORT TERMINALS

ABSTRACT

Technical systems such as terminal for importing liquefied natural gas (LNG) are extremely important and the potential consequences of disruption in their work are exceptionally large. It is expected that the importing LNG terminal has a high degree of reliability, and failure-free operation, i.e. to work within the boundaries of permissible deviations during the entire design life, with a high degree of safety level.

Because of high demands regarding the reliability and availability, and the complexity of the system with high dependency between subsystems, it is necessary to ensure integrated logistics support. Integrated approach provides communication with the entire system in real time, managing engineering services and technical activities for collecting data, and analysis and synthesis of information obtained by subsystems, identifies deviations and performs appropriate corrective action, or on the basis of feedback carries out prevention of future deviations and leads to a high degree of reliability of the terminal.

This paper will show the importance of scientific research of the integrated logistics support role on the LNG terminals in order to increasing reliability, availability and safety of LNG terminal.

KEY WORDS

liquefied natural gas; integrated logistics support; reliability; availability, liquefied natural gas import terminals

1. INTRODUCTION

Natural gas is assuming a central role in devising energy strategies of developed countries, meeting three important requirements: it is a secure energy source with reserves more abundant and more lasting than oil reserves, an environmentally friendly fuel compared to other fossil fuels, and as technology develops it is a natural predecessor of the energy source of the future –hydrogen. Security of supply is an important issue which cannot be addressed without taking into consideration the reliability of transportation. Diversification of sources and transmission routes is essential to ensure security of natural gas supply. [1]

The transport of liquefied natural gas provides this required diversification of both supply and transportation routes. The transported substance – liquefied natural gas has a high value and high transportability because of its changed physical state and by 600 times reduced volume, as a result of the liquefaction process.

Due to a variety of different factors which appear in different locations, strict international legislation standards, directives and recommendations as well as laws of the host country prescribe the obligation to undertake a set of studies and fulfilled necessary criteria in order to situate the LNG import terminal as well as anticipated for the terminal construction.

Taking into account the physical properties of LNG/natural gas and in order to prevent potential accidents and minimise potential risk, all operations on LNG terminal have to be covered with prescribed procedures by applicable laws and meet best industrial standards.

Based on the aforementioned procedures and requirements, in accordance with conditions of the site and the preliminary terminal design, integrated logistics support is developed and implemented throughout the life of the technical system of the LNG import terminal in order to enhance reliability, efficiency and safety of the performed required function, both for the terminal and for the environment.

By studying published articles which are most professional paper and posted for the purpose of discussing the preliminary design of the LNG terminals or related professional studies, and by using scientific methods of generalization and specialization as well as analysis and synthesis, authors of this paper concluded that it is necessary to scientifically investigate role of integrated logistic support in order to increase the reliability, availability and safety of the LNG terminal.

2. FUNCTIONAL ANALYSIS OF THE LNG IMPORT TERMINAL SYSTEM AND AREAS OF INTEGRAL LOGISTIC SUPPORT IMPLEMENTATION

In order to develop the optimums logistics support it is necessary to define main functions and operational requirements of the entire system, which are also defined through integral parts - subsystems of an LNG import terminal in Figure 1.

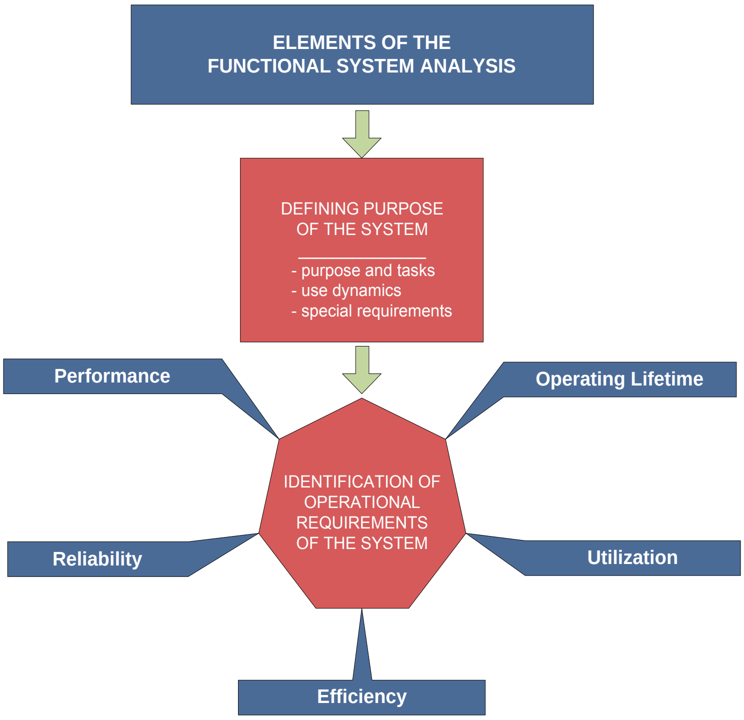

Figure 1 - Elements of the functional system analysis [2]

Main substance processed at the terminal is liquefied natural gas, consisting mostly of methane (CH4). In order to facilitate its storage and transport, until gasification gas is kept in liquefied condition at the cryogenic temperature -162 °C and almost atmospheric pressure its volume being 600 times smaller compared to the gaseous state.

Main functional parts of the production process at the LNG import terminal are: ship landing, LNG unloading from ship tanks into the storage facility of the terminal, LNG storage, BOG treatment, LNG gasification, gas calorific value adjustment, sending out gas into the transmission system (Figure 2).

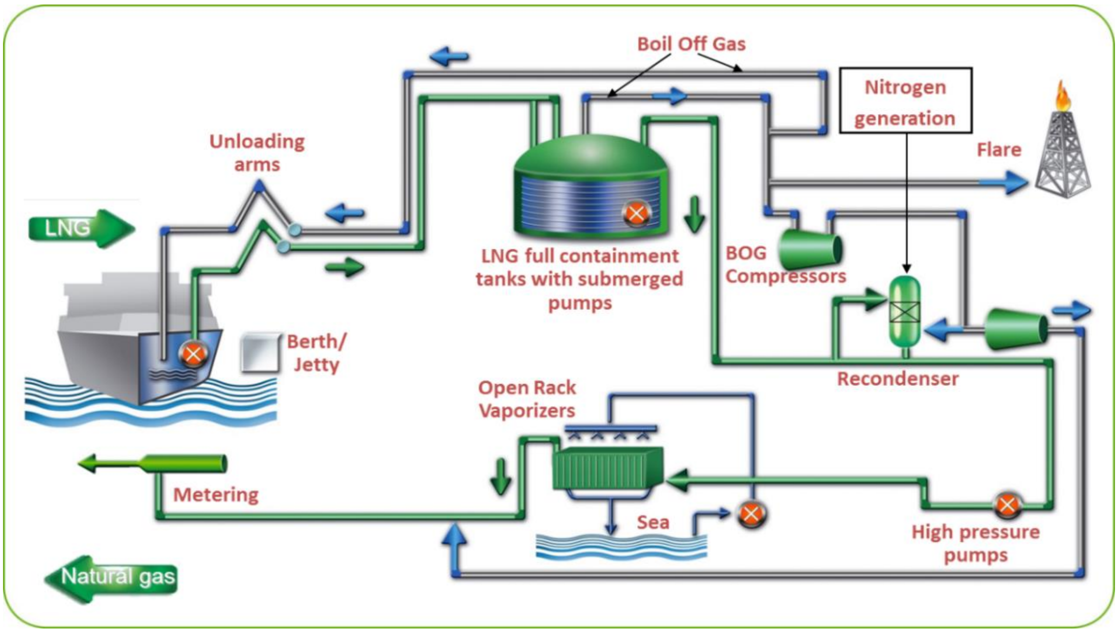

Figure 2 - Scheme of the LNG import terminal components [3]

2.1 Main function components of an LNG import terminal

Main function components of an LNG import terminal can be divided into two groups [4]:

1) Main terminal facilities and structures which are parts of the production process
2) Associated structures/buildings

Main terminal systems and structures:

- jetty and unloading facilities
- LNG and natural gas pipelines
- LNG storage tanks, low pressure LNG pumps submerged in tanks, and related facilities
- condenser
- high pressure pumps
- vaporizers
- sea water systems and associated structures
- compressors for BOG and zero send-outs into the network[1]
- emergency gas flaring system

[1] Boil of Gas which due to temperature exchange with the environment, during unloading operations or during storage spontaneously vaporised and transferred into the gaseous state. Considering that with the change of physical state pressure increases it is necessary to evacuate BOG (possibilities: by the return line into the ship tank to help push LNG during unloading, via the compressor station into the send- out gas, or flaring in case of accidents.

- metering station
- space housing equipment for pipeline survey and cleaning

Description of processes at main terminal systems are:

In line with the planned production capacity, defined annual LNG receipt volume, and annual natural gas send out volumes, jetty dimensions are determined including the mooring system, depth in line with the maximum drafts of planned fully loaded ships and according to worst expected weather conditions, with the unloading system and the necessary number of unloading arms. Besides the number of unloading arms defined by the capacity, a special loading arm is necessary for returning boil of gas, in order to maintain pressure in ship tanks. Pipelines from unloading arms go into one large diameter unloading pipeline, through which LNG runs into the LNG storage tanks on land.

Figure 3 - Unloading arms at an LNG import terminal [5]

LNG is stored in special tanks, which are appropriate for cryogenic temperature and other physical and chemical properties of the stored liquid. The tanks consist of an inner tank made of nickel alloyed (minimum 9%) stainless steel, insulation and a domed outer tank of reinforced concrete. All instrumentation and evacuation pipelines from the tank to the gasification system go through the rough to prevent LNG spillage in case of a pipeline accident. Scheme of an LNG tank and their ancillary equipment which ensures their effective and safe operation are shown in the Picture 4.

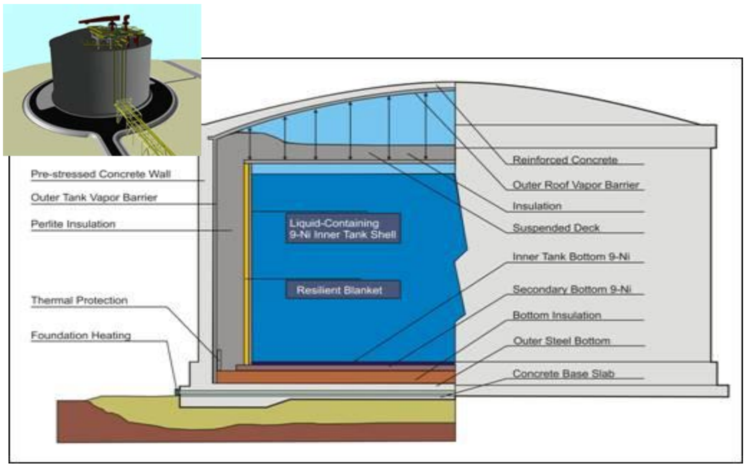

Figure 4 - Scheme of an LNG tank [6]

LNG is taken from the tanks to the vaporiser by electrical submersible pumps in the tanks which are installed in pump wells. High pressure send-out pumps increase the pressure of LNG coming (via low-pressure pumps) through pipelines from the tanks and, send it through vaporiser which transform LNG from the liquid into the gaseous state via the metering station to the high pressure natural gas transmission system.

Gasification is carried out in vaporisers, due to high reliability and low operating costs mostly in open rack vaporisers, which take heat from the sea water (Figure 5).

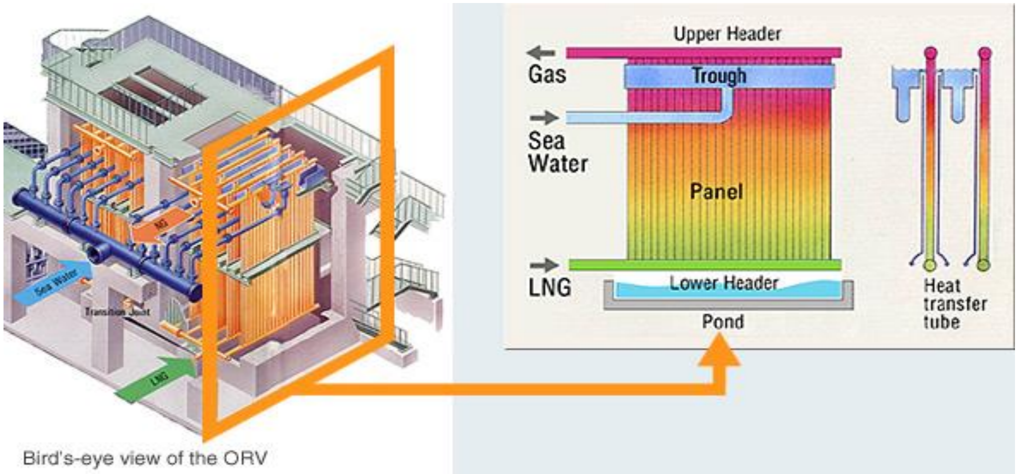

Figure 5 - Scheme of an open rack vaporizer [8]

By high pressure pumps LNG comes to the vaporiser where at a high pressure it flows through tubes of falling panels, being heated and vaporized. Vaporisation is carried out by exchange of heat with the seawater falling down the outer surface of the tubes. Natural gas flows into the natural gas transmission system and, after treatment, seawater is returned to the sea through the seawater discharge line. The LNG flow rate and the seawater flow rate are adjusted to achieve the necessary flow rate/pressure of the natural gas transmission system, and it is necessary to reach the outlet gas temperature of a minimum of +2°C to avoid pipeline freezing.

Associated structures/buildings:

- administrative building
- ancillary facilities
- central command building
- workshop and warehouse building
- roads and infrastructure including fence

Description of processes at associated terminal structures:
Associated structures serve to accommodate secondary processes at the LNG import terminal; buildings to accommodate administration, central command facility, facilities for ancillary plant accommodation, warehouses and workshops. Ancillary structures also include access roads, roads within the terminal and associated infrastructure.

2.2 Areas of integrated logistic support implementation on LNG Terminal

In order to meet parameters: reliability, availability and minimum risk, the areas of providing integrated logistics support to an LNG terminal can be presented as the following scheme (Fig.6).

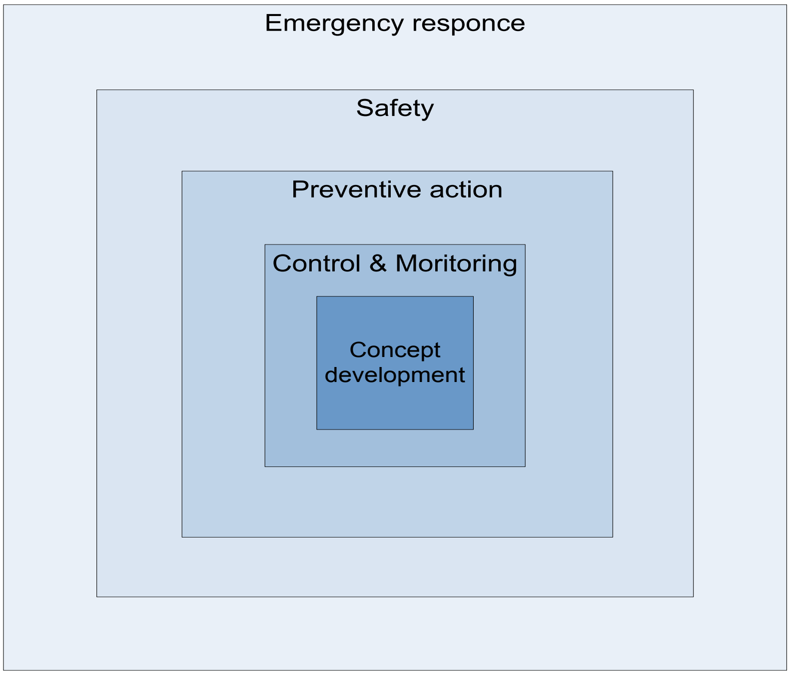

Figure 6 - Development and levels of integrated logistics support system at an LNG import terminal

In the terminal conception phase, logistics support of the LNG import terminal manages several engineering and technical activities: planning, designing and development, keeping abreast of necessary regulations for construction and selection of installations and equipment, coordination during construction, testing during the test period over several trial phases and during several modes of operation and working conditions, along with analysis of obtained data and modification proposing/implementing.

Over the entire producing life of the terminal logistics support is provided in the form of the technical system maintenance, establishing communication within the system and between the subsystems and its surroundings, monitoring of production cycle, flows of materials, equipment and necessary work force according to operational requirements of the terminal, new technological developments and their implementation for the purpose of improving required terminal operations.

For preventive action implementation, using ETA and FTA methods[2] with prior risk assessment according to LNG industry data (potential hazards, frequency of unwanted events and severity of consequences) logistics support develops scenarios of potential accidental situations which are then prevented by optimum maintenance, necessary number of parallel systems, constant personnel checking/ testing /training.

3. INTEGRATED LOGISTICS APPROACH AND SYSTEMS ON THE LNG TERMINAL

Considering that LNG import terminal provides security of supplying natural gas as one of main energy sources, a high degree of reliability, failure-free operation, operation within allowed tolerances is expected from an LNG terminal over the entire design life[3].

There is often confusion between the terms Reliability, Availability, and Risk.

- Reliability is a probability at a certain level of confidence that the system will successfully perform the required function for which it is intended, failure-free and within the limits

[2] ETA – Event Tree Analysis, FTA - Fault Tree Analysis
[3] Anticipated terminal life is 30 years with possible periodic extensions, of 5 to 7 years each.

of allowed tolerances, in the design producing life and set environmental conditions, i.e. when it is used in the prescribed manner and under specified load. Reliability related to the overall LNG terminal can be defined as the probability that the terminal as designed will perform its function (unloading LNG/storage/regasification) over a specified period of time under normal operating conditions.

- Similarly, the availability of an LNG terminal is the fraction of time that it CAN perform its function under normal operating conditions.
- Risk complements safety, higher degree of safety means lower risk and vice versa. In risk analysis safety is often defined as a measure of acceptable risk. There is also often confusion between the terms hazard and risk. Hazard is something which causes/may cause harm, and is ranked according to the magnitude of damage it causes, but such ranking does not include the probability of hazard occurrence. Risk is a "potential hazard", including not only consequences of the exposure to hazard but also the probability of hazard occurrence [9].

The equation below illustrates the ratio of the hazard events frequency with the severity of the consequences / harm in the risk assessing and defining the risk as the ratio of the potential consequences of hazard events in the observed period.

$$risk\ \left[\frac{consequence}{time}\right] = frequency\ \left[\frac{hazard\ event}{time}\right] \times consequence\ magnitude\ \left[\frac{consequence}{hazard\ event}\right]$$

3.1 Risk assessment as input data for integrated logistic approach

Taking into account the physical and chemical properties of LNG and, after regasification natural gas, potential consequences of hazard events at an LNG import terminal which are the basis for further risk assessment are shown in Table 1.

Table 1 - Potential consequences of hazard events at an LNG import terminal [10]

LNG pool fire	If LNG is spilled near an ignition source, the evaporating gas in a combustible concentration of gas (5-15%) and air, will burn above the "LNG pool" and the resulting "pool fire" would spread as the LNG pool expanded away from its source and continued evaporating. Pool fire is intensive, the released temperature is considerably higher than the temperature released by oil or gas burning. It cannot be extinguished, and all LNG in such a pool will burn out. Experts agree that a large "pool fire", especially on water, poses the greatest LNG hazard. [11]. In line with the consequences of a potential accident, where considering high temperature of LNG burning thermal radiation may hurt people or facilities at large distances from the source, strict safety measures are implemented to prevent potential occurrence of said situation.
Explosion	In certain conditions LNG vapours are explosive, and explosions are divided into two categories: deflagration (when due to burning vapours in closed or restricted areas, a high pre-pressure level occurs) and detonation (vapour burning process when the shock wave spreads faster than the local speed of sound).
Vapour clouds	During uncontrolled leakage from the tank in which it is kept in cryogenic conditions, LNG starts to heat and vaporize, making a cold cloud of vapour – natural gas, which remains close to the ground or on water. The cloud spreads in the open area, and dilutes when mixed with air. Vapours are not toxic, but are hazardous because they lower the oxygen content in a vapour cloud.
Freezing caused by direct contact with LNG	In case of uncontrolled LNG release, in the direct contact of a person with extremely cold liquid, chilblains with fatal consequences will occur, and in contact with the material not suitable for cryogenic temperatures, significant material damage will occur.
Rollover phenomenon	When a tank is loaded with LNG of different densities, unstable layers might be formed within the tank. As a result of density differences, lighter layer spontaneously goes up in order to stabilise the liquid in the tank. This is when rollover occurs, with sudden LNG vaporisation which can be too large for controlled venting through vent valves, and potentially could lead to cracks or other defects on the tank structure.
Rapid phase transition	In case of uncontrolled LNG spill on water, due to lower density LNG floats on water and vaporizes. In case or release of extremely large LNG volumes which in the end might cause LNG mixing with water, too fast vaporisation or rapid phase transition may occur. Rapid phase transition can consequently vary from a small bang to explosions strong enough to potentially damage light structures.

Considering the potential consequences of hazard events at an LNG import terminal shown in table 1, ETA and FTA analyses and risk matrix identify critical events, probability of a critical event occurrence, and severity of consequences. An analysis example [12] is provided in Table 2 (red cells is used for unacceptable risk level, which requires design/technology/material modification, yellow cells is used for ALARP area[4], where risk has been minimised, green cells denotes an acceptable risk level).

Data for calculating the probability of unwanted event occurrence are taken from the database of the LNG Industry Study Group, based on 30-year experience at 20 facilities.

- probable – several times during the facility lifetime ($> 10^{-2}$),
- low probability – once in every 10 to 20 similar facilities in the period of 20 to 30 years of the facility lifetime ($10^{-2} – 10^{-3}$),
- very low probability – once in 100 or 200 similar facilities worldwide in the period from 20 to 30 years of the facility lifetime ($10^{-3} – 10^{-4}$),
- extremely low probability – already occurred in this industry, but corrective action has been taken and never happened again ($10^{-4} – 10^{-5}$)
- negligible – event is physically possible but has never happened ($<10^{-5}$).

[4] ALARP stands for "as low as reasonably practicable", and is a term often used in the milieu of safety-critical and safety-involved systems. The ALARA principle is that the residual risk shall be as low as reasonably achievable.

Table 2 - Risk matrix [12]

The probability of event	**Probable (> 10^{-2})**					
	Low probability (10^{-2} – 10^{-3})	Inability of supply with instrumentation/ service air Interruption of drinking water supply Process control system outage	Rollover phenomenon			
	Very low probability (10^{-3} – 10^{-4})	BOG discharge through relief valves on top of the tank BOG discharge through flare but without its burning (non execution of flare function) Interruption of the facility for sea water treatment against fouling	Leakage of arm for returning BOG into ship tanks Leakage from the pipe returning BOG into the ship tanks Leakage of pipeline from an LNG tank to the compressor station Leakage of zero send-out compressor	LNG leakage from the pipeline or unloading arms at the jetty platform LNG leakage from the line going from the ship to the storage tank Low-pressure LNG collector leakage BOG leakage from the condenser or related line LNG leakage from the condenser or related line LNG high pressure collector leakage BOG release through relief valves of the vaporizer		
	Extremely low probability (10^{-4} – 10^{-5})	Power supply interruption	Zero send-out compressor breakdown	LNG leakage from the drain vessel for unloading arms Leakage at the inlet or outlet of the metering station at the transmission system entry point		Natural gas leakage from the outlet collector
	Negligible (<10^{-5})	Nitrogen supply interruption Interruption of sea water supply to vaporizers Communication system failure	Compressor inlet vessel breakdown	Breaking disconnection of the BOG return arm Rupture of the pipeline leading LNG to the high-pressure pump section High pressure LNG line rupture Compressor discharge pipe breaking	Breakdown of the unloading arm drain drum at the jetty area BOG return line rupture Rupture of the line from tanks to the compressor station Rupture of the vaporised gas collector	Breaking/disconnection of 1 unloading arm; Breaking/disconnection of 4 unloading arm; LNG pipeline rupture on the berth platform; Rupture of LNG pipeline from the ship to the tank; Recirculation pipeline rupture; Rupture of the LNG pipeline inside the tank/ on top of the tank; Rupture of low pressure outlet LNG collecting line; Condenser breakdown; Rupture of the high-pressure inlet LNG collector; Rupture of the high-pressure outlet LNG collector; Rupture of outlet natural gas collector; Pipeline rupture at the metering station inlet or outlet.
		MODERATE	**SEVERE**	**HUGE**	**CATASTROPHIC**	**DEVASTATING**
		SECERITY OF CONSEQUENCES				

3.2 Prevention as integrated logistic approach for safe, available and reliable LNG terminal operation

Based on obtained data, through engineering and technical activities integrated logistics support can undertakes preventive and safety measures for every identified critical event, having in place an internal emergency plan which is regularly reviewed and improved in cooperation with the international LNG industry.

By integrated logistics approach and functional operational system analysis, operational requirements are identifies and in order to increase the safety and availability of the LNG import terminal following activities should be implemented:

- During the period between two unloading operations the unloading facilities have to be maintained at the cryogenic temperature by low LNG recirculation flow rate, thus ensuring operational readiness and avoiding temperature dilatations of the pipeline. Following this, the unloading facilities have to be equipped by pressure and temperature relief valves with venting in the safe zone, a sump for collecting LNG leakage in case of an accident, and other safety systems which completely isolate a potential accidental situation from onshore facilities.
- Some LNG volume should be remains in the tanks in order to be able to maintain cryogenic temperature within the LNG tank and to ensure net positive lifting height for low-pressure pumps.
- During the roll-over event[5], there is a sudden movement of large volumes of LNG. As result, pressure increases significantly, and large BOG quantities are formed, which again increases pressure and can lead to activation of emergency gas venting.

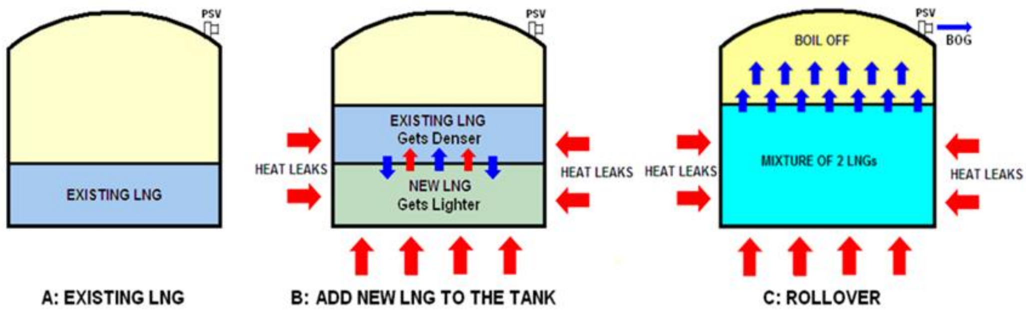

Figure 7 - Roll-over phenomenon [7]

In order to prevent roll-over following activities should be implemented:

- filling the tank via two pipelines: one which will directs LNG to the top, and the other one to the bottom,
- mixing LNG using pumps submerged in tanks through recirculation pipelines,

[5] Taking into account the physical properties of LNG, an important parameter in LNG storage is detected - stratification effect. Due to different compositions of natural gas depending on its country of production (content of heavier components C2+), shipments contain LNG of different densities. After unloading into the storage area of the terminal LNG of the same composition and density can cause roll over phenomenon. It occurs if certain volume of higher density LNG makes a layer above a lower density LNG layer and these layers try to swap i.e. the denser layer tries to go under the less dense one.

    - installing the system which monitors temperature, density, LNG and BOG levels, and immediately response of terminal operator in case of any deviation from set parameters.
- In every outlet gathering pipeline of the LNG tank a shut off valve should be installed to enable shutting off the tank pump set from the common outlet pipeline.
- Each tank should have connection to the branch of the common BOG collector, connected with the BOG cryogenic compressors[6].
- Installation of pressure control valve system to enable sending the excess gas to the flare in disturbed operating conditions, i.e. when/if the BOG compressor flow rate is higher than the compressor/condenser capacity, or when the pressure in tanks and in BOG collector increases and exceeds the pre-set pressure value.
- Safety gas venting system should consists of safety valves, low-pressure network which collects BOG from the BOG collector, liquid separator and the flare. In case of a sudden and drastic pressure increase, where the formed BOG volume cannot be condensed or pressurised into the transmission pipeline, the flare system will be activated.
- The flare should be always kept in ready-to-use condition by the pilot burner system at which a small volume of natural gas is flared.
- In order to increase the safety, following integrated logistic safety systems should be installed/implemented:
    - Gas alarm and LNG spillage detection system, designed to detect and alert the presence of all flammable gases and vapours which may occur at the terminal and its close vicinity (methane, ethane, propane, butane, ethylene). It should be calibrated to low values and located at all critical positions of the terminal (line detectors for controlling larger areas and pointed ones for potential spillage sites), capable of early local leak detection. For LNG spillage detection low temperature detectors have to be used in all areas where there is a probability of spilled LNG flow and/or accumulation, and they should be used in combination with gas detectors (due to quick “evaporation“ of LNG which turns into the gaseous state and becomes natural gas).
    - Firefighting/rescue facilities and firefighting systems, divided into the fire alarm system and passive and active fire protection.
    - Nitrogen generation and distribution system for cleaning/neutralising systems and instruments at the terminal, for achieving inert conditions before maintenance operations and for adjusting some natural gas properties before sending it out to the gas transmission system.
    - Instrument/service air generation and distribution system - to be used for cleaning electric and pressure equipment, and dry air powered tools.
    - Drainage system, consists of open (for unhazardous waste liquids, permanent venting into the atmosphere) and closed drains (for all processes through which LNG passes). Closed drains collect potentially spilled LNG, take it via collectors into the LNG tank or into drainage vessels.
    - Fuel gas system – to be used for heating and for the flare’s pilot burner.

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[6] According to the Best Available Techniques (BAT) and LNG industry practice, two BOG cryogenic compressors by one LNG tank is set as a minimum.
BOG compressor controls the tank pressure and tries to maintain it at a constant level by suctioning formed BOG for direct application or by enabling the return of this gas by increasing its pressure to the value needed to make possible condensation by mixing with the cooled LNG in the condenser.

- Emergency diesel generator sets – to be used in case of emergency for supplying power to control rooms, loading arms operation, foundation slab heaters, pumps inside tanks, air compressors, air driers, firefighting pumps, flare control system, terminal stand by operation, until the activation and the completion of the ESDS[7] process.
- Wastewater discharge system and treatment facility to ensure that waste water from contaminated areas is collected in waste pits and then treated. Unpolluted surface precipitation water is directed into the open drainage system and after mechanical filtration discharged into the sea.
- Power generation system – to start up in case of an outage of power supply from the distribution network. Emergency supply is provided for all the critical systems of the terminal, and uninterruptible power supply is built into all control and safety systems to enable safe transition from the network supply to the generator supply.
- Control system including gas and fire detection systems and emergency shutdown system – to ensure that LNG terminal operation meets all necessary operational and safety requirements. Control is performed by electronic instruments which in real time send reports, and via the Integrated Control and Safety System these reports are processed and process operation is monitored at all terminal components.
- Telecommunication system – to enable internal (voice, data) communication within the terminal site and external, via the public commuted telecommunication network, while the radio system enables communication within the terminal site and in the immediate terminal vicinity.
- main guard house and jetty guard house

All above listed activities and systems of integrated logistics support the LNG terminal in real time, communicates with the entire technical system and subsystems of terminal, managing necessary activities, identifies deviations and implements appropriate corrective action, i.e. based on feedback prevents future deviations resulting in high degree of the terminal reliability.

5. CONCLUSION

LNG import terminal is an energy infrastructure, high importance facility that providing security of supplying natural gas as one of main energy sources. Because of complexity of the LNG terminal as system with high dependency between subsystems, high demands regarding the reliability, availability, safety and systematic risk management, it is necessary to ensure integrated system to support all required activities and operations.

By studying the published articles that define reliability, availability and safety of the LNG import terminal, it was noted that they cover topic from the expert, professional side and for the purpose of discussing the preliminary design of the LNG terminals or related professional studies. Also, field of engineering support of an LNG import terminal is separately covered in professional publications, observing certain features of the terminal or individual segments or operations performed on the terminal.

[7] ESDS – Emergency Shut Down System

Using the scientific methods of generalization and specialization as well as analysis authors of this paper noted importance and necessity of scientific research of the integrated logistics support role on the LNG terminals in order to increasing reliability, availability and safety of LNG terminal.

By synthesis of published data authors determined that:

- Integrated logistics support represents a set of multidisciplinary and interdisciplinary knowledge and skills which study and apply the laws of planning, organisation, managing and controlling the flows of materials, persons, energy and system information, and find methods for establishing high reliability and safety criteria for a complex system such as an LNG terminal.
- By functional system analysis of LNG import terminal, integrated logistics support identifies operational and functional requirements of the terminal as a technical system, and acts in an integrated manner through its subsystems providing support through managing technical and engineering activities.
- Integrated approach provides communication with the entire LNG terminal in real time, managing engineering services and technical activities for collecting data and analysis and synthesis of information obtained by subsystems, identifies deviations and performs appropriate corrective action, or on the basis of feedback carries out prevention of future deviations and leads to a high degree of reliability of the terminal.
- Based on obtained data, through engineering and technical activities integrated logistics support can undertakes preventive and safety measures for every identified critical event, identifies operational requirements in order to increase the safety and availability, having in place an internal emergency plan which is regularly reviewed and improved in cooperation with the international LNG industry.
- Objective of the integrated logistics support is also a development of new technologies and their implementation in order to improve required terminal operations.

Integrated logistics support with engineering service and technical activities manages to communicate in real time with the entire system and its surroundings; from planning and developing a basic concept of an LNG import terminal in which it provides analysis of possibilities and solutions to technical and operational requirements, through exploitation phase during the entire terminal's life, to the terminal closing at the end of its producing life along with scraping and restoring the environment to the condition before the terminal construction.

Integrated logistics support of LNG import terminal is suitable for further scientific research and also especially applicable as scientific and technical basis for development strategies of the LNG import terminal planned to be situated in the Republic of Croatia.

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INFLUENCE OF MAXIMUM STOCK ON THE SUPPLY CHAIN

ABSTRACT

Maximum inventory in the warehouse represents upper limit of the quantity of goods that must not be exceeded in a certain period of time. It is a quantity, which is still economically justified in the relation of the costs of storage, order costs of new stock and the capability of meeting demands of consumers. Holding maximum inventory is justified in the case when suppliers are unreliable, where delays are possible, if production and customer orders oscillate during the year. Companies insure themselves from shortages of goods by holding inventory levels. Maximum inventory in the supply chain could be found in every phase. There are several methods to calculate maximum inventory rate. This paper presents influence of maximum inventory orders on supply chain by calculating maximum inventory in the phase of distribution. By knowing the amount of maximum inventory it is possible to optimize the logistics processes in the phase of distribution, so the total disorders in supply chain will be reduced.

KEY WORDS

maximum inventory, inventory level calculation, supply chain

1. INTRODUCTION

Common problems in inventory management are demand unpredictability, long delivery terms, unreliable supply process, long term delivery, great amount of products, etc. These are some of the reasons for holding maximum inventory, which is therefore the upper limit above which no new purchase is justified and economically unduly. Maximum inventory represents the upper limit which in itself includes integrity assortment of certain products. Holding maximum inventory in certain situations is justified due to the reasons that can stop the production or sale, harm the business etc. Although the expenses for holding maximum inventory are high, sometimes it is more profitable to have greater amount of inventory in the warehouse.

There are several ways to calculate normative for holding the maximum inventory and they will be shown further in the text.

In this paper, results of a research in the field of maximum inventory are presented. Based on historical data, maximum inventory has been calculated for one year in order to facilitate storage organization. Demand data, as well as supply chain data are taken from ABC Company in Croatia. ABC Company distributes certain kind of car parts and owns warehouse.

Research was made on the supply oscillation during one year period. As observed company inventory policy is to keep high customer service level, they strive to hold maximum inventory.

2. MAXIMUM INVENTORY OF HOLDING JUSTIFIABILITY

To analyze stated kind of inventory it is necessary to define maximum inventory, normative for it, function and criteria for holding it.

Maximum inventory, in contrast to minimum, represents the upper limit above which new purchase is not allowed because of the unprofitability. Relativity for minimum inventory works also for maximum inventory. Reason for some company to have *mini max* order or model of regeneration inventory to default level is because of the dynamic changes of market conditions [1].

Maximum inventory normative change with the market change and the company needs for supplies and sales.

Maximum inventory normative are quantity or value of the stock, over which the stock is unnecessary and superfluous. This quantity or value of the stock comes to the fore when the sale is not equal, or when procurement process are unreliable. Equation (1) for maximum inventory calculation is given below [2].

$$Zmax = \frac{largest\ planned\ sales}{\text{days of selected period}} \cdot standardized\ number\ of\ days \tag{1}$$

There are several possible ways to calculate maximum inventory. The previous mentioned equation is the most commonly used way where the value of the largest planned sales is divided by days of the planned period and is multiplied by the standard days (number of days in which the company must have the appropriate amount of stock).

Two tendencies in determining the maximum supply are [3]:

1. The High maximum stocks that are created by purchasing large quantities of the product in the long cycles of acquisition;
2. Low maximum inventories, which are determined by the purchase of small quantities in short cycle’s procurement.

The system of stock holding as one of logistics subsystems, is closely linked with the system of execution of orders. It is often indicated as a system of reserves or the inventory management.

Inventories are needed in differences of temporal and quantitative structure of input and output flows of material goods [4]. Keeping the maximum stock makes sense when production or customer orders, more or less fluctuate during the year, but the company policy of keeping a maximum inventory ensures absence of shortages.

Keeping maximum inventory also makes sense if suppliers are unreliable. When ordering new goods, it is necessary to take care that during and after delivery, level limit of maximum inventory is not exceeded, and the amount should not fall below the safety stock. The maximum inventory upper limit is economically justified for a certain period. When inventory level drops to the level of safety stocks, it is necessary to order new quantity of goods, as shown with figure 1.

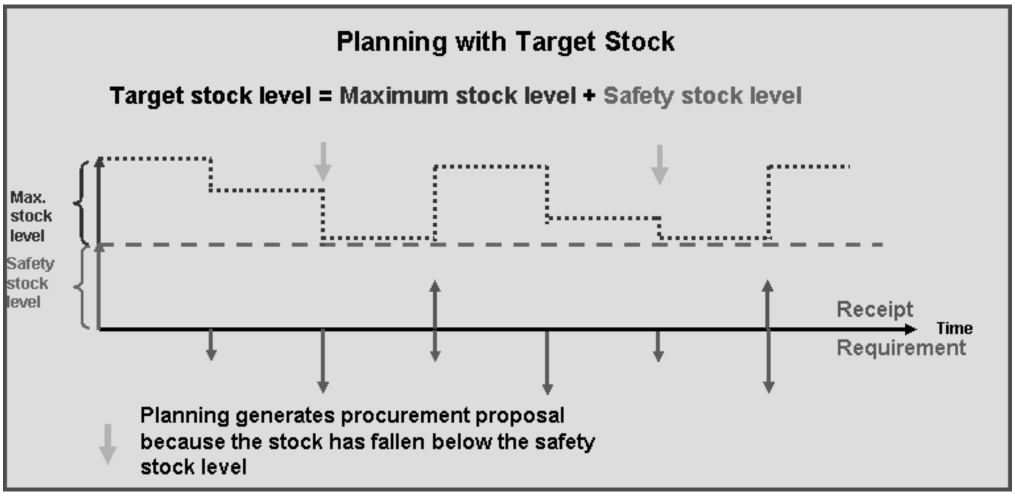


Figure 1 - Planning with target stock
Source: [5]

Criteria that justifies the maximum inventory are [6]:

1. Level of consumption - If the supplies are spent faster than expected it is necessary to have a maximum amount of inventory on stock
2. Production requirements – If exist a high demand and requirements in production, it is necessary to buy stock in large quantities (maximum).
3. Storage expenses - If the storage cost is lower than the transport cost it is necessary to store stock in order to save funds
4. Insurance expenses – There is a risk of loss of the goods due to fire or any other reason.
5. Inventory must be insured during transportation or during time in the storage.
6. Availability of storage space - It is necessary to provide a specific surface area of storage where inventory will be stored.

3. ANALYSIS OF THE MAXIMUM INVENTORY INFLUENCE

For the purpose of maximum inventory influence on supply chain analysis, the survey in real sector was made. As supply chain of the observed company is complex for the simplification only phase of distribution is analyzed.

The survey was carried out in the ABC Company, which deals with the distribution and sale of car parts [7]. The company owns self-storage facilities. ABC Company is engaged in distribution and sale of car parts for the Croatian market. Car parts are delivered to customers (consumers) and authorized car workshops. The company has 150,000 different car parts. To have continuity of sale or distribution, in certain situations the self-storage needs to have the maximum amount of stock. The calculation of the annual maximum amount of stock for the ABC Company is shown in hereinafter.

3.1. Review of an annual consumption and demand

In this example, the calculation of consumption, and the maximum amount of inventory will be counted for disc pads. It should be noted that the disc pads are parts which must be replaced every 100.000 to 150.000 km, although the change depends on factors such as total mileage, mileage on different types of terrain, etc. These factors affect brakes actuary, as well as interval of disc pads replacement. Disc pads are replaced in set. Set is packed in one box, and when it is ordered from supplier it is ordered in the number of boxes.

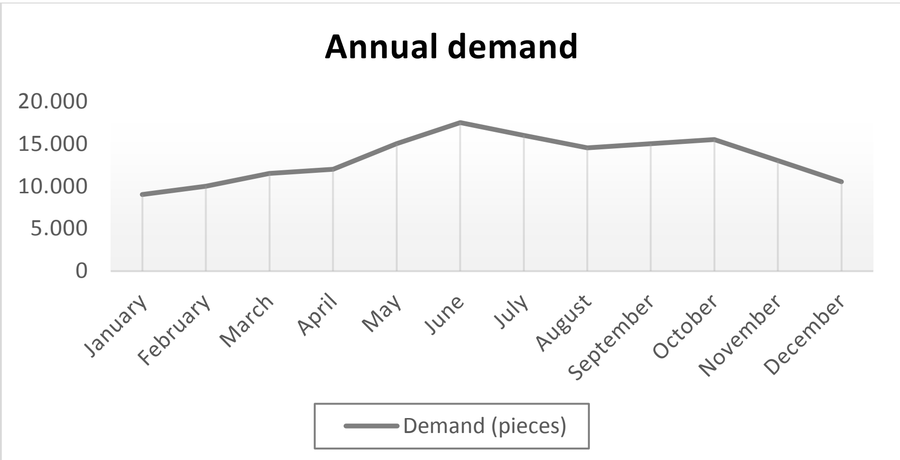
In table 1. the approximate annually demand of disc pads packages (sets) is shown. Among several suppliers (manufacturers) of disc pads, the company has chosen the optimum solution, by quality and price. Also, as observed company supplies market and car services for both, expensive and cheaper cars, and the disc pads unit price difference in car price class, when ordering inventory it is not easy to distinguishes quantities by price class. Therefore, the average calculation price for one disc pads package is stated to be 450, 00 KN. In one set are 4 disc pads, pads for one axis of the car. Based on the data provided, it is necessary to calculate the average annual consumption of products, and the maximum inventory level. The purchasing cycle (normalized number of days) is 18 days.

Table 1 - Annual demand and total value of disc pads

Month	Demand (sets)	Total value (kn)
January	9.000	4.050.000
February	10.000	4.500.000
March	11.500	5.175.000
April	12.000	5.400.000
May	15.000	6.750.000
June	17.500	7.875.000
July	16.000	7.200.000
August	14.500	6.525.000
September	15.000	6.750.000
October	15.500	6.975.000
November	13.000	5.850.000
December	10.500	4.725.000
Total	159.500	71.775.000

Source: [7]

The graph 1. shows that demand varies during the year. In winter months, demand is lower and in summer months, demand is higher. Variations in demand are large during the year. Therefore, these variations are equal to the maximum amount of inventory in the warehouse.



Graph 1 - Annual demand for disc pads

By the change of cars ageing on observed market as well as changes in cars price class variation in demands will be higher during the different period of time. So, from the results of company survey, annually demand variation are 7, 9, 13, 15 %. For the stated demand variation in table 2. calculation of average consumption is shown.

Table 2 - Increasing demand and average consumption

Month	Demand (sets)	7%	9%	13%	15%
January	9.000	9.630	9.810	10.170	10.350
February	10.000	10.700	10.900	11.300	11.500
March	11.500	12.305	12.535	12.995	13.225
April	12.000	12.840	13.080	13.560	13.800
May	15.000	16.050	16.350	16.950	17.250
June	17.500	18.725	19.075	19.775	20.125
July	16.000	17.120	17.440	18.080	18.400
August	14.500	15.515	15.805	16.385	16.675
September	15.000	16.050	16.350	16.950	17.250
October	15.500	16.585	16.895	17.515	17.825
November	13.000	13.910	14.170	14.690	14.950
December	10.500	11.235	11.445	11.865	12.075
Middle value of annual consumption	13.291,67	14.222,08	14.487,92	15.019,58	15.285,42

3.2 The calculation of the maximum inventory

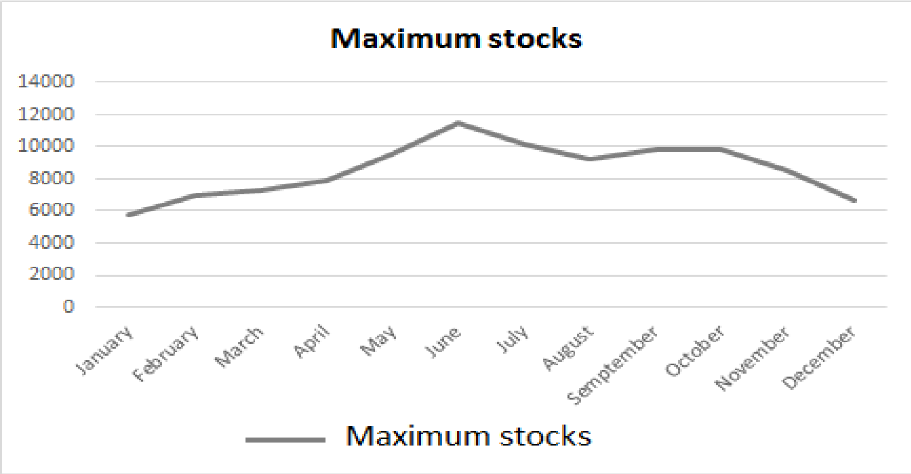
Table 3. shows the calculated results of the maximum stock for a demand without increasing, for the increase, and the average maximum inventory during the year.

The procedure of calculating the maximum quantity of stock is carried out using the formula (1).

Table 3 - The amount of the maximum inventory before and after the increase in demand

Month	The demand without increasing (sets)	7%	9%	13%	15%
January	5.226	5592	5696	5905	6010
February	6.429	6879	7007	7264	7393
March	6.677	7145	7278	7545	7679
April	7.200	7704	7848	8136	8280
May	8.710	9319	9494	9842	10016
June	10.500	11235	11445	11865	12075
July	9.290	9941	10126	10498	10684
August	8.419	9009	9177	9514	9682
September	9.000	9630	9810	10170	10350
October	9.000	9630	9810	10170	10350
November	7.800	8346	8502	8814	8970
December	6.097	6524	6645	6889	7011
Middle value of annual maximum stock	7.862	8413	8570	8884	9042

As an example, graphical review for maximum inventory after an increase in demand for 9% is shown in graph 2. The amount of the maximum inventory increased in May, reach the climax in June, and then fall. In the winter months, demand is lower and not require larger amounts of stock. With increasing amounts of inventory, it is necessary to provide storage space and this causes an increase costs. Graph 2. is a similar to graph 1. which means that the amount of inventory depending on demand.



Graph 2 - Quantity of maximum stock

3.3 Disscusion of results

As it can be seen from the generated results, securing high customer service level by inventory is not easy to achieve. Market demand is conditioned by different factors such as age of the cars and cars price class. The results shows that demand in the summer months has increased, therefore, it requires a greater amount of disc pads stock in the warehouse. To enable better customer service and selling it is necessary to have enough stock.

To secure maximum inventory on hand, company has to carefully forecast future demand and to plan orders. Each time when order, company order big quantity of disc pads so it makes disturbance in supply chain. Big orders if not planned in advance can make disturbance in supply chain especially in a phase of distribution, as well as in warehousing.

The problem with inventory planning is the unpredictability of demand, therefore the maximum supply is suitable in the case of seasonal fluctuations, so the budget is set also for the increase in demand. Demand for disc pads is not constant, so this is another reason for keeping the maximum stock.

The results are an indication that the maximum inventory burden the phase of distribution. With this calculation it is possible to lower the ordering cost, costs of holding inventory and transport costs.

4. CONCLUSION

Maximum inventory can serve as a factor in the supply chain and enables continuity of production and distribution, because it creates security, and complements the lack of articles or materials. Certain criteria and features that justify keeping the maximum stock are also justifying the extra costs and larger space that maximum inventory occupies. Criteria and functions make the reasons for keeping the maximum stock, and some of them are: the level of consumption, storage costs, availability of storage space requirements in production and others.

Research results at the ABC Company, which is shown in this paperwork, is an indicator of how to safely manage a maximum inventory. Historical data show the average demand of certain items, or how it was spent in certain months during that year. Maximum inventory occurs in the supply chain in the event of demand fluctuations, or when demand varies. Using such data, maximum inventory can be calculated for future period. The results shows what amount of goods is necessary to keep in stock for the distribution and sale. Maximum inventory in supply chain, especially in the distribution stage, affects the costs increase of keeping inventory in stock, increasing transportation costs and ordering. Using calculation it can be determine the maximum amount of stocks that is not too high and not too low, or to initiate a minimal cost of ordering, transportation and storage, and that the distribution takes place continuously. With the maximum inventory company ensures itself from unreliable suppliers, oscillation demand and shortages of goods. Although the maximum supplies require additional costs, by calculating the maximum possible supplies, one can keep the optimal level, which also means minimization of the costs for maximum inventory.

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OPTIMIZING VEHICLE ALOCATION IN THE RENT-A-CAR NETWORK BY APPLYING MATHEMATICAL MODEL

ABSTRACT

Satisfying vehicle demand of rent-a-car network branches is a complex and time consuming task, which can be facilitated by applying linear programing mathematical model. The goal is to obtain the optimal solution of vehicle allocation, by satisfying demand at minimum costs. With reference to that, the objective functionis defined as minimal total distance for vehicles transfers, where distance in kilometers represent cost to be minimized. The optimal solution can be achieved by applying linear programing mathematical model. The implementation of the model is outlined on real-life cases, which are analyzed and compared in order to quantify the improvements.

KEY WORDS

Vehicle allocation, optimal solution, mathematical model.

1. INTRODUCTION

In order to remain competitive on the market, rent-a-car companies need to optimize the operations and reduce costs. The most important issue in this sense is daily vehicle allocation among branch offices in different cities, within the rent-a-car network. This is a complex combinatorial problem [1], which must be solved on daily basis, in shortest time. Based on the current vehicle deployment among branch offices and the vehicle demand for the next day, the optimal vehicle allocation is to meet the next day vehicle demand, at minimum total distance traveled in transferring vehicles, from branch offices of current location, to branch offices where the vehicles are needed.

In this paper, implementation of linear programing mathematical model is proposedto facilitate solving the vehicle allocation problem. Generally, feasible values of the decision variables are limited by a set of constraints that are described by mathematical functions of the decision variables [2]. The feasible solutions are compared against the objective function value which depends on the decision variables. For a linear program the objective function and constraints are required to be linearly related to the variables of the problem.

This approach enables supporting daily operational decisions in a rent-a-car company, by providing for suitable and easy to use solution. In order to outline the possibility of the mathematical model implementation, several typical real life situations in a rent-a-car company daily operations are analyzed. For this purpose, input data from ORYX Rent-a-car Company are used. After the mathematical model of the problem is defined, the optimal solution can be obtained by using various software tools, such as WINQSB or Solver(Excel Spreadsheet Optimizer) [3]. The input data are generated by rent-a-car software CaRS and imported in Excel spreadsheet, in order to be further processed. The data refer to the number of vehicles of particular types (groups), current locations of vehicles, vehicle demand at branch offices and distances between branch offices.

The problem is solved by optimizing the mathematical model applying MS Excel software tool Solver, which uses Simplex method to find optimal solution. Prior to using Solver, all components of the problem (decision variables, objective function, constraints) have to be included in the model. This software tool is chosen due to its availability (included with the standard MS Office software) [4].

2. DESCRIPTION OF THE LOGISTIC PROBLEM

Operator at the rent-a-car company deals with the vehicle allocation problem when making decisions which vehicle, from which source (branch office of current location), totransferto which destination (branch office of demand), while minimizing the total distance traveled. Practically, by the end of the day, the operator in technical support division receives the information on current locations of the vehicles that are returned to the branch offices and orders (vehicle demand) of the branch offices for the next day. Based on that information, he needs to plan transfers of the vehicles in order to meet the next day demand.

In low season, the problem is not so difficult, however in high season, when capacity of the rent-a-car fleet is highly exploited, meeting demand requires optimal vehicle allocation. Possibility of clients to extend the rental period (a couple of hours ora few days), regular maintenance and accidental damages orfailure which puts a vehicle out of service, make the problem even more complicated. Currently, the entire procedure is carried out manually, by operator in technical support division. There is no software available to facilitate making decisions on vehicle allocation that could be used by the operator. Since most of the vehicles must be transferred (more than 70% on average) from current location to the point of demand, allocating fleet of 1700 vehicles is very demanding task, that must be done in limited time frame, on daily basis.

If the demand cannot be satisfied by the exact type of vehicle, it can be substituted by a suitable vehicle of a different type. For this purpose, a set of internal rules are specified, that regulate exchanges between groups of vehicles. Vehicles of the ORYX Rent-a-car Company fleet are grouped into 22 groups (each group consists of several types of vehicles), as shown in Table 1.The numbers of vehicles each group consists of, areinput data to be entered into the mathematical model.

Table 1 - Groups of vehicles

Vehicle Group	Vehicle Type
MCMR	VW UP, OPEL ADAM
EDMR	VW POLO, ŠKODA FABIA
CCMR	VW GOLF, SEAT LEON, OPEL ASTRA
CCAR	GOLF AUTOMATIK
CDMR	AUDI A3
ITMR	AUDI TT
SDAR	PASSAT AUTOMATIK
IDMR	ŠKODA OCTAVIA, RENAULT FLUENECE
SXMR	VW PASSAT 1.6 TDI
SDMR	VW PASSAT 2.0 TDI
PDAR	AUDI A6
LDAR	AUDI A8
EWMR	ODA FABIA CARAVAN, SEAT IBIZA CARAV
IWMR	ŠKODA OCTAVIA CARAVAN
SWMR	OPEL INSIGNIA CARAVAN, VW PASSAR CA
IVMR	OPEL ZAFIRA, VW TURAN
FVMR	VW SHARAN
CKMR	VW CADDY FRUGON
IFAR	VW TIGUAN
PVMR	VW MULTIVAN
LVMR	OPEL VIVARO, VW CARAVELA
XKMR	VW T5 FURGOM

Source: Adapted from[5]

ORIX rent-a-car network consists of 16 branch offices that are located in Croatia, as shown in Table 2. Total number of branch offices, their locations and distances between them, are also input data to be entered into the mathematical model.

Table 2 - Oryx rent-a-car branch offices

Location	Branch Office
ZAGREB	VUKOVARSKA CESTA 74
ZAGREB	HOTEL ESPLANADE, MIHANOVIĆEVA 1
VELIKA GORICA	ZRAČNA LUKA PLESO
KARLOVAC	ZRINSKI TRG 4
OMIŠALJ, KRK	ZRAČNA LUKA RIJEKA
RIJEKA	RIJEČKI LUKOBRAN 4
PULA	SCALIVEROVA 1
LIŽNJAN	ZRAČNA LUKA PULA
ROVINJ	SŠETALIŠTE VJEĆA EUROPE BB
POREĆ	ALDO NEGRI1
ZADAR	VRATA SV. KRESEVANA
ZADAR	ZRAČNA LUKA ZADAR
KAŠTELA	ZRAČNA LUKA SPLIT
SPLIT	SV PETRA STAROG 1
ČILIPI	ZRAČNA LUKA DUBROVNIK
DUBROVNIK	ZAGREBAČKA BB

Source: Adapted from [5]

3. PROPOSED SOLUTION OF THE VEHICLE ALOCATION PROBLEM

Problem of allocating vehicles in the rent-a-car network is in fact an optimization problem, which can be approximated by integer linear programing mathematical model [6].With reference to that, the mathematical model that encompasses all the elements of the problem,can be defined as follows:

Objective function:

$$minF = \sum_{k=1}^{l}\sum_{i=1}^{n}\sum_{j=1}^{m} x_{kij} \cdot d_{ij} \qquad (1)$$

Subject to the constraints:

$$\sum_{k=1}^{l} p_{jk} = \sum_{i=1}^{n}\sum_{k=1}^{l} x_{kij} \ \ \forall \ j = 1, \dots, m \qquad (2)$$

$$\sum_{k=1}^{l} s_{ik} \geq \sum_{j=1}^{m}\sum_{k=1}^{l} x_{kij} \ \ \forall \ i = 1, \dots, n \qquad (3)$$

$$x_{kij} \in \mathrm{I}_{+} \ \ \forall \ i = 1, \dots, n; \ j = 1, \dots, m; \ k = 1, \dots, l \qquad (4)$$

Where:

x_{kij} = number of vehicles of type*k*which are located at branch office *i*and must be transferred to branch office*j* (decision variable, must be non-negative integer)

d_{ij} = distance from branch office*i* to branch office*j* in kilometers

n = total number of branch offices where vehicles are located

m = total number of branch offices which demand vehicles

l = total number of vehicle types

p_{jk}= demand of branch office *j*(number of vehicles of type *k* that are needed in branch office *j*)

s_{ik}= available vehicles at branch office *i* (number of vehicles of type *k* which are currently located at branch office *i*)

Objective function (1) is to minimize total distance traveled while transferring vehicles from the point of current location to the point of demand. Its value is calculated by summing up all products of the number vehicles to be transferred and the respective distances on which they are transferred. If a vehicle is demanded by the same branch office where it is currently located, the distance d_{ij} takes the value of zero (0).

Equation (2) expresses the constraint that demand at each branch office must be satisfied. Inequity (3) expresses the constraint that the maximum number of vehicles of a particular type, to be transferred from a branch office, must not exceed the number of vehicles that are currently located at that branch office. Expression (4) sets the allowable values of the decision variable to be non-negative integers.

4. DISSCUSION OF THE RESULTS

Depicting full-scale results would exceed the work frame of this paper, so only a limited but representative segment the problem (three branch offices, three groups of vehicles) is sorted out to outline the proposed solution, although the solution was applied to the entire rent-a-car network, for all groups of vehicles. For this reason, the optimal solution may seem obvious for this particular segment, however it is only a small part of the vehicle allocation problem in the entire rent-a-car network.

A solution obtained by the operator is entered into the spreadsheet in order to be compared to the solution obtained by optimizing mathematical model. Two typical real-life cases are considered:

- Case 1: demand can be satisfied by the exact types of vehicles as requested;
- Case 2: exchange of vehicle groups is needed (some vehicles are substituted by another vehicle of the suitable type).

Case 1

Table 3. refers to the situation with MCMR Group of vehicles, when each branch office meets the demand out of available vehicles (currently located there), so no transfer is needed:

- Branch office Zagreb (ZGD) demands 15 vehicles, while having 18 vehicles available (currently located there);
- Branch office Karlovac(KAR) demands three vehicles, while having four vehicles available (currently located there);
- Branch office Rijeka(RID) demands five vehicles, while having 11 vehicles available (currently located there);

Table 3 - Optimal solution for MCMR Group

MCMR Group						
From/To	**ZGD**	**KAR**	**RID**	Provided		**Available**
ZGD	15	0	0	15	<=	**18**
KAR	0	3	0	3	<=	**4**
RID	0	0	5	5	<=	**11**
Provided	15	3	5			
Demand	**15**	**3**	**5**			

In this situation, the operator decides to satisfy the demand at each branch office by vehicles that are currently located there, which is the same solution as the one obtained by optimizing the mathematical model of the problem. This solution is given in Table 3. (value of the objective function equals to zero, meaning no distance is traveled). Although the solution is obvious in this example (which is only one segment of the entire problem), the fact that optimized solution corresponds to the operator's solution actually shows representativeness of the mathematical model.

Another real-life situation refers to EDMR Group of vehicles, where branch offices ZGD and RID meet the demand out of available vehicles (currently located there), while branch office KAR demands more vehicles (three) than currently available (two), so one more vehicle must be provided there. That vehicle could be transferred either from branch office ZGD which has 20 vehicles more than demanded (43 - 13 = 20), or from branch office RID which has two vehicles more than demanded (36 - 34 = 2).

The operator decided to meet the demand by transferring one vehicle from branch office RID to branch office KAR, as shown in Table 4.

Table 4 - Operator's solution for EDMR Group

EDMR Group						
From/To	**ZGD**	**KAR**	**RID**	Provided		**Available**
ZGD	13	0	0	13	<=	**43**
KAR	0	2	0	2	<=	**2**
RID	0	1	34	35	<=	**36**
Provided	13	3	34			
Demand	**13**	**3**	**34**			
Total distance =		**115**	**km**			

Total distance traveled according to that solution is 115 km. It has to be emphasized that this decision is only one of the numerous decisions the operator makes in allocating the entire fleet of 1700 vehicles, among 16 branch offices, in a limited time.

Optimal solution for allocating EDMR Group of vehicles, obtained by using Solver software tool on the mathematical model of the problem, is shown in Table 5.

Table 5 - Optimal solution for EDMR Group

EDMR Group						
From/To	**ZGD**	**KAR**	**RID**	Provided		**Available**
ZGD	13	1	0	14	<=	**43**
KAR	0	2	0	2	<=	**2**
RID	0	0	34	34	<=	**36**
Provided	13	3	34			
Demand	**13**	**3**	**34**			
Total distance =		**55**	**km**			

According to the optimal solution, the vehicle is transferred from the branch office ZGD instead RID, which yields total distance of 55 km. This solution is better than the operator's solution, as the total distance is shortened by 60 km (115 km - 55 km = 60 km).

Case 2

Case 2 refers to one of the real-life situations with MCMR Group of vehicles, when total demand for vehicles of that types exceeds the total number of available vehicles of that types, in particular:

- Branch office Zagreb (ZGD) demands 15 vehicles, while having 20 vehicles available (currently located there);
- Branch office Karlovac(KAR) demands 12 vehicles, while having four vehicles available (currently located there);
- Branch office Rijeka(RID) demands 15 vehicles, while having 11 vehicles available (currently located there);

The demand for vehicles of MCMR Group can be met only partly, because 42 vehicles are demanded and there are only 35 vehicles available at branch offices. According to the company internal rules, vehicles of types that belong to MCMR Group can be substituted by vehicles of types that belong to EDMR Group. Therefore, the operator decides to satisfy the demand by allocating available MCMR vehicles and to compensate lack of vehicles by substituting with unallocated vehicles from EDMR Group, as shown in Table 6.

Table 6 - Operator'ssolution for MCMR Group with substitutions

MCMR Group						
From/To	**ZGD**	**KAR**	**RID**	Provided		**Available**
ZGD	15	0	0	15	<=	**20**
KAR	0	4	0	4	<=	**4**
RID	0	0	11	11	<=	**11**
Provided	15	4	11			
Demand	**15**	**12**	**15**			
Total distance =		**0**	**km**			

EDMR Group						
From/To	**ZGD**	**KAR**	**RID**	Provided		**Unallocated**
ZGD	0	8	0	8	<=	**28**
KAR	0	0	0	0	<=	**0**
RID	0	0	4	4	<=	**25**
Provided	0	8	4			
Demand	**0**	**8**	**4**			
Total distance =		**440**	**km**			

According to the operator's solution, total distance travelled in transferring vehicles is 440 km. It is to be noted that the number of unallocated vehicles from EDMR Group is given as a result of the complete allocation plan provided by the operator for the entire rent-a-car network.

Optimal solution for allocating MCMR Group of vehicles, including substitutions with EDMR Group of vehicles, obtained by using Solver software tool on the mathematical model of the problem, is shown in Table 7.

Table 7 - Optimal solution for MCMR Group with substitutions

MCMR Group						
From/To	**ZGD**	**KAR**	**RID**	Provided		**Available**
ZGD	15	5	0	20	<=	**20**
KAR	0	4	0	4	<=	**4**
RID	0	0	11	11	<=	**11**
Provided	15	9	11			
Demand	**15**	**12**	**15**			
Total distance =		**275**	**km**			

EDMR Group						
From/To	**ZGD**	**KAR**	**RID**	Provided		**Unallocated**
ZGD	0	1	0	1	<=	**25**
KAR	0	2	0	2	<=	**2**
RID	0	0	4	4	<=	**26**
Provided	0	3	4			
Demand	**0**	**3**	**4**			
Total distance =		**55**	**km**			

Total distance according to the optimal solution is 330 km (275 km + 55 km), which is better than the operator's solution by reducing the total distance traveled in transferring vehicles by 110 km (440 km - 330 km = 110 km).

5. CONCLUSION

Operator's logistic solution for vehicle assignment that was analyzed, didn'tfully meet the demandsof efficiencyand effectiveness (allocation based onoperator's assessmentandexperience). The optimal solution of the vehicle assignment problem was obtained by applying the software tool on the mathematical model. In order to quantify the improvements, the solution implemented by the operator was tested on the model and the results were compared to the optimal solution obtained by the software tool.

In almost every iteration, the optimized solution was better than the operator's solution, only in few iterations the solutions were similar. For this reason, the vehicle transfers in practice generallyinvolve more vehicles and more kilometers traveled than actually needed.

Optimal vehicle allocation enablesreducing number of vehicle transfers and the total number of kilometers traveled at transfers, which results in better utilization of the fleet and operator's working hours.Due to simplicity of use, flexibility and quick problem solving, optimizing mathematical model of the problem is particularly suited for daily use in real-life situations,especially whensubsequent modifications are required.

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IMPACT OF WINTER MAINTANANCEON RETROREFLECTION OF ROAD MARKINGS

ABSTRACT

Road markings represent one of the most important safety elements of modern roads that lead and regulate road transport, separate lanes, prohibit certain maneuvers and behavior, delineate the edges of the pavement and provide information to participants in traffic. Road marking must be visible in all weather and traffic conditions to be useful and fulfill its functions. The retroreflective properties of the markings represent their most important characteristic. Marking visibility is closely related to their durability or service life that is affected by several factors. One of the factors is winter maintenance activities, or removing snow form roads. The mentioned factor is subject of the analysis carried out in this paper. The analysis was made based on the results of retroreflection measurementsof painted road markings before and after winter on state roads in Republic of Croatia. The research results show that in similar traffic conditions, retroreflection of the painted road markings was significantly degraded on the roads with winter service activities in relation to the roads without winter service activities. The average absolute difference of the retroreflection degradation of painted road markings on the roads with and without winter service is 17.40% for the center lines and 21.01% for the edge lines.

KEY WORDS

road markings, retroreflection, winter maintenance, traffic safety

1. INTRODUCTION

Road markings, in accordance with Croatian regulation, are part of the traffic signalization that withuse and combination of lines, signs and symbols form a traffic area and as such cannot be substituted by other signs or regulations. They have the same legal value as the traffic signs and traffic light signals and can be placed alone or in combination with them if it is necessary to point out and fully explain their meaning[1].

From the above it can be concluded that the basic tasks of road markings are: warning (about the state and the situation in the area in front of the vehicle which requires special attention and caution to continue driving safety), guidance (the driver to their travel target by identifying them safe path), information (the driver about the legal restrictions) and help in regulating traffic in an optimal way. Generally, it can be said that driving is a dynamic activity with a continuous decision making based largely on information which have visual character. Since the road markings are located in the central driver's field, their quality is extremely important for safe traffic flow. Inadequate and poorly maintained markings are considered an important factor that contributes to traffic accidents. Conducted scientific studies have shown that the application of modern traffic signalization and its proper maintenance can reduce the number of traffic accidents [2].

Road markings durability, according to [3],effect 11 factors: (1) material type; (2) location of marking line; (3) estimated age; (4) Annual Average Daily Traffic - AADT; (5) road/highway type; (6) number of lanes per road; (7) pavement surface condition; (8) speed of traffic; (9) normal amount of salts; (10) normal amount of abrasives and (11) snow removal. In addition, according to scientific research [4, 5], an important factor are also glass beads whose quality and quantity directly affects visibility and durability of road markings. Quality of the glass beads depends on their granulation, refractive index, roundness and chemical coating that allows tighter connection of the beads with the road marking material.

From the above it can be concluded that the application of appropriate technologies and materials for road markings, according to traffic-geographic-meteorological conditions in the area, can contribute to reduction of traffic accidents and thereby increase the general rate of traffic safety.

The aim of this paper is to analyze the impact of winter maintenance activities on the degradation of the painted road markings on Croatian state roads.

2. LITERATURE REVIEW

Scientific researches related to road markings are mainly oriented towards the research of retroreflection and durability.

The authors in [6] investigated the minimum required level of retroreflection for older drivers when driving with low beam. Results of the study showed that more than 85% of respondents older than 60 years rated retroreflection of 100 mcd/m^2•lx as the sufficient minimum.Zwahlen and Schnell in [7] conducted a study with the aim of testing and confirming the hypothesis that drivers adjust their spatial scanning and driving speed in accordance with visibility of road markings. The result of the study confirms this hypothesis and proposes minimum levels of retroreflection according to the speed limit on the road.

Similar studies related to subjective minimum value retroreflection conducted the authors in [8], [9] and [10]. These investigations have resulted in the proposed minimum values of retroreflection: 120, 150 and 130-140 mcd/m^2•lx.

Apart from the mentioned studies, a series of studies was conducted to gain insight into the driver needs in wet and rainy night conditions [11, 12, 13]. Based on subjective evaluation of marking visibility derived from a variety of materials with simulated wet conditions, the authors in [11] proposed 150 mcd/m^2•lx as the minimum value of retroreflection.

Martin et. al. [14] tried to conclude the relationship between pavement marking life expectancy and traffic levels. Authors identified the main elements of pavement marking management system without developing such a system. Only AADT and age were considered to predict the reflectivity measurements and to calculate the service life of marking material.

Fares et al. [15] developed pavement marking performance models that predicted the condition of different marking materials under various service conditions, including weather, traffic and snow removal plans based on a condition rating scale, which numerically ranges from 1 to 5 and linguistically from excellent to critical, respectively. The developed models are validated and the results show that the average percent validity varies from 87% to 99%.

Classification of data was based on three main parameters: (1) location of the marking line (e.g. left line, center line, or right line), (2) category of the road (e.g. highways, arterial roads, secondary streets or collectors), and finally (3) marking material (e.g. alkyd paint, or epoxy). Deterioration curves are developed that assess the condition of the pavement marking based on the developed models. However, according to [16] the RA technique is not efficient when modeling the effect of qualitative factors.

Pilot study conducted in [17] explored the effect of snow removal operations onthermoplastic pavement markings. The data was collected from ten thermoplastic markings using a hand-held retroreflectometer. Data collection began 60 days after initial marking application and ended 12 months after initial marking application. A significant finding was that during the first year, white thermoplastic markings located in the center of the road, and that are exposed to snow removal operations do not reach the apex of their break-in phase. Thus, the start of the linear degradation phase does not start until at least one year after initial application.

Author in [18] developed performance prediction model for paint pavement markings that included the impact of snow removal operations. Research determined that each snow plow event degrades paint pavement markings by 3.22 mcd/m^2•lx which is more than one month of service life. The work also showed that AADT has a small but significant impact on the degradation of painted pavement markings.

3. DATA COLLECTION METHODOLOGY

The data related to the road markings retroreflection, used in this study, was collected using dynamic measuring method by the Department for traffic signalization, Faculty of Transport and Traffic Sciences, University of Zagreb. Dynamic method involves measuring the nighttime visibility or retroreflection of road markings along their length on a particular road using the dynamic measuring device. Dynamic retroreflectometer Zehntner ZDR 6020 used in this study was placed on measuring vehicle Mercedes Viano on the left or right side depending on the markings position.

Measuring geometry of the specific retroreflectometer complies with the EN 1436: 2007 + A1: 2008 standard which involves measuring light rays reflected from the examined surface at an angle of 2.29° with the entrance angle of light 1.24° at a distance of 30 m using low beam [19].

Before measuring, device was calibrated to ensure measurement accuracy and 50 meter measuring interval was selected. As mentioned, dynamic retroreflectometer measures retroreflection every two milliseconds and the measurement interval represents the length of the section for which the device will give an average measured values. The accuracy of the measurement, i.e. of the calibration, has been reaffirmed with the Zehntner ZRM 6014 static retroreflectometer. Measurements were performed during the day without closing the traffic on each section in their entire length and with the normal driving speed (about 50 km/h).

The tests were conducted into two phases. In the first phase, markings were measured in the period from the 30th to 60th day after the marking restored according to Guidelines and technical requirements by Croatian Roads Ltd. [20]. In the second phase markings were measured after the end of the winter period.

A total of eleven roads in the different regions and counties have been analyzed. In the analysis, separately were analyzed central and edge road markings in order to determine the impact of winter service on degradation of markings depending on their position. Analyzed roads are divided into those in which the activities of winter service were present and where mentioned activities were not present.

4. RESULTS

As previously stated, during the analysis, the central and edge markings were separately analyzed on roads where winter maintenance activities were present and on which the above activities weren't present.

Table 1 shows the average value of the retroreflection of central lines(restored and existing) on three Croatian state roads in Bjelovarsko-bilogorska and Viroviticko-podravska County on which the activities of winter maintenance were recorded. A total of 12 measurements from the period from 2011 to 2014 were analyzed. The average value is the retroreflection average of all 50 meter intervals on each measured section. The table further shows an absolute percentage degradation of retroreflection value between the two measurements as well as the time interval between measurements, the number of snowplow passing'sin that time interval and AADT.

Average values of retroreflection of renewed road markings used in this paper, were measured usually at the end of the summer, after the restoration, and the value of retroreflection of the existing markings was measured in the next spring after the end of the winter maintenance season.These data are shown in Table 1.

Table1 -The analysis of the retroreflection degradation of the central lines on roads with winter service activities

Date	State road	Status	Line type	Average retroreflection	Absolute degradation of retroreflection	Days between measurements	Number of snowplows	AADT
23.08.2013	DC45	Restored	Central	247	43.32%	256	11	2,013
06.05.2014		Existing	Central	140				2,031
19.10.2012	DC45	Restored	Central	278	56.47%	179	29	2,038
16.04.2013		Existing	Central	121				2,013
23.08.2013	DC2	Restored	Central	306	43.46%	255	18	4,478
05.05.2014		Existing	Central	137				4,839
20.08.2012	DC2	Restored	Central	269	47.21%	268	31	4,580
15.05.2013		Existing	Central	142				4,478
21.07.2011	DC2	Restored	Central	333	62.16%	293	40	5,231
09.05.2012		Existing	Central	126				4,580
23.08.2013	DC5	Restored	Central	330	29.39%	273	18	945
23.05.2014		Existing	Central	233				1,054
Average					**47.00%**	**254.00**	**24.5**	**3,190**

Source: By Authors

Table 1 shows that the average absolute retroreflection degradation of the central line is 47.00%. The average number of passing plow on the roads analyzed is 24.5 times, while the average AADT is 3,190 vehicles per day. The biggest drop of retroreflection (62.16%) has been recorded on the state road DC2, where has also been recorded the highest winter service activity (a total of 40 passing's of snow plow during the winter) and the biggest AADT. From these results one can conclude that the average retroreflection degradation of the central line is 6.20 mcd/m^2•lx per winter service activity (snowplow).

Table 2 shows the results of the retroreflection measurements of edge lines. A total of 24 measurements have been analyzed, on the same state roads as in the previous analysis of the central lines. The measurements were performed in the same time period (2011 to 2014).

Average absolute retroreflection degradation of edge lines on the analyzed roads is 41.31%, which is 5.69% less than on the center lines. Since the roads were analyzed in the same period, AADT has remained the same (3,190). Increased degradation of the retroreflection of central line is the result of the greater impact of winter service because of the two-way plow passing, and also because the central line has been more frequently “stepped over“ by the vehicles in traffic flow. The average degradation of edge line retroreflection is 6.00 mcd/m²•lx per winter service activity (snowplow) which is almost identical result to the one of the central line.

Table2 - The analysis of the retroreflection degradation of the edge lines with winter service activities

Date	State road	Status	Line type	Average retroreflection	Absolute degradation of retroreflection	Days between measurements	Number of snowplow passing	AADT
23.08.2013	DC45	Restored	Righ edge	316	31.33%	256	11	2,013
06.05.2014		Existing		217				2,031
23.08.2013	DC45	Restored	Left edge	282	45.04%	256	11	2,013
06.05.2014		Existing		155				2,031
19.10.2012	DC45	Restored	Righ edge	306	50.33%	179	29	2,038
16.04.2013		Existing		152				2,013
19.10.2012	DC45	Restored	Left edge	287	53.66%	179	29	2,038
16.04.2013		Existing		133				2,013
18.10.2013	DC2	Restored	Right edge	270	42.59%	199	18	4,478
05.05.2014		Existing		155				4,839
18.10.2013	DC2	Restored	Left edge	257	56.03%	199	18	4,478
05.05.2014		Existing		113				4,839
30.08.2012	DC2	Restored	Right edge	313	38.02%	245	31	4,580
02.05.2013		Existing		194				4,478
30.08.2012	DC2	Restored	Left edge	318	38.99%	245	31	4,580
02.05.2013		Existing		194				4,478
21.07.2011	DC2	Restored	Right edge	320	33.75%	293	40	5,231
09.05.2012		Existing		212				4,580
21.07.2011	DC2	Restored	Left edge	349	35.82%	293	40	5,231
09.05.2012		Existing		224				4,580
23.08.2013	DC5	Restored	Right edge	321	32.71%	270	18	945
20.05.2014		Existing		216				1,054
23.08.2013	DC5	Restored	Left edge	336	37.50%	270	18	945
20.05.2014		Existing		210				1,054
Average					**41.31%**	**240.3**	**24.50**	**3,190**

Source: By Authors

In order to determine the impact of winter service on the retroreflection, roads on which there were no reported winter service activities have been also analyzed. A total of nine roads, located in the Mediterranean part of Croatia (Istria and Dalmatia) were analyzed.

The retroreflection degradation of central lines on the road where there was no impact of winter service has been significantly lower, which is evident in Table 3. Average absolute retroreflection degradationin this case is 29.60% with approximately same average number of days between the two measurements (303.38 days) and slightly higher average AADT (3,671). From the above it can be concluded that even with higher AADT, average retroreflection degradation is lower than on the roads with winter service activities.

Table 3 - The analysis of the retroreflection degradation of the central lines without winter service activities

Date	State road	Status	Line type	Average retroreflection	Absolute degradation of retroreflection	Days between measurements	AADT
11.09.2012	DC44	Restored	Central	324	24.69%	274	2,204
12.06.2013		Existing		244			2,226
21.09.2012	DC48	Restored	Central	305	37.05%	264	4,010
12.06.2013		Existing		192			4,004
21.09.2012	DC64	Restored	Central	331	42.60%	264	2,322
12.06.2013		Existing		190			3,497
05.07.2013	DC66	Restored	Central	317	8.83%	256	3,663
18.03.2014		Existing		289			4,133
13.06.2011	DC303	Restored	Central	233	18.03%	346	5,010
24.05.2012		Existing		191			4,997
11.09.2012	DC500	Restored	Central	250	31.20%	274	1,788
12.06.2013		Existing		172			1,806
30.09.2014	DC116	Restored	Central	170	45.29%	428	1,333
02.12.2015		Existing		93			/
25.05.2012	DC8	Restored	Central	230	29.13%	321	7,026
11.04.2013		Existing		163			7,045
Average					**29.60%**	**303.38**	**3,671**

Source: By Authors

From Table 4 it is evident that on the roads where there was no impact of winter service, the average absolute retroreflection degradation of edge lines is 20.30%, which represents a difference of 9.30% compared to the central line on the same roads and 21.01% compared to edge markings affected by the winter service.

Table 4 - The analysis of the retroreflection degradation of the edge lines without winter service activities

Date	State road	Status	Line type	Average retroreflection	Absolute degradation of retroreflection	Days between measurements	AADT
17.09.2012	DC44	Restored	Left edge	334	13.47%	262	2,204
06.06.2013		Existing		289			2,226
17.09.2012	DC44	Restored	Right edge	322	14.91%	262	2,204
06.06.2013		Existing		274			2,226
21.09.2012	DC48	Restored	Left edge	322	18,63%	264	4,010
12.06.2013		Existing		262			4,004
21.09.2012	DC48	Restored	Right edge	243	19.34%	264	4,010
12.06.2013		Existing		196			4,004
21.09.2012	DC64	Restored	Left edge	344	19.77%	264	2,322
12.06.2013		Existing		276			3,497
21.09.2012	DC64	Restored	Right edge	350	36.00%	264	2,322
12.06.2013		Existing		224			3,497
02.10.2013	DC66	Restored	Right edge	259	11.58%	168	3,663
19.03.2014		Existing		229			4,133
02.10.2013	DC66	Restored	Left edge	257	23.74%	168	3,663
19.03.2014		Existing		196			4,133
13.06.2011	DC303	Restored	Left edge	317	8.83%	346	7,930
24.05.2012		Existing		289			7,902
13.06.2011	DC303	Restored	Right edge	274	24.82%	346	7,930
24.05.2012		Existing		206			7,902
21.09.2012	DC500	Restored	Left edge	318	38.99%	264	1,788
12.06.2013		Existing		194			1,806

21.09.2012	DC500	Restored	Right edge	341	35.78%	264	1,788
12.06.2013		Existing		219			1,806
30.09.2014	DC116	Restored	Left edge	194	18.04%	428	1,333
02.12.2015		Existing		159			/
30.09.2014	DC116	Restored	Right edge	187	12.30%	428	1,333
02.12.2015		Existing		164			/
25.05.2012	DC8	Restored	Left edge	220	13.64%	321	7,026
11.04.2013		Existing		190			7,045
25.05.2012	DC8	Restored	Right edge	214	14.95%	281	7,026
11.04.2013		Existing		182			7,045
Average					**20.30%**	**287.13**	**3,671**

Source: By Authors

From the foregoing, it is evident that, with approximately equal traffic conditions, retroreflection of road markings is considerably more degraded on the roads in colder areas where winter maintenance service activities are present. Also, the retroreflection degradation of road markings depends on the line type or line location, so due to the impact of a two-way passing snowplow and the larger traffic flow which steps over the line, the central line degrades faster than edge lines.

5. CONCLUSION

The aim of this paper was to analyze the impact of winter maintenance activities on the degradation of the painted road markings on Croatian state roads. The paper analyzes the roads in various Croatian regions under different weather conditions. Based on the processing of the collected data and comparisonof the values of road markings absolute retroreflection degradation,analysis showed that the impact of winter maintenance service (plows and salting) on wear and retroreflection degradation of the markings is significant. Average absolute retroreflection degradation of the central line on roads without impact of winter service is 29.60% with a slightly higher AADT which, compared to the center line of roads where winter service activities were recorded, represents a difference of 17.4%. Similar results are shown in the analysis of the edge lines where the absolute average degradation of markings with winter service and no winter service is 21.01%.

Also from these results it can be concluded that the average retroreflection degradation of the central line per winter service activity is 6.20 mcd/m^2•lx while of the edge lines is 6,00 mcd/m^2•lx. These retroreflection decrease per number of winter maintenance activities are almost twice higher than in [18] where the authors concluded that the average decrease was 3.22 mcd/m^2•lx. That can be explained with the different geographic and climatic factors and traffic flow characteristics on the roads analyzed in both studies.

Due to the drivers subjective estimate, studies carried out in [6, 7, 8, 9 and 10] propose a minimum value of retroreflection ranging 100-140 mcd/m^2•lx. For the roads on which winter service activity was recorded it can be concluded that the painted markings reached mentioned minimum values in less than a year, which implies an annual road markings renewal. From the above, the replacement of painted markings on roads in colder areas with longer-lasting and more resistant materials is proposed, which would optimize the road maintenance system.

Further study of the impact of winter maintenance activities on road markings retroreflection with a greater number of statistical data is necessary to confirm the results and so that the findings could be efficiently implementedin a road markings maintenance system.

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AIR SHOW AIRSPACE MANAGEMENT CONCEPT

ABSTRACT

Paper deals with the concept of the military air shows airspace management. Military air show operations consume the significant portion of the airspace as well as the availability of airports. Structuration of airportand air show military aircraft operations are researched, as well as the derived degradation of airspace availability for civil air traffic. Available set of improvements for the peculiar airspace management is studied in order to indicate usable directions of further approach to the joint civil-military use of airspace and facilities for air shows.

KEY WORDS

Airspace; air show; airport; airspace management

1. INTRODUCTION

In order to optimise the use of airspace, requirements of all users, civil and military, should be accepted and rehearsed. Although the military aircraft operations have privileges there is need to plan the airspace use flexibly and to demonstrate fairness and transparency [1]. Airspace management should result in increased capacity of the air traffic system and the flexible use of airspace is developed and applied for that purpose [2].

Conduct of military operations that deviate from commonly used procedures at airports with significant civil and joint military operations represent specific case and challenge for military planners.

Temporal segregation of airspace can be justified by the safe and efficient performance; nevertheless, it is necessary to study the possibility of different approach and use of reserved airspace. That requires greater precision of planning and coordination between air traffic control services and military control units during conduct of military operations.

Air display represents military activity which may pose a threat to civil traffic and coordination between relevant air traffic control service and military units is required [3].

Peculiarities of air shows performed at an airport as described in [4], can be classified in two categories: one regarding the guidance on organizing: advertising, marketing, commercials, sponsorships, revenues, public relations, transportation, security and medical support; and the one regarding operational aspects. The second category deals with the organisation of the site and the use of the airspace.

Following subjects are involved in the operational organisation of the site and the use of the airspace: air traffic control, air operations manager, ground operations manager (either airport/base authority representative or the subject in close cooperation with airport/base authority), airshow narrator, all performers (team leaders or the entire team), rescue and fire-fighting, emergency medical service and safety coordinator. There are also representatives of the aviation authorities involved.

Organisation of the site can be presented in the generic airport layout map containing position of spectator area relative to runway and parking positions of participating aircraft with safety separation line. Examples of minimum distance of spectator enclosure from taxiing or performing aircraft can be found in [5].

If the air show airport is closed for non-participating traffic air traffic control unitmanages participating aircraft in accordance with the air show flight operations schedule. If other, commercial, traffic is allowed to operate at the airport, the role of the air traffic control unit is to ensure the separation between arriving/departing traffic and air show participating aircraft. Typically for air shows at an airport, all participating aircraft, civil and military, are controlled by same air traffic control unit.

Details of the planned activity regarding air show airspace, time and duration, preparations and rehearsals schedule and specific measures regarding safety and emergency procedures shall be provided to the air traffic service. Airspace available for flight displays is defined in accordance with the participating aircraft airspeed, formations size and manoeuvres. Air show airspace dimensions shall enable safe and continuous conduct of air show activities as well as minimal interference with civil operations. Co-ordination has to develop procedures for civil aircraft emergency situations that require immediate approach for landing as well as procedures for other situations which influence air show operations. This influence can either degrade air show time-line or terminatethe air show completely[3].

Military air show planning body has to initiate coordination process with air traffic services concerned early enough in order to enable coordinated development of optimal plans and procedures. Furthermore, process has to enable promulgation of information for airspace users concerned.

There are three levels of ASM[1] prescribed by [6]: strategic – ASM Level 1, pre-tactical – ASM Level 2 and tactical – ASM Level 3.

The National High-Level Airspace Policy Body has the authority to define the circumstances and criteria when civil air traffic services unit or military controlling unit is responsible for separation between civil and military flights[6]. It is this level's responsibility to ensure the progressive establishment of flexible airspace structures and adequate real-time civil-military co-ordination procedures. Such airspace structures volume shall be structured as minimum necessary to fulfil operational requirements and ensure safety. This paper deals with the sharing ofdefined volume of airspace and crossing of temporary reserved/restricted areas.

Airspace Management Cell - AMC, as Level 2, is established and authorised by The National High-Level Airspace Policy Body to conduct airspace allocation and management. AMC decides about airspace allocation for air shows. This airspace can be either TRA[2] or

[1] ASM - Airspace Management

[2] TRA - Temporary reserved area - A defined volume of airspace normally under the jurisdiction of one aviation authority and temporarily reserved, by common agreement, for the specific use by another aviation authority and through which other traffic may be allowed to transit, under ATC clearance [6].

TSA[3]. TSA and TRA management and allocation are under AMC's jurisdiction. If the nature of activities requires segregation to protect participating and non-participating traffic, TSA is used. In that case, any crossing of the activated area is not allowed. In order to improve the flexibility of the use of the airspace, tactical crossing of non-participating traffic when the activity inside doesn't require a protection can be allowed and TRA is used [7].

The National High-Level Airspace Policy Body ensures written agreements regarding coordination procedures at Level 3 that enable direct communication between civil and military air traffic service units, such as direct controller to controller voice communication,for the safety resolution of specific traffic situations.

2. PECULIARITIES OF AIR SHOW AIRSPACE DESIGN

There is a specific case of air show in which aircraft take-off from home base(s)/airport(s), transfer to the designated air show airspace, and return back to the base(s)/airport(s) of origin.

Planning for such specific type of air operations copes with the problems of: size and structure of required airspace, feeding and departing procedures and accurate arrival on the defined spot – the spectator position.

Typical for such operations aircraft perform either flying display in the defined portion of the reserved airspace or formation (or single ship) fly-by over the designated point.

The fly-by of participating aircraft is usually performed in sequence. Aircraft can be arranged in formations and sub-formations with same or similar airspeed. Spacing between succeeding fly-by formations and sub-formations, or between fly-by formations and flying display aircraft (or formation of aircraft) can vary. Spacing is determined at the predefined point, usually the position of (VIP) spectators.

Lateral boundaries and altitude of the reserved airspace for air show are defined in accordance with the participating aircraft requirements regarding type of the performed activity, total number of aircraft or formations and air show detailed schedule.

Initially, the position of spectators is defined and the spectator's field of view. Related to this position, flying display zone and the fly-by axis are defined. The size of the flying display zone is predetermined by the flying display program structure. If the direction of fly-by over the defined fly-by axis is not pre-defined the position of feeding base(s)/airport(s) is taken into considerations regarding the simplicity of feeding and exit procedures.

Figure 1 presents a generic structure of air show reserved airspace.

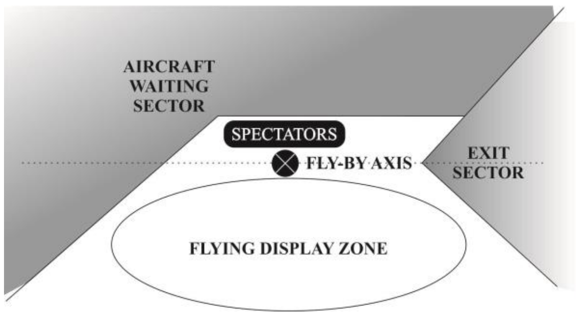

Figure 1 - Generic structure of air show reserved airspace, prepared by author

[3] TSA - Temporary segregated area - A defined volume of airspace normally under the jurisdiction of one aviation authority and temporarily segregated, by common agreement, for the exclusive use by another aviation authority and through which other traffic will not be allowed to transit [6].

On-scene commander controls the proper timing of airborne activitiesrelated to air showground activities. On-scene commander position has to be close to the spectator area in order to enable the exact insight of airborne and ground activities. On-scene commander’s clearances to enter flying display zone and commence flying display are issued in order to ensure exact timing and safe separations between sequenced aircraft/formation(s).

There are peculiar cases of aircraft or formations fly-by with close intervals between succeeding aircraft or formations. The interval is measured at the defined spot in front of the centre of spectator’s area.

If participating aircraft or formations maintain equal airspeed all aircraft are echeloned in a trailing formation.Spacing between aircraft or formations equals the required on-spot separation intervals. Participating aircraft or formations are placed in waiting sector and cleared to fly-by in such a manner whichprovides enough time to arrive on spot on time.

Sequencing of aircraft or formations that maintain different airspeeds deals with convergence and divergence problem described in [8]. All fly-by aircraft or formations have to settle on fly-by axis at the same altitude prior to arrival on the spot. In order to arrive on the spot in front of slower aircraft, due to required timing, faster aircraft would have to pass through the preceding, slower, aircraft. Therefore, slower aircraft are arranged in front of faster aircraft.

Aircraft waiting for fly-by clearance are arranged in holding patterns at prescribed altitude in order to enableprecise arrival on the spot. Preferably, flight time from holdingfix to the spot for each aircraft or formation should be the same. If that is not applicable, holdings are defined to ensure the spacing between succeeding aircraft or formations equal to the interval of on-spot arrivals of succeeding aircraft or formations. On-scene commander issues clearance to fly-by in advance in order to provide enough time for aircraft or formation in holding to arrange flight for precise arrival on the spot. The advance period is the sum of flight time from holding to the spot plus buffer time. The buffer time has to be sufficient for the manoeuver from the farthest position in holdingto the holding fix.

In order to prevent influence of low ceiling and to ensure separation between waiting aircraft, holdings are arranged in fishbone layout as figure 2 presents.

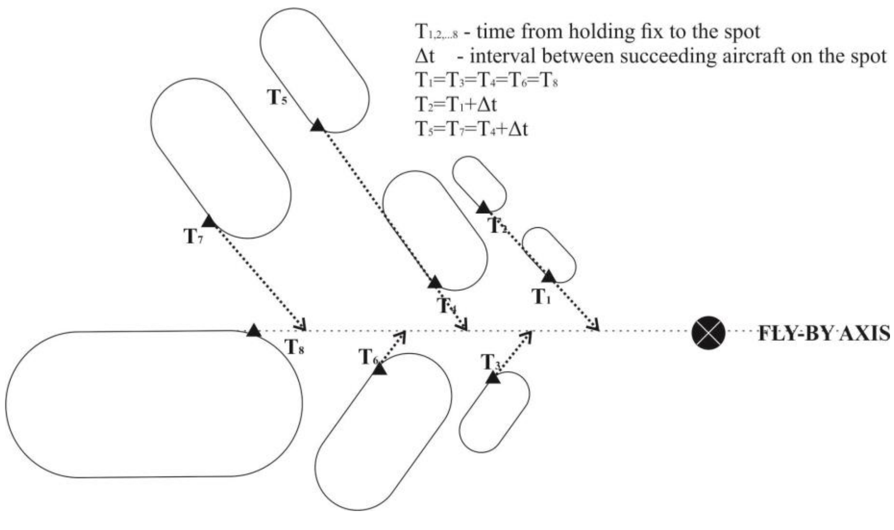

Figure 2 – Generic holdings fishbone layout, prepared by author

Visual contact between aircraft or formations, vertical separation between aircraft in adjacent holdings as well as vertical separation between aircraft in holdings and aircrafton fly-by axis have to be maintained.

Trajectories of departing aircraft have to be designed to provide separation between faster, overtaking aircraft, and slower aircraft. Airspace of certain dimensions has to be provided in order to enable manoeuvring of participating aircraft toward exit points.

Entry points for air show reserved airspace are positions at which takeover of aircraft control is performed. Entry points are determined by the sequencing of aircraft and the position of holdings. Entry points are not necessarily the nearest one to the home base. The same applies for exit points. Figure 3 presents the generic layout of arrivals and departures with entry points and exit points for previously constructed reserved airspace.

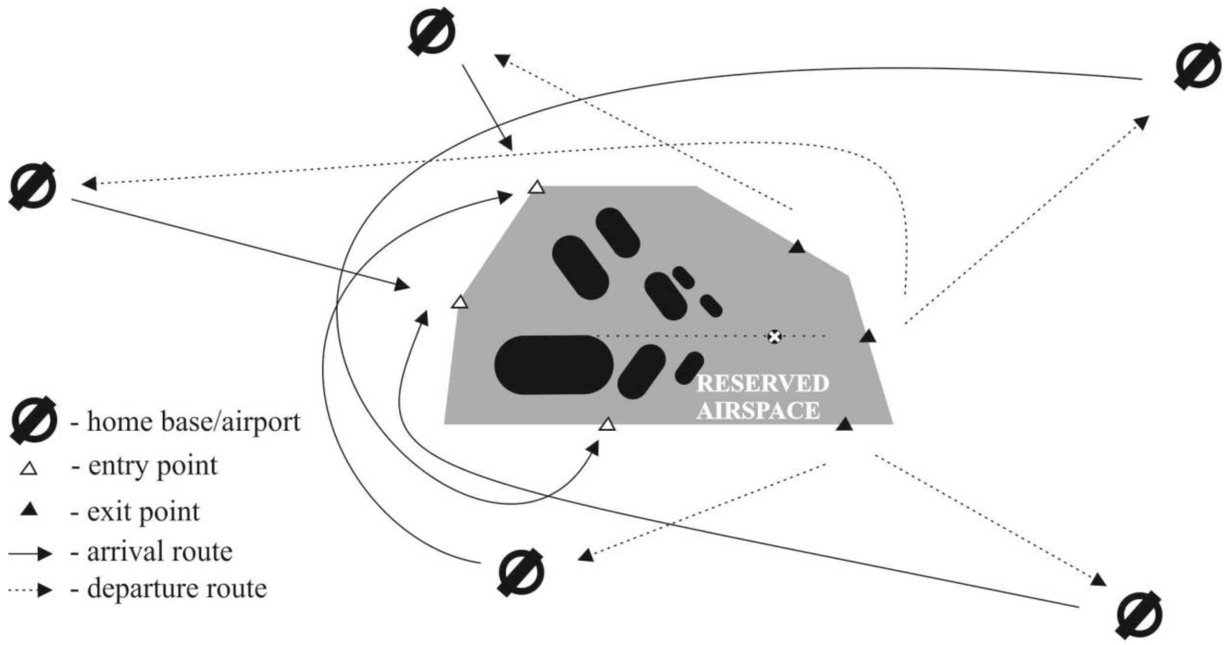

Figure 3 – Generic arrivals and departures layout, made by author

3. DESIGN OF AIR SHOW AIRSPACE INCLUDING AIRPORT

Air show reserved airspace that, due to operational requirements, includes an airport, represents specific problem and challenge for planners regarding control of participating aircraft as well as the commercial traffic. Figure 4 presents a generic example of airspace structure for the case.

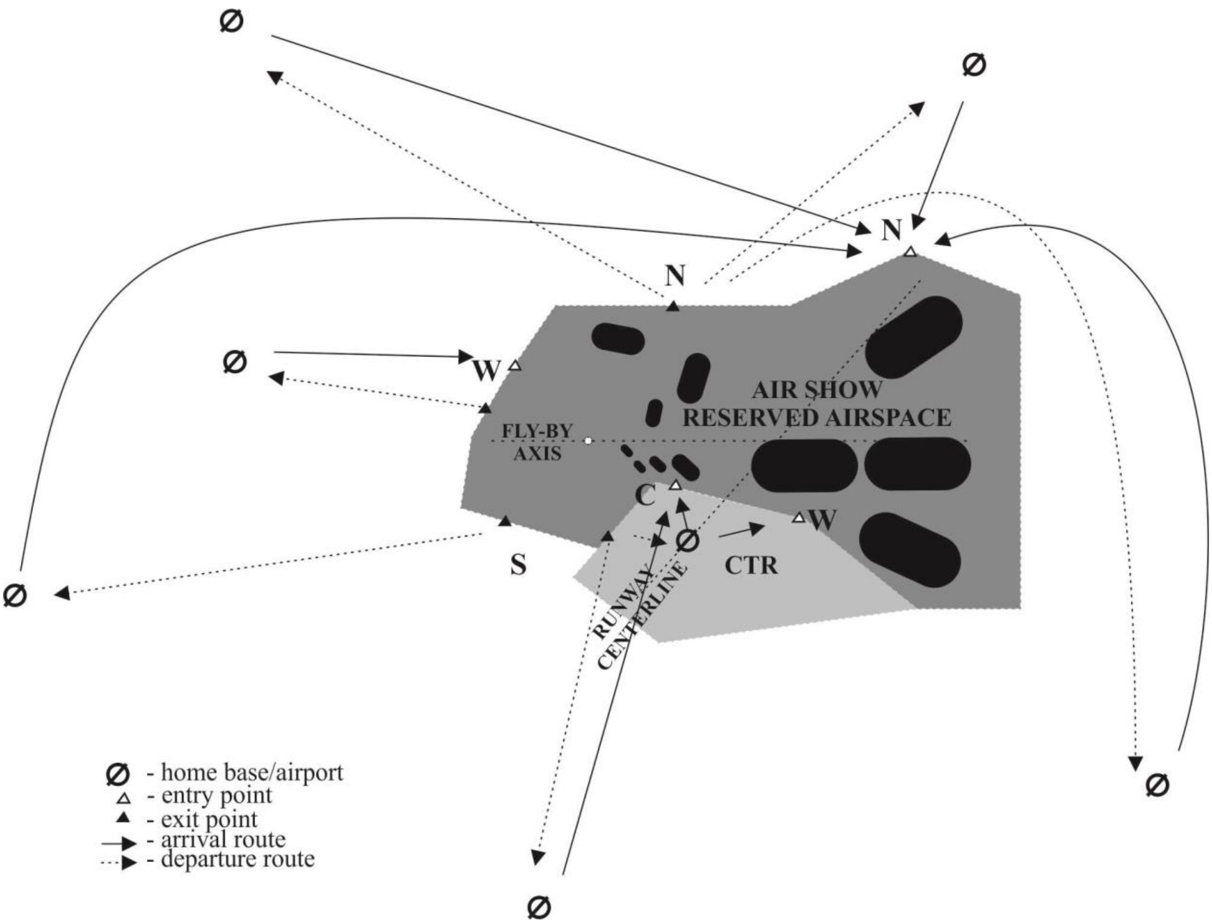

Figure 4 – Air show airspace containing airport, prepared by author

Position of the spot, fly-by axis and direction and holdings layoutcoupled with air show schedule compromise the runway. TSA is activated and the airport is unavailable for all non-participating traffic for the duration of the air show and rehearsals. Air traffic control tower unit is responsible for the airport traffic; approach control service for the arriving and departing air show aircraft; and on scene commander has the responsibility for the traffic inside the reserved airspace.

Although the non-participating traffic is not allowed to transit throughTSA the emergency aircraft with declared immediate landing has to be dealt with.Conflicting air show aircraft have to be removed to the safe distance in order to ensure safe landing procedure. Prerequisite for that is continuous two-way communication between air show on-scene commander and air traffic control unit that controls the emergency aircraft.

Specific requirements of airport operations have to be considered during air show airspace designing process in order to ensure flexibility of air show airspace use. Airspace required for approach and departure operations of commercial traffic have to be defined. Positions and dimensions of waiting zones for precise air show participants fly-by on the spot and remote waiting zones for conflicting aircraftneed to be defined. Timeline of overlapping of waiting zones and arrival/departure protected areas need to be developed.

Air show on-scene commander declares in advance the closure of arrival/departure airspace in accordance with air show schedule. Time from this declaration has to include buffer time in order to enable arrival/departure in progress and time needed for remote aircraft to reach the waiting zones.

Conflicting air show participating aircraft have to be cleared to remote holdings in case of aircraft in emergency. On-scene commander relays the information relating delays to the air show narrator.

Figure 5 presents a generic example of figure 4 reconstructed airspace structure.

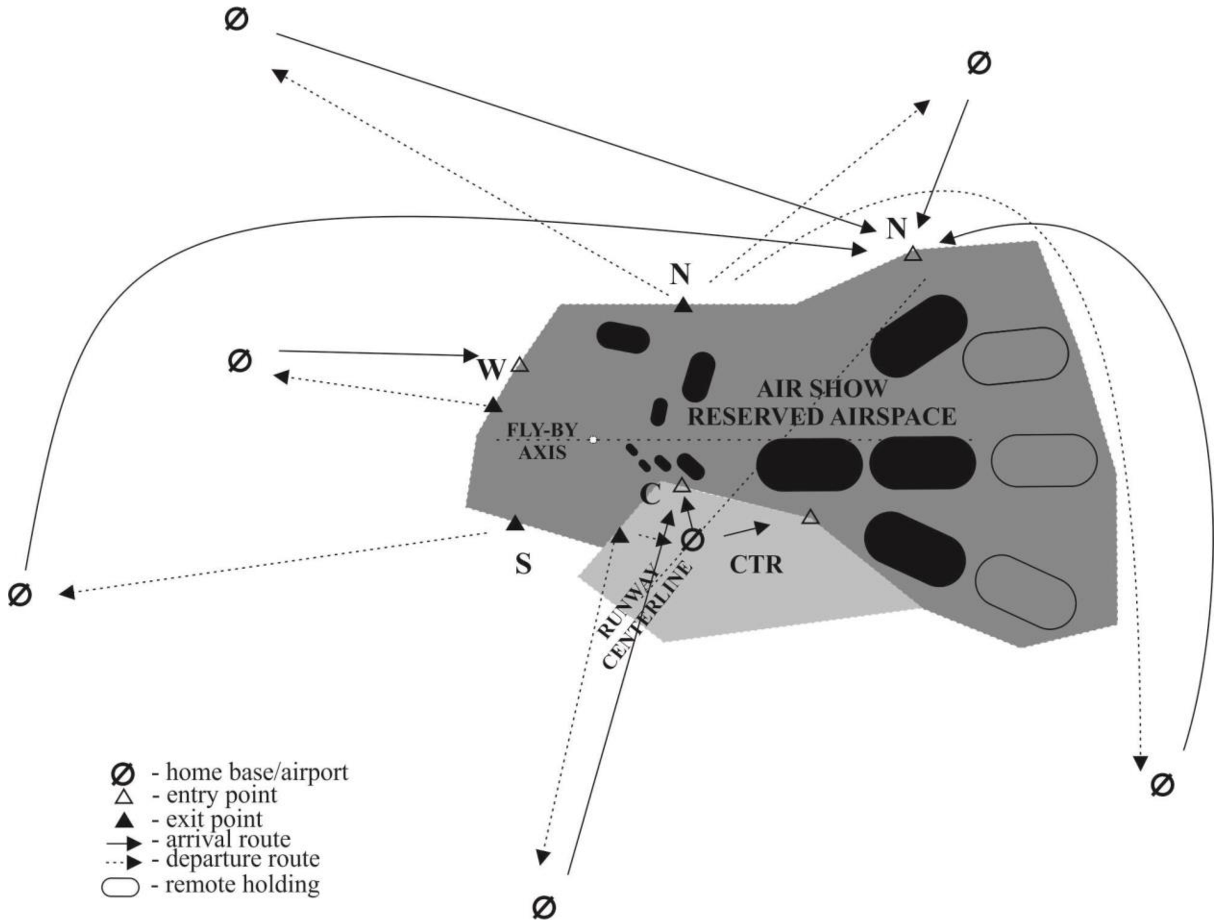

Figure 5 – Air show airspace containing airport reconstructed to enable flexibility ofairspace use, prepared by author

4. CONCLUSION

Planning of air show operations with synchronised sequenced fly-by of aircraft or formations is essentially demanding process for military planners. It requires a comprehensive approach in order to ensure conduct of operations with minimum interference of military and civil traffic.

Military air show planning process have to enable airport operationsuninfluenced by air show operationsas much as possible while ensuring undisturbed air show timeline.

Flexibility of airspace use is of great importance and mutual civil-military planning of airspaceuse for air shows can lead to minimisation of airport operations degradation.

Properly developed procedures and continuous two-way communication between on-scene commander and civil air traffic control service is the basis for successful air show planning.

This paper elaborates peculiarities of civil and military flying operations related to air show organisation in the vicinity of an airport and represents the guideline for further planning of such activities, not only for air operations planners but for air show organisation board also.

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TRAFFIC FLOW MANAGEMENT IN EMERGENCY SITUATIONS

ABSTRACT

Emergency situations are those that occur at the time or after an unplanned event. Unforeseen circumstances can cause various problems on the critical infrastructure in different economic fields, and they lead to an evacuation of the population. The activities in the case of a certain situation are regulated by legislative acts. Textbooks on operating procedures are published for operating forces. The implementation of protection and rescue measures, including victims' assistance, evacuation and rehabilitation, largely depends on the organization of traffic flows. Traffic flows are managed in a way that there exist as few points of conflict as possible. By analyzing the particularities in certain unforeseen circumstances and studying various models in the world, it was concluded that traffic management in crisis and emergency situations is significantly different from everyday management due to unforeseen circumstances.

KEY WORDS

unplanned event, traffic flow, traffic management, emergency situation, unforeseen circumstances, evacuation

1. INTRODUCTION

Emergency situations consider situations that are not often and common, and occur during or after a disaster. The probability of occurrence of emergency situation is small. In some cases they are also called crisis. Most often they are caused by natural disasters (such as floods, earthquakes, fires) or catastrophes (terrorist attacks, radiological accidents, leakage of toxic materials).

Emergency situations are stochastic in nature, which means that cannot be precisely predicted, or that do not have a regular form of appearance. It is therefore very important to know the terminology, legislation, regulations and the techniques and technologies related to this issue. The occurrence of unexpected situation not only affects the traffic, or particular traffic subsystem, but is most commonly associated with other activities. Therefore, the analysis of the road transport system in crisis without observing interdependence with other systems has very little significance.

The management of traffic flows is critical for efficient evacuation of endangered population. It can be done through the issuance of the notification of the responsible services in the media or the physical management of the roads. In the future application of ITS (Intelligent Transportation Systems) system and other forms of automated traffic control is expected . To manage traffic flows from a professional point of view it is important to know the theory and organization of traffic flows.

This article describes the legal framework for handling emergencies and peculiarities caused by some of the most common disasters. Models for managing such situations in the world are analyzed and the importance of the application of simulation tools in the development of evacuation plans is explained.

2. LEGISLATION IN THE REPUBLIC OF CROATIA

In the analysis of the management of road traffic flows in emergency situations is taken into account more specific regulations which may regulate the procedure in emergency situations, but also ways of planning the protection of them, rescue planning and risk assessment of certain areas. The aim of the legal regulation is good preparation which will, if possible, prevent greater consequences of an emergency or its formation, and also enable a planned and timely response to the situation. This means that the possible defects and damage must be remedied as soon as possible in order to regenerate the functions of the system or subsystem (eg. transport network).

The fundamental laws of the Republic of Croatia regulating and prescribing protection measures, actions, planning, etc. in connection with emergency situations are the Law on Protection from Natural Disasters and the Law on Critical Infrastructures. In addition to these laws, by 31 July 2015, in force was the Law on Protection and Rescue, which is replaced by the Law on the System of Civil Protection. The laws that are related to the traffic flows on the roads are Road Law and Law on Road Safety. In addition to the above laws, in activities related to the emergency situations, can be taken into account others, such as the Law on Transport of Dangerous Goods, Fire Protection Law, The Flammable Liquids and Gases Law, Law on Seismic Activities, Law on Radiological and Nuclear Safety and numerous ordinances, regulations and strategies.

The Law on the System of Civil Protection, adopted on 10 July 2015, prescribes a system of civil protection and measures and activities related to these in Croatia. The system of civil protection is organized at the local, regional and national level. It links the resources and abilities of participants, task forces and citizens in a single unit to reduce the risk of disaster, providing rapid and optimal response to threats and hazards occurrence and mitigate the effects of large accidents and disasters. According to this Law, the term evacuation means moving vulnerable people, animals and movable property from threatened areas or facilities.

3. ANALYSIS OF EMERGENCY MODEL MANAGEMENT IN THE WORLD

The world's understanding of the importance of the transport system in connection with emergency situations is at a very high level because the goal is to achieve more efficient evacuation. Major disasters that require moving large numbers of people from vulnerable to certain areas, are common. It is important to find the optimal model of managing existing transport infrastructure mainly because population growth is faster than the construction of new infrastructure. For areas where occurrence of natural or technical - technological disasters is likely, especially if they are large urban areas or highly populated areas, it is important that there is a regulated Emergency Management. Such situations are most often caused by earthquakes and floods, fires and other natural disasters. Accidents at nuclear facilities are not as frequent, but because of the scale of the consequences that can occur after an accident, they are at the very top when it comes to necessary planning of Emergency Management.

From understanding of the importance of connection between emergency and transport system, primarily for the purpose of evacuation, but also for the faster return to function if transport infrastructures is put out of operation, in the world often arise manuals for effective planning of evacuation, use of roads, management of specific extraordinary situation, etc. Various models are being developed for management according to empirical and statistical data.

The US Department of Transportation issued in 2006 and 2007, the document containing guidelines for effective planning of evacuation using a system of roads. This document is in accordance with the official state documents, and it was created as the result of numerous surveys and studies that followed the catastrophic incidents in which it was necessary to evacuate. The guidelines should help local and national authorities to use them as a tool in the execution of the evacuation. The guidelines have been set specifically for situations which preceded the notification (advance notice) and the situation arising without prior notice or with very limited notification (no-notice) when it is impossible to plan ahead. Potential causes of emergencies in which evacuations must be carried out are: earthquakes, floods, release of dangerous substances, hurricane, technological causes, terrorism, tornadoes, train derailments, tsunamis, and fires.

Advance notice evacuation refer to the four stages: readiness, activation, operational phase and return to a state of readiness. In no-notice evacuation stage of readiness is considerably reduced or missing, because the event has already taken place, while the advance notice evacuations just announced the possibility of a threatening event. Because the evacuation can refer to hundreds or hundreds of thousands of people the importance of improving the existing evacuation plans that takes place through the use of transport networks is understood. It is emphasized that all types of security incidents affect the transportation system, and sometimes the transport efficiency is more significant during recovery of the situation, but during the response to it [1].

With no-notice and advance notice situation, the emphasis is on several important activities, such as an evacuation plan and route planning evacuations, available resources, hierarchy of participants and the quality of communication between the organizers of the evacuation, the participants who will carrie it out and vulnerable citizens.

Figure 1. Stakeholders involved in evacuation
Source: [1]

As an example of the organization evacuation in Europe, an example of Bulgaria is explained. The impact of natural disasters on the transport system in Bulgaria is very large. As the biggest threat proved floods that occur due to the large amount of precipitation, snow melt and strong winds, which often overflow the dam and leads to the rupture of the embankment, and some floods are the result of the earthquake. Crisis management or emergency situations management is a set of activities performed by the competent authorities for the prevention of emergencies and development crisis. A National system for crisis management is developed. It provides assessment of disaster risk, maintenance analysis of preparedness for emergencies, information sharing, effective use of available resources and coordination of forces needed to respond to the situation. It is divided into central and regional levels and includes governing bodies, control centers, information - communication system and task forces for the response to the crisis.

4. NUCLEAR POWER PLANT ACCIDENTS

Accidents of nuclear power plants are undesirable events on plants that are experiencing ionizing radiation and its harmful effects on the environment and people. Although the nuclear accident can occur during processing, storage or transport of nuclear materials, the greatest danger is an accident on the power reactor. Due to the presence of large quantities of radioactive substances, the consequences of such accidents can be considerable and manifest in the wide area. Depending on the degree of danger, in the event of a nuclear accident, some areas have to be temporarily or permanently evacuated.

In Croatia, there is a National System of Preparedness in Case of Nuclear and Radiological Accidents and the principal actors involved are the National Centre 112, the Emergency Headquarters of the State Office for Radiological and Nuclear Safety, National Protection and Rescue Directorate and operational forces and special teams. For the management of the nuclear accident in charge is the National Protection and Rescue Directorate, which makes decisions on the application of safeguard measures, and organizes and supervises their implementation. Through the National Centre 112 a 24-hour exchange of information is carried out. Crisis Centre is leading supporting body in the event of a nuclear accident. The Centre must collect, process and distribute the necessary information, prepare the technical basis necessary for making decisions on protective measures, and promptly and accurately inform the public. The State Office for Radiological and Nuclear Safety operates the Croatian Early Warning System (CEWS). It consists of 33 measuring stations and the central unit for data collection and processing. It allows the alarm in case of high radioactivity in the environment and provides input data for assessment of doses for the population [2].

Due to the seriousness of the consequences of an accident in a nuclear power plant may have, it is extremely important that the implementation of evacuation is fully efficient and successful. The management of traffic flows is the key factor. Given that the level of human panic behavior will be at a high level as an aggravating circumstance, it is concluded that the evacuation would be more successful as more people know about the procedures that at some point need to be taken. A mitigating circumstance can be that traffic or road infrastructure remains largely intact (except for a greater explosion). In determining evacuation routes is considered the capacity of roads and transport hubs, the distance between major hubs, the number and type of vehicles that will carry out the evacuation, the critical point of merging in the main road, and so on. For each affected infrastructure and affected areas, there should be a plan for the evacuation for several possible scenarios and outcomes.

5. EVACUATION IN CASE OF EARTHQUAKE, FIRE AND FLOOD

Managing traffic flows in emergency situations is not based on one time data, but must adequately monitor condition changes during time. The input parameters can be partially predetermined (population, number of vehicles, the capacity of roads, etc.), but a lot of information is learned during the emergency (number of casualties, the infrastructure conditions, etc.), which means that their nature is not deterministic. ITS systems are used and will be increasingly used in management in such stochastic conditions. By further development they should show the real conditions on the roads to the management structure.

In emergency situations caused by earthquakes and floods occur significant and catastrophic damage to the traffic and other economic infrastructure. A direct consequence of the earthquake are ruins that interfere with the functionality of the system and cause human casualties. Floods cause damage by flooding of facilities and environment, in which also appear human victims. It is not excluded that the floods will cause ruins if the force of water is large enough.

Carrying out evacuation in an emergency situation caused by the flood mainly can be carried out before the incident, because in a case of monitoring the water level of rivers and rainfall such situations can be predicted. Embankment cracking or hydroelectric dam break is usually not predictable. After the flood occurs, it is certain that some roads could not be used, and boats and other suitable means of transport will be used for rescuing. If areas that could be affected by floods is identify in time, it is possible to provide the necessary transport corridors (e.g. construction solutions when planning the construction of roads, current construction of temporary dikes) in order to be functional for the rescuing and evacuation of the population.

An earthquake as the cause of an emergency is not predictable. Conditions on the infrastructure after the earthquake and flood are the main guidelines for the traffic flow management during the evacuation. Although it is necessary to execute the evacuation by prepared evacuation plan, the plan should be adjusted according to the situation in the field. In addition to managing the flows which are on evacuation routes, it is particularly important to maintain the routes used by rescuing forces and the emergency medical services viable. The evacuation plan must determine the main movement directions and places where people gather, critical points on the routes, evacuation areas and locations for the reception of people to evacuate. The vulnerability of the infrastructure during the earthquake in the cities is the result of inappropriate land use and improper construction (transport networks, urban installations). Residential areas and areas that are used continuously in time are the most vulnerable during the earthquake. The type of buildings and their mutual accommodation at the resort are also a criticality factor in case of an earthquake. The physical characteristics of the building (age, facade and construction materials, number of floors, construction type) are of a primary importance in determining the buildings sensitivity. Urban infrastructure such as transport networks has a significant effect in reducing the vulnerability of the city to the consequences of the earthquake. This is manifested in the ability of the transport network to meet the criterion of access to the most critical areas (residential buildings, schools, hospitals, etc.), which can be achieved by proper road hierarchy. Availability of roads is crucial for the effective operation of emergency services after the occurrence of the earthquake. The key routes which will remain functional after the earthquake should be identified while planning the rescue. It will be more functional if the structure of the access roads is simple and if they are short and direct. Also, the ratio of the width of roads in relation to its location in space (embankment, bridge, notch, etc.) is important. The higher the density of potentially affected area, the greater the likelihood of overloading roads, slowing down the transfer of population and extends the time of evacuation. Therefore, it is important for cities a correct and understandable physical division through the streets, neighborhoods, areas and settlements. Of critical importance is the existence of open space between the used grounds to reduce the interaction of the parts of affected infrastructure. Simplified, more compact area with many buildings is more critical of the separated but correctly formed urban areas with plenty of open space. An important factor is the direction of expansion of cities, i.e. whether the city is expanding more in height (vertical) or horizontally. Vertical expansion generally increases the sensitivity to the consequences of the earthquake [3].

Although fire accidents do not necessarily have catastrophic effects in road infrastructure, the fire is very destructive and can quickly reach a significant number of victims. Fire is specific in relation to earthquakes and floods. Its action is not instantaneous, such as the created by earthquake, but spreads depending on the weather conditions and the presence of flammable substances. Apart from the burning, the fire is detrimental because it causes large amounts of heat, gases and vapors generated from combustion. What is emphasized in emergency situations caused by fire is a phenomenon of panic or a moment of psychological paralysis when a person does not think logically, but it is lead by their instinctive reactions [4].

If the fire threatens an urban or other populated area, is rapidly expanding and is not under control, the competent service or person has to organize the evacuation. Because of the speed of propagation of fire and the possible consequences for the people, proper evacuation is crucial. Mitigating circumstance for roads is that they will not be destroyed during the fire, unlike during the floods and earthquakes where there is often damaged infrastructure throughout the city or its large parts. The fire service monitors important access roads for fire extinguishing. Firefighters by their tags or by people in the field manage traffic flows, i.e. they direct vehicles from the threatened zone and limit the range of movement.

6. APPLICATION OF SIMULATION TOOLS

The use of simulation tools in the planning and management of evacuation traffic flows is increasing. The use of such tools can greatly facilitate planning because through the representative model of the potential situation we can simulate real conditions and achieve a clearer understanding of the situation and thus more effective preparation. For this purpose, in the last few years, software for modeling traffic flows in emergency situations are being developed. Moving a large number of people, which occurs during the evacuation, requires significant planning. Simulation software are used as a tool in the decision making process when the affected population should be transferred to a safe area and are used to increase the effectiveness of evacuation. By using simulation tools and traffic situation modeling, the data on the efficiency of utilization of routes planned in the evacuation is received, the structural design of the road is evaluated, and travel time can be optimized according to given routes. Traffic simulation in emergency situations, but also in construction or conversion of infrastructure, is a useful tool for testing hypotheses and alternatives and evaluation of their strengths and weaknesses.

Software packages such as OREMS (Oak Ridge Evacuation Modeling System), DYNEV (Dynamic Network Evacuation) and ETIS (Evacuation Traffic Information System) are specialized for evacuation traffic flows modeling. They show the situation in detail and are suitable for mutual comparison. There are also software packages used for general purpose modeling of traffic, such as the CORSIM and VISSIM. Packages have some common characteristics, such as requesting route information, information about the evacuees, etc., but are also applicable to a particular situation individually [5].

According to [6] a model in PTV VISSIM of the simulation of population evacuation in case of accident at the nuclear power plant Sequoyah in the valley of Tennessee in the USA was developed. Several scenarios have been developed (traffic management control by the police, change of direction of traffic lanes) in order to select the optimal scenario. The results have shown that the pre-defined operative strategies in case of crisis increase the number of evacuated inhabitants. Also, greater efficiency of evacuation has been shown by the application of dynamic assignment of trips in VISSIM, than according to the existing urban evacuation plans. According to [6] McGhee and Grimes made in 2007 a simulation of evacuation of the inhabitants of the city of Hampton in case of the occurrence of hurricane of different levels of intensity. VISSIM is used for the evaluation of traffic management at entry and exit ramps of the highways, redirected traffic lanes, etc. The results of studies have shown that in case of high traffic loads only the traffic management at entry/exit road ramps can ensure the evacuation of vehicles at acceptable speeds. At the end of 2012, a detailed plan of evacuation of the city of Plymouth was developed (93,000 inhabitants) in the USA in the zone of the nuclear power plant Pilgrim [7]. By applying the simulation model an expected evacuation encompassed 90% of inhabitants of the zone of up to 9 km from the nuclear power plant in the duration of two to three and a half hours depending on the weather conditions and time of day.

Software used for modeling traffic during evacuation serve three basic purposes: analysis of prior planning (pre-planning analysis), the real-time operational procedures (real-time operation) and procedure analysis after the planned procedures (post-planning procedures). Analysis of prior planning is most often used for modelling traffic in emergency situations. The resulting information is used to determine the routes that minimize the total time of the evacuation and to develop strategies for the dissemination of information to the affected population concerning acts in evacuation procedures. Real-time simulation models can be continuously updated by using automated systems for detecting real data on roads. By this procedure the real status reports on each evacuation route are received. Analysis of the performed procedures by simulation model is used for evaluating the success of the evacuation, and a model created based on the collected data is very useful and effective in the future planning of the intervention [5].

Evacuation traffic models that have been developed are largely based on the conventional model of trip demand made of four steps. The model analysis includes routing, routes distribution, modes separation and purpose of travel. Evacuation traffic models have three basic input data: route information (direction), information about the affected population and other external information. Information about the direction is the roadway geometry, analysis zones, public transport schedule and the compliance of time of passing through the intersection. Information about the people that are in the affected area includes the number of people, number of vehicles per household and preferably destinations. Time of day and weather conditions are outside information. Programs for traffic modelling are being developed in order that the simulation could calculate as many different incidents and emergencies. Also, it is wanted to improve the possibility of including the various forms of human behavior to the software (unusual behavior, panic, the impact of mobile phones or other devices on the driver and the passenger impact on the driver, etc.). Increasing the accuracy of the simulated traffic situations data is expected, which can be used in planning and executing a successful evacuation by road traffic. Implementation of real-time information via ITS detectors is already used in developed urban areas, but it needs to be extended to roads that pass unpopulated or rural areas. Data collected this way lead to dynamic modeling, which provides better insight into human behavior and so enhance the effect of all tasks mentioned above and benefits of traffic flows modeling [5].

The simulation can be carried out at several levels, depending on the level of detail display of traffic flow and are thus defined by a microscopic, mesoscopic and macroscopic model. Macroscopic simulation analyzes the flow of traffic on the network links. The result of a large area with high demands on the transportation system is quickly available. Microscopic simulation is stochastic (appear random) and dynamic (changeable in the analyzed period) model of individual vehicles in different systems of transport networks. Each vehicle is moving through the network in a given period of time, depending on its technical characteristics (length, maximum acceleration, etc.), the basic laws of motion and the rules of driver behavior. Simulation of vehicle movement is carried out in series of predefined time steps, and at the end of each time step, the position, velocity and acceleration / deceleration of the vehicle is recorded. The output results of microsimulation are animation and numerical data. Animation 2D or 3D display shows the movement of individual vehicles through the transport network in simulation time. Numerical data can be viewed for each vehicle in detail or as an average data of the entire network or any part thereof [8].

As part of the project funded by the European Union: "Preparedness for evacuation in case of a nuclear accident" with participation of the district of Krško, city of Zagreb and city of Cernavoda in Romania in one of the measures it was necessary to present the simulation of evacuating the inhabitants from the district of Krško. The Jankomir node at the entrance into the city of Zagreb was selected as the demonstration example. The micro-simulation presentation of the Jankomir node has been made by means of the software tools PTV VISSIM 5.40 – 08. in three different scenarios of traffic flow regulation. Since the software tools cannot simulate the driver behaviour in cases of panic the aggressiveness of the drivers was increased by using the Wiedemann 74 model in order to present as realistically as possible the evacuation situation. The number of evacuated vehicles has been determined in the simulation under the constant peak traffic load which exceeds the node capacity in order to be able to analyse the vehicle flow and driver behaviour during lane-changing and weaving into flows.

For each scenario the time of evacuation through the Jankomir node has been analysed, as well as the number of evacuated vehicles in half-hour intervals. Also the travelling times through the node and the average delay time have been determined [8].

Figure 2. Evacuation simulation through node Jankomir

7. IMPROVEMENT PROPOSALS

Traffic flow management can be defined as informing road users about the goals of movement. At the direction of traffic flow, or the decisions of road users in the selection of a specific itinerary, affect transport network regulation (one-way streets), prohibitions, traffic sign information and experience of road users. Traffic flow management should stream to reduce the number of conflict points (reducing the number of unnecessary overtaking). Reducing the conflict relationship between traffic flows is a guiding thought in the organization of transport in general. This leads to the conclusion that during emergency, mutual negative impacts of traffic flows are even more pronounced given the circumstances (state of infrastructure, the occurrence of panic behavior, communication errors).

Information resources particularly important for managing traffic flows are: informative traffic signs, or visual and other information that the driver or road user immediately receives from the environment and which may affect on driver's decision for choosing its path to the destination.The preceding information, as well as education are also extremely important to select the path of the driver [9].

In order to achieve success in the conduction of evacuation is necessary to provide professional and quality staff to develop a plan of evacuation. Also, we should act on the population through education and other forms of information, so that it was ready to react in case of need for evacuation. Although the management of traffic flows in emergency situations is of a temporary nature, it is based on the same principles as the organization of transport in normal circumstances. The opinions of the profession is therefore be taken into account when managing traffic flows on roads in emergency situations, especially if carried out the evacuation of vulnerable populations. Most of the institutions and the legislative and executive bodies understand the important role of transport in emergency situations, but through legislation, manuals and instructions it is not enough emphasized nor explained. Evacuation plans for specific areas or cities should be clearer and more accessible to all residents. In addition to regular monitoring of the population movement and the state of infrastructure, infrastructure maintenance, monitoring changes in the number of personal vehicles and vehicles available for bulk evacuation, the management of the traffic flows in an emergency will be more effective and easier to implement. In doing so can certainly help implementation of ITS systems, especially in major urban areas.

World models show smart approach to building measures for protection and rescue as well as in the preparation of evacuation plans. The appearance of some disaster or emergency often triggers research or studies. With this approach, the real data is given and results are from first hand. With conduction of analyzes, surveys, observations, and other research methods, we recognize the errors in previous systems management organization in crisis and emergency situations. The conclusions of the studies can be easily compared with the findings from other countries and realize where there is room for improvement and whose practice is better. In addition, using such research and studies, future plans for protection and rescue will be based on practical, not just theoretical data. Many useful information can be generated from computer simulations, but data from the situation that actually occurred are the most valuable assistance for improving existing practices.

Croatia has a very wide network of roads and developed road traffic in general, far more advanced than some other transport modes. This speaks to a fact that a potential evacuations should be successful, especially with the proper organization of traffic flows. It is important to determine the proper hierarchy of roads and interchanges, according to their capacity, nearness of potentially affected areas, technical - architectural features, etc.

The advantage of the development of mobile and computer technology should be taken in the account and with variety of media people can promptly and massively be informed. In addition to information on the procedures in an emergency situation, the media should serve for educational information and to raise awareness of all citizens in connection with potential disasters, incidental events and emergency situations.

8. CONCLUSION

The management of traffic flows on roads in emergency situations is a complex activity that depends on statistical data and variable data in real time. Characteristics of the accident that caused an extraordinary situation adapts to the way of managing traffic flow. Routes during evacuation depend on the state of critical infrastructure, the position of evacuation location, number and structure of the population, the number of personal vehicles and public transport, the position of the main roads, and more. Methods and ways of managing the flow should be decided by a peopele familiar with the basics of the theory and organization of traffic flows and the particularities of potential emergencies and situations.

The analysis of studies about the connection of natural and other disasters with traffic show that transport infrastructure is part of the critical infrastructure because when some emergency occurs always a greater or lesser part of the effect are presented at transport infrastructure. These effects can only be an increase in traffic density and congestion of traffic flow or physical damage to roads and other infrastructure. Roads and other facilities is important to regularly maintain, and in the construction to apply seismic, fire and other standards. This increases the reliability and availability of the infrastructure in the event of a phenomenon that causes an extraordinary situation. In the case of reliable roads, traffic flows can be well planned in advance.

In Croatia, there is space for improvement action in emergency situations, including the development of evacuation plans and organization of traffic flows. Although legislation is extensive, citizens are relatively poorly educated about potential emergencies and of their responsibilities in case of an emergency situation. Through analysis and scientific study of past accidents, effective actions to potential future emergency situations can be planned.

The use of simulation tools in the organization of traffic flows is significantly increased. The value of modelling flows on road traffic during the design of the rescue and evacuation plans is recognized.

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CUSTOMIZING RISK ASSESSMENT FOR OPERATION IN CHALLENGING ENVIRONMENT

ABSTRACT

Safety management systems (SMS) are being implemented globally by stakeholders in the aviation industry. Safety risk management, which includes identification of hazards, assessment of risk and the mitigation of risk, forms a core element of the SMS. Many service providers that are required to implement a SMS use standard risk assessment processes without first establishing if it is most effective for their organization and customising it to meet their objectives. This paper discusses the need for development of a customized risk assessment process that reflects an organizations appetite for risk. A detailed risk assessment process is also developed for humanitarian operations and practically applied to determine the high risk concerns that that enables a mature decision making process to determine controls for mitigating the risk.

KEY WORDS

Risk; Safety Risk Management; Risk Assessment; Risk Matrix; Humanitarian Air Operations

1. INTRODUCTION

The aviation industry comprises of a wide range of service providers that are required to implement a safety management system which, at the least, is required to identify hazards, assess the associated risks and implement remedial actions to maintain an acceptable level of safety.

There are several instances when service providers are faced with challenging situations in which they have to accept relatively higher risk to carry out an operation. For example, even though there is a higher risk of operation into 'stolports'[1] and 'altiports'[2], whose standards are not precisely defined by ICAO, these airports are created because their benefits outweigh the risk of operating at these locations and their infrastructure is developed to support as safe and effective a public air transport as possible under the circumstances. This offers social and economic advantages in areas constrained by limited space or restricted terrain.

[1] ICAO defines stolports as "unique airports designed to serve airplanes that have exceptional short-field performance capabilities".

[2] An altiport is a small airport in a mountainous area with a steep gradient runway, used for landing up the slope and for take-off down the slope, thereby making use of only one approach/departure area.

Similarly, air operations conducted during emergency and rescue missions in wars and natural calamities are carried out with relatively higher risks but offer the all-important benefit of saving lives of individuals affected by such emergencies.

From the examples above, we understand that the ‘amount’ of risk that is tolerable in different organizations is unique and closely tied to its objectives. The standards and guidance included in the Safety Management Manual (SMM) (ICAO Doc 9859 2013) provide the foundation for the notion of Acceptable Level of Safety (ALoS) and continuous improvement. According to the SMM the criteria for ALoS “may vary depending on the specific context” (ICAO Doc 9859 2013: 4-12). For this reason, each organization must first establish clear guidelines on how it determines the amount of risk that is acceptable to them.

This paper discussed the development of a customized risk assessment process that can be implemented in high risk environment such as the operation carried out by the United Nations Humanitarian Air Service (UNHAS).

2. RISK CALCULATION

2.1 Probability and severity

ICAO defines safety risk as “the predicted likelihood and severity of the consequences or outcomes of a hazard.” This definition in itself forms the foundation of the risk assessment process outlined in the SMM. There are two important elements to this definition:

1. Risk is only a “prediction”, therefore, it is a highly subjective term and organization must develop proper guidance to standardize its use.
2. Risk is a combination of likelihood and severity of an occurrence. This combination can be done in many ways to determine a value that best represents the risk.

The calculation of ‘risk value’ is based on the worst foreseeable consequence of a hazard. It is important to account for this because one hazard can to lead to several occurrences and the outcome may be different each time. For example, a hazard report involving a ‘near air miss’ when two airborne aircraft miss colliding with each other may be classified as a significant occurrence, but the worst foreseeable consequence of this hazard could well be an accident if the crew are unable to take the right actions to avoid a mid-air collision.

The process developed by ICAO is in the form of an alphanumeric risk assessment matrix (Figure 1). This matrix allows the determination of a risk value that represents the risk. The alphanumeric values can often be confusing but nevertheless this matrix is widely used to estimate the risk.

Risk probability		Risk severity				
		Catastrophic A	Hazardous B	Major C	Minor D	Negligible E
Frequent	5	5A	5B	5C	5D	5E
Occasional	4	4A	4B	4C	4D	4E
Remote	3	3A	3B	3C	3D	3E
Improbable	2	2A	2B	2C	2D	2E
Extremely improbable	1	1A	1B	1C	1D	1E

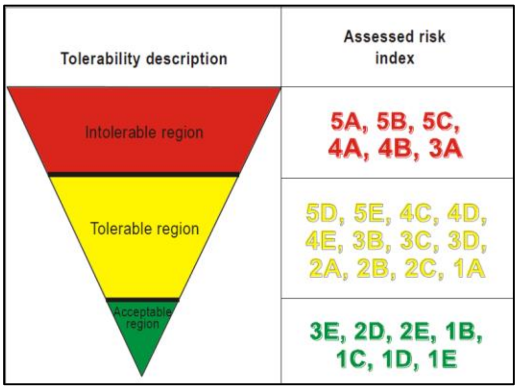

Figure 1 - Risk assessment matrix in Safety Management Manual: [4]

To simplify the estimation of the risk, UNHAS uses a similar risk assessment matrix using numerical values only (Figure 2). It denotes a linear risk value ranging from 1 t0 25 (1 being the lowest and 25 being the highest risk) as a product of severity and likelihood (probability). Though it is easier to comprehend risk using a linear scale, it can be argued that this process makes no distinction between the values used for severity and probability as indicated in Figure 2. This is a limitation because the outcome of severity is far more significant than probability.

SEVERITY		LIKELIHOOD				
		FREQUENT	OCCASIONAL	REMOTE	IMPROBABLE	EXTREMELY IMPROBABLE
	VALUES	5	4	3	2	1
CATASTROPHIC	5	25	20	15	10	5
HAZARDOUS	4	20	16	12	8	4
MAJOR	3	15	12	9	6	4
MINOR	2	10	8	6	4	2
NEGLIGABLE	1	5	4	3	2	1

Figure 2 - Risk assessment matrix in ASM: [8]

2.2 Defences

A two dimensional risk assessment process as shown above fails to account for the key element of 'defences' that have been developed by the aviation industry over many decades. It is a mature industry that has built several layers of defences to prevent accidents and serious incidents. It is vital to carry out an analysis of the existing defences and evaluate their effectiveness before concluding the risk value of any given hazard.

To explain using an example, even though the risk of Controlled Flight Into Terrain (CFIT)[3] is 'unacceptable' in humanitarian air operations, there are already several defences in place. These include performance of flights in day visual conditions only, establishing minimum safe altitudes for each route, the operation of twin engine aircraft with consideration for single engine ceiling and installation of Class A Terrain Awareness and Warning system (TAWS). All these defences are quite effective and hence make the risk of CFIT in humanitarian operations quite low.

It is therefore important to factor all the existing defences before determining the final risk value of a hazard.

3. RISK GUIDANCE

The objectives of UNHAS obliges the organization to provide humanitarian assistance wherever it is needed or requested. Many of these operations are carried out during emergencies and therefore leave no choice but to engage in air operations that have a generally high risk.

The organization must therefore find ways in which it can maintain an acceptable level of safety performance (ALoSP). The key term here is 'acceptable'. Since UNHAS management accepts a much higher risk when compared to other commercial air operations around the

[3] This refers to an inflight collision or near collision with terrain, water, or obstacle without indication of loss of control

world, it needs to go beyond conventional methods to understand and manage the risk in the air operation.

In line with its objectives, the risk assessment guidance was developed to identify those hazards that pose the greatest danger to fatally or seriously injure any occupant travelling in UNHAS contracted aircraft. The damage to aircraft and property is important but is a secondary consideration because these are adequately covered through insurance.

The below risk assessment process was tested using a trial and error method over a six month period (March to September 2014) utilising data from the UNHAS hazard database. The main elements used in the development of this process are:

- Severity of the consequence of a hazard
- Probability that an occurrence will happen
- Effectiveness of existing defences to reduce the risk

The trial and error method involved testing various numerical values for these three elements in a formula that was developed to calculate the 'risk value'. Fixed values were assigned with designated descriptions that best represent the risk in humanitarian operations. According to the description, a value for each element is chosen and used in the formula to derive the 'risk value'. The values and descriptions are given below:

Severity	Value (*S*)	Description of Severity of Occurrence
Catastrophic	25	Accident where most passengers are likely to be fatally injured
Major	20	Accident where passengers are likely to get injured and some fatally
Significant	15	Degradation of safety margins where passengers and/or external people are likely to get injured
Minor	10	Limited consequences causing slight injury to passengers and/or external people
Negligible	5	No injuries

Probability	Value (*P*)	Description of Probability of Occurrence	Approx rate of occurrences per 100,000 Hours
Certain	4	It is certain that the aircraft will be exposed to the hazard as there are no defences in place	100
Frequent	3	There will be several occurrences due to the hazard	50
Likely	2.5	There may be occurrences due to the hazard	10
Possible	2	Isolated occurrences may happen	1
Exceptional	1.5	Rare occurrences known to occur in similar operations	0.1

Effectiveness of Defence	Value (*D*)	Description of Effectiveness of Defence
Missing	0%	no defence in place
Weak	10%	may work some of the time but needs improvement
Likely	25%	likely that defence can work but needs improvement
Assured	50%	effective most of the time
Certain	100%	hazard has been removed

Using the above values, a final risk value ranging from 0-100 is deduced using a simple formula. This formula is based on the relationship that the risk value R is equal to a product of the severity S and probability P. Since this paper incorporates the third factor i.e. existing defences, the probability is reduced based on the effectiveness of the defence D. Therefore the risk value,

$$R = S \times [P - (P \times D)] \quad (1)$$

Applying this formula to a practical scenario in humanitarian operations, the calculation of the risk value for ‘runway incursion by wildlife’ is explained below.

The example considers an unfenced aerodrome located close to a settlement with a focal point on ground who is responsible for ensuring that the runway is clear before an aircraft arrives.

Severity: There is likelihood of an accident where passengers are likely to get injured and some fatally due to incursion by large domestic animals such as cattle, donkeys, camels etc. i.e. Major (S = 2o).

Probability: There will be several occurrences due to the hazard based on historical information for similar aerodromes and the fact that the runway is unfenced and located close to a settlement i.e. Frequent ($P = 3$)

Effectiveness of defence: May work some of the time but needs improvement since a focal point cannot always ensure that the entire runway is clear of wildlife at the time of landing i.e. Weak ($D = 10\%$)

Therefore, the risk value

$R = 20 \times [3 - (3 \times 10/100)]$, so

$R = 54$

The risk value obtained can then be assessed using the customized risk tolerability matrix in Figure 3 for decision making and acceptance of the risk. It indicates four levels of risk ranging from:

- 0-24 Low risk
- 25-49 Medium risk
- 50-74 High risk
- 75-100 Extremely high risk

Severity		**Probability**				
		Certain 4	Frequent 3	likely 2.5	Possible 2	Exceptional 1.5
Catastrophic	25	100	75	63	50	38
Major	20	80	60	50	40	30
Significant	15	60	45	38	30	23
Minor	10	40	30	25	20	15
Negligible	5	20	15	13	10	8

Figure 3 - Risk Matrix [Authors]

The formula assumes that the defences always reduce the probability of an occurrence. Though this is true in majority of the cases, in rare instances a defence may also reduce the severity of an occurrence. In this case, it is important to reduce the severity value of the occurrence when calculating the risk value. For example, the severity of runway excursion on a gravel runway with a ditch running along the side of the runway is ‘catastrophic’ ($S = 25$), however, if the ditch is levelled, the probability of the runway excursion still remains the same, but the severity is reduced to ‘significant’ ($S = 15$). Hence, the levelling of the ditch is a defence that reduces the severity and not the probability of the occurrence.

4. APPLICATION OF RISK ASSESSMENT

UNHAS has a comprehensive database of occurrence and hazard information containing over 20,000 reports recorded from 2004 to date.

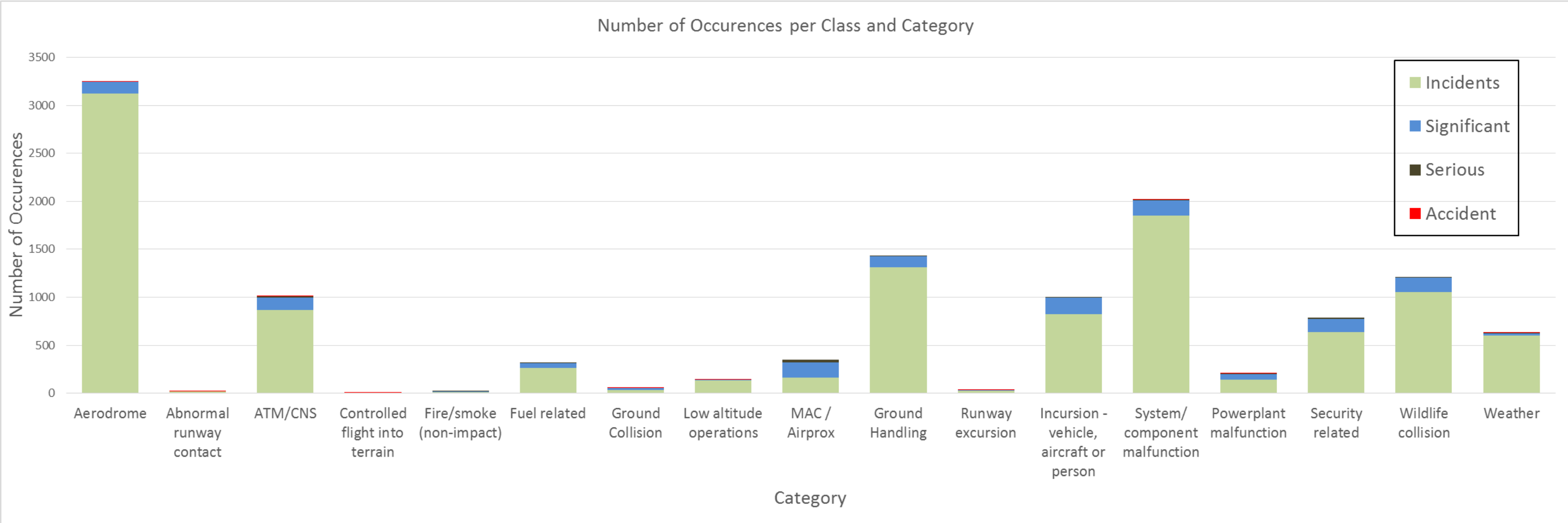

Figure 4 - Total number of WFP occurrences per category of events [Authors]

The graph in Figure 4 shows the most prominent category of occurrence reports in the database. It includes the number of occurrences which are further broken down into different categories and classes. It does not include all the categories used in the database to avoid cluttering the report with categories that do not represent a high risk. The graph shows that aerodromes, aircraft system/component malfunctions, wildlife collision, ground handling, Air Traffic Management (ATM), runway incursions by vehicles, aircraft, and people are the most reported occurrences in UNHAS operations in that order.

The risk assessment process described in this paper was applied to this database to identify those high risk hazards that have the greatest potential to lead to serious incidents and accidents. The analysis revealed the main categories of hazards that represented the highest risk in humanitarian air operations. These high risk categories are put into two groups that are deemed to be broadly similar. The Mid-Air Collision (MAC) and Air Traffic Management (ATM) related categories form the first group and all other categories come under the second group, aerodrome safety standards. These are further explained below.

5. NEAR MID-AIR COLLISION

MAC and ATM represent the high risk hazards that have the potential of causing inflight collisions with other aircraft. The primary reasons that this category is a serious concern for areas in which humanitarian operations are carried out include:

- Poorly designed airspace structure
- Unqualified air traffic controllers
- A combination of military and civilian operations
- Operation of Drones and Unmanned Air Vehicles (UAV)
- English language proficiency of Russian and Eastern European flight crews
- Aircraft not installed with transponders or transponders that are intentionally switched off

Even though the threat of Mid-Air Collisions is one of the main safety concern in areas where humanitarian flights are conducted, there are already some controls in place such as the mandatory requirement for a functional Aircraft Collision Avoidance System (ACAS II) on every flight. This is especially enforced in high risk countries such as Afghanistan, Sudan and Somalia which have weak air traffic management.

6. AERODROME SAFETY STANDARDS

The high risk categories of reports that are either directly or indirectly linked to the lack of standards for operations in unlicensed aerodromes are abnormal runway contact, runway excursion, runway incursion by vehicles, aircraft, people and wildlife and security related events. There are several occurrences in these categories primarily due to the poor conditions in unlicensed aerodromes used for humanitarian operations.

The state in which an air operation is carried out is normally responsible only for certified aerodromes in the country. However, the state assumes no responsibility for 'unlicensed' aerodromes and it is therefore eventually up to the operator to assume the final responsibility for carrying out safe operations in such aerodromes.

The operators therefore develop their own procedures, which are approved by the state of the operator, to ensure safe operation in these aerodromes. With no clear standards and guidance available for operations in remote locations, most operators develop basic standards which do not restrict them from carrying out operations and rely primarily on the decisions of experienced pilots to ensure the safety of operation.

7. CONCLUSION

A robust risk assessment process forms the foundation for an effective risk management system. Organizations must first have a clear understanding of risk, and standardize its assessment in a way that is useful and relevant to the organization. The process needs to clearly identify those hazards that have the potential to lead to serious incidents or accidents. The identification and addressing of these high risk hazards forms the key to preventing accidents.

The customization of the risk assessment process is essential since the appetite for risk is unique in each organization and based on its objectives. The process for developing a customized risk assessment process that is described in this paper should be followed by each organization to develop a practical tool that clearly identify high risk hazards.

The risk assessment tool developed for humanitarian air operations was practically implemented to identify the main high risk hazards in the operation. This forms the foundation that allows a mature decision making process to determine controls for mitigating the risk.

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DEPLOYMENT STRATEGIES OF FTTH TECHNOLOGY IN THE SERBIAN BROADBAND MARKET BASED ON PRICE AND MARKETING IMPACTS

ABSTRACT

This paper investigates the potential strategies of Fibre-To-The-Home (FTTH) technology deployment in the Serbian broadband market by considering the price reduction and marketing efforts. Based on the performed analysis FTTH providers are able to select the best investment plan, suitable pricing strategy and accordingly to obtain a more realistic forecasting of FTTH deployment dynamic. The forecasting is performed using the generalized Bass diffusion model. Furthermore, this paper examines the economic interactions between FTTH providers with different deployment strategies. The best pricing strategy is obtained using the Nash equilibrium concept in order to optimize the provider's profit by adjusting the service price. Throughout the numerical example, the proposed model is tested in the case of the Serbian market with two FTTH competitive providers.

KEY WORDS

broadband market, deployment strategies; diffusion model; forecasting; fibre-to-the-home; Nash equilibrium, pricing strategy.

1. INTRODUCTION

Long-term broadband demand forecasts have been crucial for marketing as well as investment decisions and dimensioning of broadband networks in recent years. Network providers around the world are looking to Next Generation Network (NGN) services to remain competitive in a radically changing telecommunications environment. Recently, the growth of FTTH has become particularly significant [1]. Different competitive technology options are available to providers for their FTTH network deployment strategy decisions such as Gigabit-Passive Optical Network (GPON), Ethernet Passive Optical Network (EPON) or Active Ethernet (AE). When choosing the specific technology aprovider should consider several technical, economic and business parameters such as type of services to be delivered, cost of the infrastructure, current infrastructure and future plans for migrating to new technologies. A provider takes the risk of picking an incorrect technology if any of these key parameters are not identified and cost optimized [2]. Additionally, being able to predict the market acceptance before taking the business risk is of critical importance. With the aim of adequately planning required network resources, it is necessary to forecast traffic demands that are in direct correlation to the forecasted number of users.

In this paper, we applied the Generalized Bass Model (GBM) [3] for FTTH forecasting as a new broadband technology. GBM is based on diffusion theory, which takes into account advertising investment and effects of different prices [4]. Here, we analyzed several possible FTTH deployment strategies. Using GBM it is possible to choose the best one according to invested resources. For the selection of one among various deployment strategies, it is necessary that a provider considers its sustainability and profitability in a competitive environment. It is shown that the optimal evolution of advertising investment after launch is highly dependent on the initial level of advertising.

In addition, we propose here the competitive model with new demand function based on providers' marketing efforts and service price. We have analysed the economic interactions of two providers offering FTTH service which we defined as a simultaneous-play game. With increasing competition in telecommunication markets, providers will attempt to achieve better market position. By means of pricing strategy, an efficient provider strives not only to maximize its profit but also to attract and/or retain the most gainful users by offering lower prices with end-to-end Quality of Service (QoS) guarantees. The proposed model determines Nash equilibrium prices for two competitive FTTH providers at the Serbian broadband market with different marketing investments and pricing strategy during time. The main innovation of the presented approach is that it combines forecasting model for new broadband technology and game theory application for the best pricing strategy selection.

The paper is organized in the following way. The second section explains GBM diffusion model that we used to forecast the broadband demand. After that in the third section, we present the forecasted results for FTTH demand at the Serbian market. In fourth section, the competitive model with new demand function based on marketing and service price parameters is given. Then, the numerical results including Nash equilibrium prices for two competitive FTTH providers are analyzed. Finally, the contributions of this paper are summarized in the last section.

2. LITERATURE REVIEW

Diffusion theory had been often used to forecast the demand of new service/technology. Understanding the diffusion process of an innovation such as a new technology has been an important research area in marketing. The most important model in this stream of research is the Bass model [5], [6]. Bass diffusion model describes the empirical adoption curve by using two important factors: innovation and imitation parameters. Diffusion of an innovation has been defined as the process by which that innovation is communicated through certain channels over time among the members of a social system. Many researchers have tried to propose extended versions of the Bass model [5]-[8]. A natural extension of the basic Bass model is to incorporate marketing or economic variables. An extensive discussion has gone on as to whether they potentially affect the market potential or diffusion parameters. A priori, for more expensive services one would expect both effects. An example of such a study incorporating the effects of advertising on telephone services is given by Simon and Sebastian who examined the adoption of PSTN in Germany and the effects of advertising on the various diffusion parameters [9]. The importance of the role of marketing-mix variables such as advertising, price, promotion and personal selling in understanding diffusion dynamics has been repeatedly emphasized by diffusion scholars [10]. Bass et al. in [11] provide an excellent survey on modelling marketing-mix influence in innovation diffusion. Chatterjee et al. in [12] made review on marketing efforts and pricing over the diffusion process. In [13] some important features of a diffusion curve related to shape, parameters, turning points and properties of diffusion during early stages of a product/service life cycle are discussed.

On the other hand, economists have traditionally employed game theory to analyse the behaviour of users in markets regulated by supply and demand. Also, game theory is a good basis for the analysis of different pricing problems in telecommunications (e.g. [14]-[16]). The problems of demand and routing control are jointly solved by achieving equilibrium in a proposed pricing mechanism [17]. Nash equilibrium is the well known concept for finding solutions in game theory and implies that each player chooses its best strategy analysing all other players` strategies in the game. Nash equilibrium is the state of a game where each player cannot profit from changing his own strategy and since the players are rational, no player prefers a different strategy if the current strategies of other players are fixed [18]. Authors in [19]discussed the existence of Nash equilibrium for two-level pricing problem. The pricing model based on cooperative game is proposed in [20]. Inthis model Internet service prices are used as a means of encouraging providers to cooperate and innovate services. In [21] authors considered competition between a provider and a user in dependence of congestion level. Based on that, Nash equilibrium for an appropriate pricing strategy is determined. In the proposed model the aim was also to prevent frequent price variations. A game-based price competition in the Indian telecommunication market is given in [22]. Authors proposed the model for determining the equilibrium price resulting with a stable market and sustainable profits to telecommunication operators. In [23] we have used Nash equilibrium concepttoexamine trade-off between service price and service provider's reputation with aim of maximizing its profit which we defined as a function of both service price and its reputation.

In this paper we model a competition between two providers offering FTTH service in the Serbian broadband market as a simultaneous-play game. The main contributions of this paper can be summarized as follows: the proposed model combines GBM for analysing different FTTH deployment strategies and game theory tools for determining the best pricing strategy; in the proposed model, a new demand function based on providers' marketing efforts and service price is defined. Earlier researches do not consider this problem in a manner that is presented in this paper.

3. GENERALIZED BASS MODEL

According to diffusion theory, a new service's sales growth at any time largely depends on the strength of word of mouth from its previous adopters. One of the main objectives inherent in most new service/technology diffusion studies is to explain the sales pattern of new service/technology over time. This is usually achieved by modelling the internal influence effect and the external influence effect in the diffusion process using a particular parametric functional form to relate these effects to the new technology diffusion process. The Bass diffusion model has been widely used as forecasting procedure of new services/technologies and it was proposed to deal with the problem of initial adopters.

The mathematical structure of the Bass model is derived from a hazard function corresponding to the conditional probability that an adoption will occur at time t given that it has not occurred yet. If $f(t)$ is the density function of time to adoption and $F(t)$ is the cumulative fraction of adopters at *t*, the basic hazard function underlying the Bass model is given by:

$$\frac{f(t)}{1-F(t)} = p + q \cdot F(t) \tag{1}$$

This model has three key parameters: the parameter of innovation, *p*, the parameter of imitation, *q* and the market potential *m*. Parameter *q* reflects the influence of those users who have already adopted the new technology, while *p* captures the influence that is independent from the number of users. By assuming that each user buys only one unit, the cumulative number of users at time *t*, *N*(*t*), could be given by following equation [3]:

$$N(t) = m \cdot \frac{1-e^{-(p+q)t}}{1+\frac{q}{p}e^{-(p+q)t}}, \tag{2}$$

where *m* refers to market potential for new technology. A number of estimation procedures have been suggested for estimating the parameters *p* and *q*, such as the ordinary least squares (OLS), maximum likelihood estimation (MLE), nonlinear least squares (NLS) and algebraic estimation (AE). The market potential, *m*, could be estimated by analyzing demographic statistical data for the observed traffic area, taking into account the birth rate and migration rate of population. Since this paper considers the broadband technologies related to the residential users, the market potential could be determined as the ratio between total observed population and the average number of household members.

The main technology characteristics: marketing, quality and price have a direct influence on user's valuation of a new technology and these in turn lead to adoption [24]. Understanding of new technological features may be affected by changing the actions of marketing efforts. Also, the understanding of a new technology greatly affects the users who have already accepted a new technology. Service utilization is a factor that should include the actual need of users for a new technology, the importance of their work or daily life, the benefits that can be achieved by new technology etc. The utility can be affected by changing the quality and marketing functions controlled by the service provider and depending on the factors of the final acceptance of technology. The acceptability of a new technology depends on the price and quality, which also controls the service provider. The development of a successful marketing strategy usually depends upon having reliable forecasts [25]. Intentions to accept new technology is difficult because potential users may not be sufficiently familiar with the proposed technology and because the various features of the technology affect one another (e.g., price, quality and distribution channel).

Generalized Bass Model, GBM incorporates control variables into diffusion models such as price and advertising. These are two marketing mix instruments that should ideally be used in extended diffusion models with marketing effects. However, researchers and managers may frequently have information on only one of the two (e.g. price). GBM presents a surprisingly simplified structure:

$$\frac{f(t)}{1-F(t)} = Z(t) \cdot [p + q \cdot F(t)], \ t \geq 0 \tag{3}$$

where:

$$Z(t) = 1 + \alpha \cdot \frac{P(t)-P(t-1)}{P(t-1)} + \beta \cdot \frac{A(t)-A(t-1)}{A(t-1)} \tag{4}$$

follows:

$$Z(t) = 1 + \alpha \cdot \Delta P + \beta \cdot \Delta A \tag{5}$$

Where are: $F(t)=N(t)/m$ – the cumulative function of adoption for time t; $N(t)$ – the cumulative adoptions, i.e. the forecasted number of users; m – the market potential; p – the parameter of innovation (initial probability of adoption); q – the parameter of imitation (diffusion rate); α – the diffusion rate as a result of price decrease for 1%; $P(t)$ – the current price; β – the diffusion rate as a result of increase advertising for 1%; $A(t)$ – the current level of advertising expenditure; ΔP – the proportional change in service price; ΔA – the proportional change in advertising efforts.

Assuming $F(0)=0$, the closed-form solution of differential equation (3) is given by [3]:

$$F(t)=\frac{\left(1-e^{-(Z(t)-Z(0))(p+q)}\right)}{\left(1+\frac{q}{p}e^{-(Z(t)-Z(0))(p+q)}\right)} \quad (6)$$

Note that the speed of adoption at a particular point in time is affected not only by the priceor advertising level at that time, but by the proportional change in those marketing mix variables at that time. If the percentage of changes in price and advertising remain the same between two successive periods, then the function $Z(t)$ reduces to a constant yielding again the Bass model. GBM allows to test the effect of marketing mix strategies on diffusion and to make scenario simulations based on intervention function modulation. Function $Z(t)$ acts on the natural shape of diffusion, modifying its temporal structure and not the value of its internal parameters: as a consequence, the important effect of $Z(t)$ is to anticipate or delay adoptions, but not to increase or decrease them. In other words, function $Z(t)$ may represent all those strategies applied to control the timing of a diffusion process, but not its size [26].

Estimation of the parameters p, q and m is required to identify the diffusion curve. Bass model could be used to predict the timing and magnitude of the sales peak, and the shape of the diffusion curve. However, the most applications of Bass model are used to make plans and decisions before the service/technology has been introduced to the market. Usually, there are no sales data which could be used for estimation of p and q. In such a case, Bass parameters could be evaluated in two manners. One way is to use analogies with other similar services or diffusion process. The second option is analytical using comparative procedure with some other countries where a service/technology already exists.

If data sales does not exist, the market potential has to be estimated by taking into account different impact factors such as economy and social development of a particular area, presence of competitive broadband technologies, providers infrastructure investment strategies, etc.

4. CASE STUDY: SERBIAN BROADBAND MARKET

Serbian broadband market is characterized by three long-standing telecommunication technologies: ADSL (Asymmetric Digital Subscriber Line), HFC (Hybrid Fibre-Coax) and FWB (Fixed Wireless Broadband). Additionally, the FTTH technology is introduced few years ago (in 2011) as a new broadband technology. Assuming that FTTH installation costs will continue to decrease in the future significantly, it is expected that FTTH could become dominant broadband access technology. In our investigations, we have used the GBM as an appropriate model for analyzing the impacts that marketing efforts and price reduction have to FTTH technology adoption rate.

We analyzed here several possible deployment strategies related with the service price for end users as well as the marketing efforts. The price of FTTH per home will be related with the chosen type of fibre architecture and cost of installation. For example, the cost of ONT in a PON will be higher (about 40%) compare to HRN (Home Run Network). We assumed this price difference because an HRN poses less stringent requirements considering the optical budget, bandwidth and protocol. In a case of an all buried network, the fibre cable to be installed for bridging the last meters is already available and connected in the pedestal. As such the trenching at installation time is minimized. In a case of an aerial user connection, the last meters from the drop box up to the house have to be bridged at installation time. This difference leads to a less costly installation in a case of all buried network.

Here we propose seven possible deployment strategies. The Bass parameters, *p* and *q*, are estimated by fitting procedure based on the available statistical data set for the Serbian market shown in Table 1.

Table 1 - Number of FTTH subscribers [27]

Year	2011	2012	2013	2014
Number of FTTH subscribers	2.096	7.784	11.524	13.778

After fitting the Bass curve to best capture the real data set for FTTH,we obtained the following values of parameters p=0.027 and q=0.28. In all proposed deployment strategies the parameter of innovation remains unchanged.

In all considered deployment strategies weassume that coefficients reflecting changes in price and advertising are very similar: α_k = -0,37 i β_k = 0,35. Also, we expect that the substitution effects will happen between new technology (FTTH) and current technologies (HFC, ADSL, and FWB). It means that overall market potential in Serbia which is estimated to 2.500.000 households will be limited to 500.000 households in a case of FTTH because of low households economy and necessary investments in network infrastructure.

Table 2 - The input parameters for Serbian FTTH demand forecasting

Deployment strategy, *k*	p_k	q_k	m_k	ΔP_k	α_k	ΔA_k	β_k
1	**0.027**	**0.28**	500.000	0	/	0	/
2	**0.027**	**0.28**	500.000	-0.2	-0.37	0	/
3	**0.027**	**0.28**	500.000	-0.4	-0.37	0	/
4	**0.027**	**0.28**	500.000	-0.6	-0.37	0	/
5	**0.027**	**0.28**	500.000	-0.2	-0.37	0.4	0.35
6	**0.027**	**0.28**	500.000	-0.4	-0.37	0.6	0.35
7	**0.027**	**0.28**	500.000	-0.6	-0.37	0.8	0.35

Alternatively value of market potential (800.000) is considered in scenarios 4 and 7according to gradual building of telecommunication network infrastructure to support a new technology. In deployment strategy 1 there is no change in price and marketing efforts. It corresponds to basic Bass model. All other deployment strategies are compared with it. Strategies 2, 3 and 4 assume that the price will be reduced for 20%, 40% and 60% respectively. The price reduction could have an impact on market growth (strategy 4).Strategies 5, 6 and 7 take into account marketing mix variables (price and advertising). Estimated parameters values for considered deployment strategies are given in Table 2.

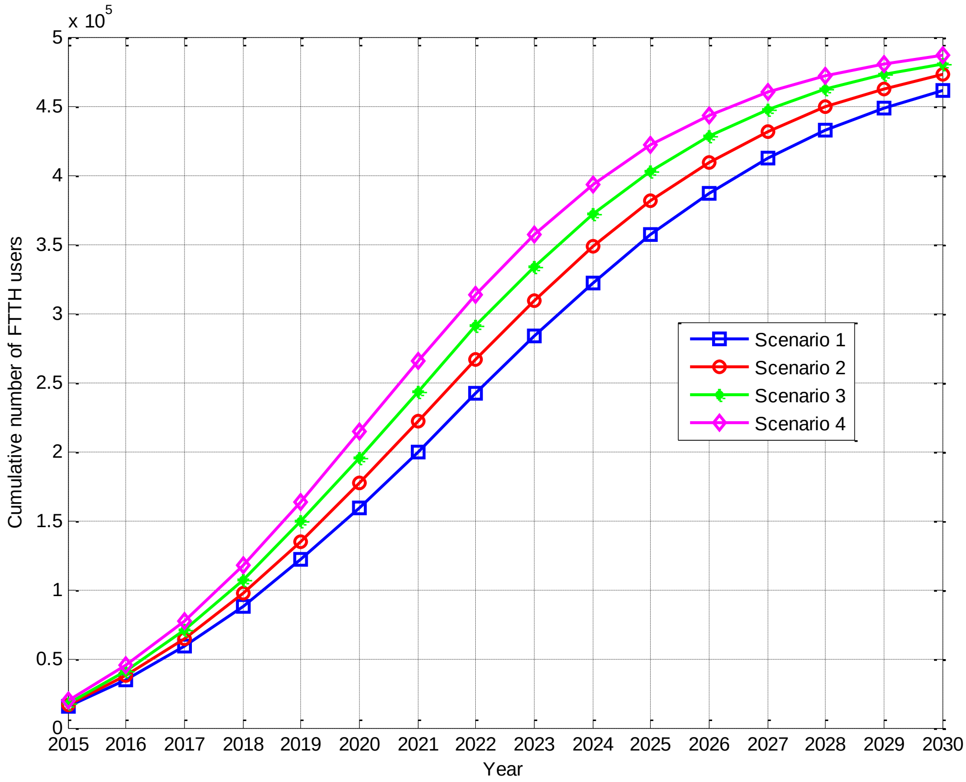

Figure 1 - FTTH technology deployment for different percentage of price reduction (20%, 40% and 60%)

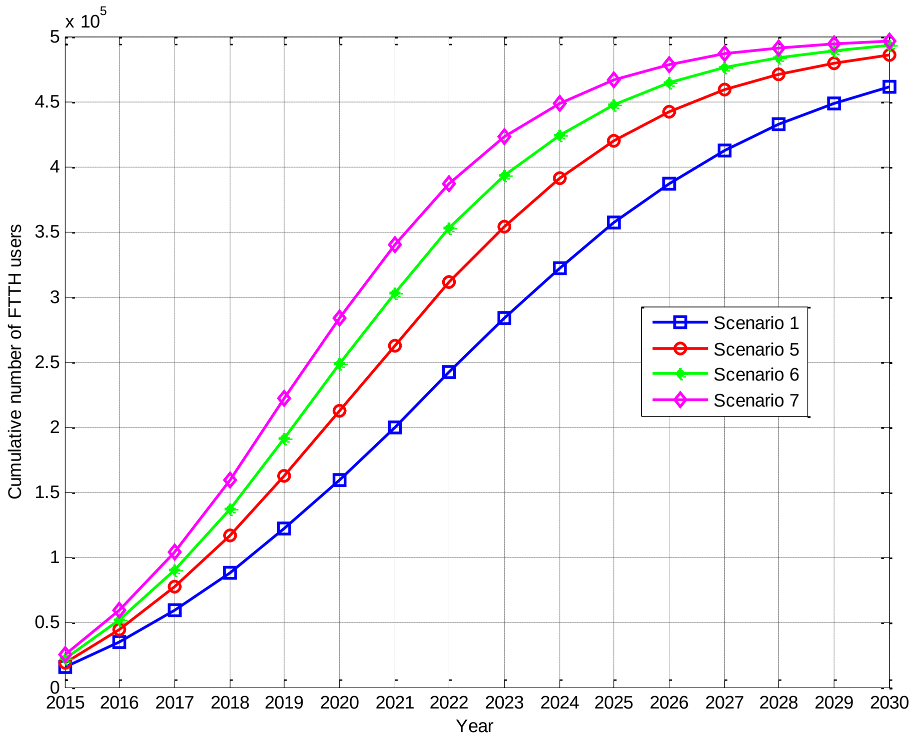

Figure 2 - FTTH technology deployment for different percentage price reductions (20%, 40% and 60%) and advertising efforts (40%, 60% and 80%)

The obtained results for proposed deployment strategies are given by Figures 1 and 2. It couldbe noticed that the number of FTTH users is heavily influenced by price reductions (Figure 1) as well as advertising efforts (Figure 2).

5. PRICE SETTING BASED ON SIMULTANEOUS-PLAY GAME

In this section, we focus on competition between two providers competing for users by setting the service prices. We consider what influence the service price has on the demand function. It is assumed that providers have different marketing strategies in the telecommunications market. A provider will choose a deployment strategy which ensures profitable operation of its communication network. Price predictability can be achieved under the assumption of a single chosen deployment strategy. Considering it is unlikely to expect all providers to adopt exactly the same deployment strategy, we assumed that provider 1 chooses deployment strategy 5 while service provider 2 chooses deployment strategy 6 (as shown in Table 1). We consider thecompetition between two service providers in the case when the forecasted number of users depends not only on the observed SP's service price, but also on the price of the other one SP. Therefore,*D(t)*, could be defined as follows:

$$D_{ik}(t) = N_{ik}(t)\left(1-e^{-P_i^B P_j^C}\right),\ i=1,2\,,\quad j=1,2\neq i \text{ and } k=\overline{1,7} \tag{7}$$

According to the expression for the forecasted number of users $N_{ik}(t) = m_{ik}F_{ik}(t)$ and equation (6), in case a provider *i* choose deployment strategy *k*, demand function could be express as follows:

$$D_{ik}(t) = m_{ik}\frac{\left(1-e^{-Z_{ik}(t)\left(p_{ik}+q_{ik}\right)t}\right)}{\left(1+\dfrac{q_{ik}}{p_{ik}}e^{-Z_{ik}(t)\left(p_{ik}+q_{ik}\right)t}\right)}\left(1-e^{-P_i^B P_j^C}\right) \tag{8}$$

where:

$D_{ik}(t)$– total users' demand for the service provider *i* offers,

P_i, P_j – service prices the provider *i* and provider *j* offers, respectively,

B – users' sensitivity to the provider *i* service price variation and

C – users' sensitivity to the provider *j* service price variation.

To determine the influence of service price and providers' advertising efforts on providers' profits, we propose the following profit function for provider *i*:

$$\Pi_{ik} = D_{ik}(t)P_i - C_{si},\ i=1,2 \tag{9}$$

Hence, the profit function is as follows:

$$\Pi_{ik} = m_{ik}\frac{\left(1-e^{-Z_{ik}(t)\left(p_{ik}+q_{ik}\right)t}\right)}{\left(1+\dfrac{q_{ik}}{p_{ik}}e^{-Z_{ik}(t)\left(p_{ik}+q_{ik}\right)t}\right)}\left(1-e^{-P_i^B P_j^C}\right)P_i - C_{si}\,,\quad i=1,2\,,\quad j=1,2\neq i\,,\ k=\overline{1,7} \tag{10}$$

where $C_{si}$are the total costs of providing a service.

We assume that the total costs of providing a service are the same for all providers, i.e. $C_{si} = C_s$. Accordingly, profit functions of two competitive providers can be expressed as follows:

$$\Pi_{1k} = N_{1k}(t)\left(1-e^{-P_1^B P_2^C}\right)P_1 - C_s \tag{11}$$

$$\Pi_{2k} = N_{2k}(t)\left(1-e^{-P_1^B P_2^C}\right)P_2 - C_s \tag{12}$$

The defined problem can be modelled as a simultaneous-play game between providers in which all of them aim to maximize their corresponding objective functions, i.e. profits. The best response of the first provider can be obtained from the optimal price P^* for which profit $\Pi_{1k}(P_1^*,P_2)$ is maximized, given the price P_2 offered by the second provider. Similarly, the best response of the second provider is the optimal price P_2^* for which profit $\Pi_{2k}(P_1,P_2^*)$ is maximized given the price P_1 offered by the first provider. This best response is denoted by $B_k(P_p) = \arg\ \max_{P_k} T_k(P_k, P_p)$, where P_p is the price offered by the other provider. Nash equilibrium gives the set of prices such that none of the providers can increase the revenue by choosing a different price, with the given price offered by the other provider. This is the point where $B_1(P_2^*)= P_1^*$ and $B_2(P_1^*)= P_2^*$.

6. NUMERICAL RESULTS

Next, the proposed model is tested at the Serbian broadband market where two FTTH providers exist. It is assumed that they have different marketing strategies regarding service price and advertising efforts (provider 1 choose the deployment strategy 5 and provider 2 choose deployment strategy 6). Also, it is assumed that provider 2 has made higher price reduction and greater advertising efforts compared to provider 1. The forecasted number of users for both FTTH providers can be observed from Figure 3. The following parameters values for both cases are: B = -3.5, C = 3.5, m = 500.000, C_s = 100. The values of users' sensitivity to the service price variation and the market potential are estimated for residential broadband market in Serbia [28]-[31]. Providers' profit functions, as the output results, with the appropriate Nash equilibrium points in years: t = 2016, t = 2023 and t = 2030 are given at Figures 3-5, respectively.

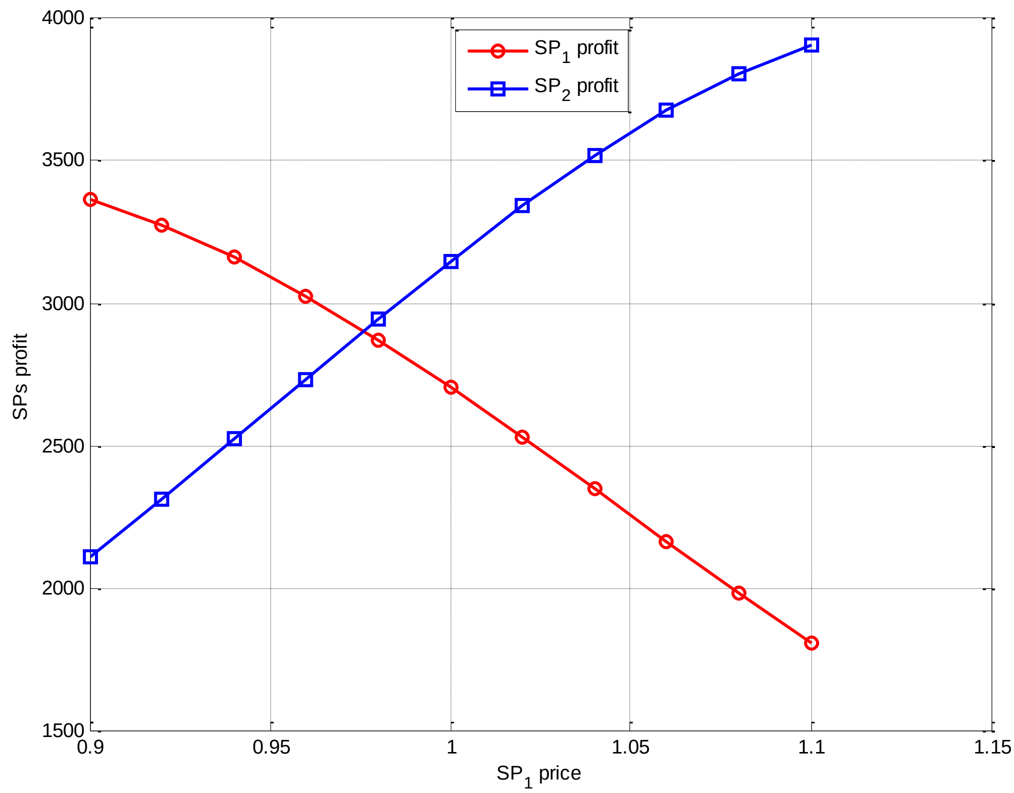

Figure 3- Providers' profit functions and Nash equilibrium prices for the year 2016

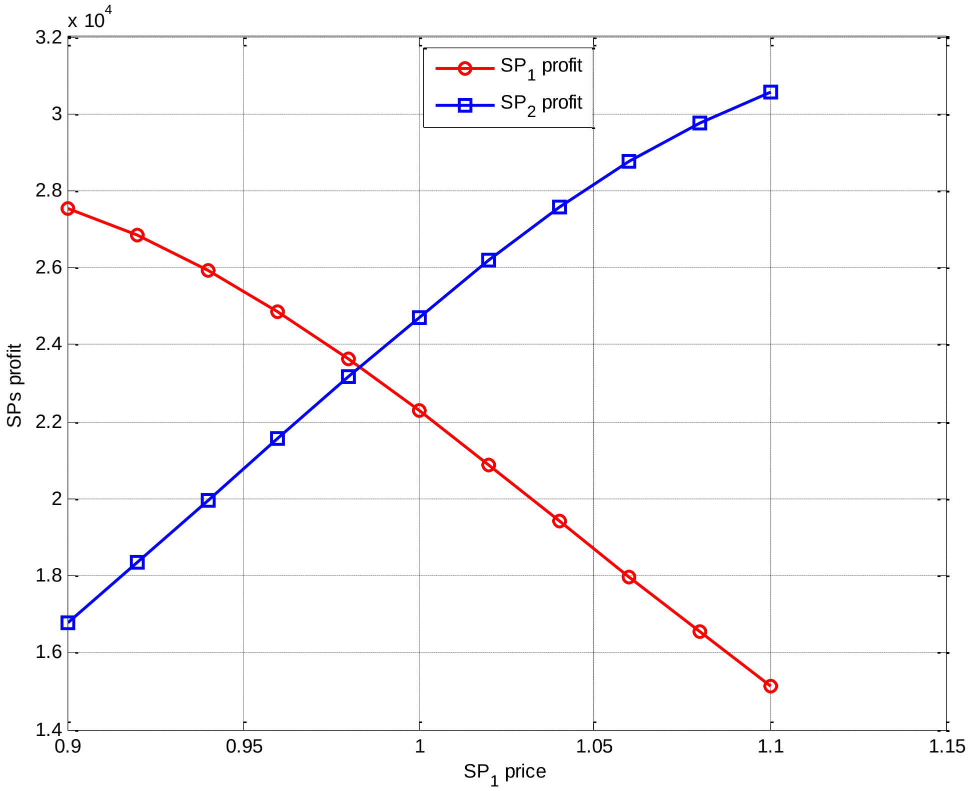

Figure 4- Providers' profit functions and Nash equilibrium prices for the year 2023

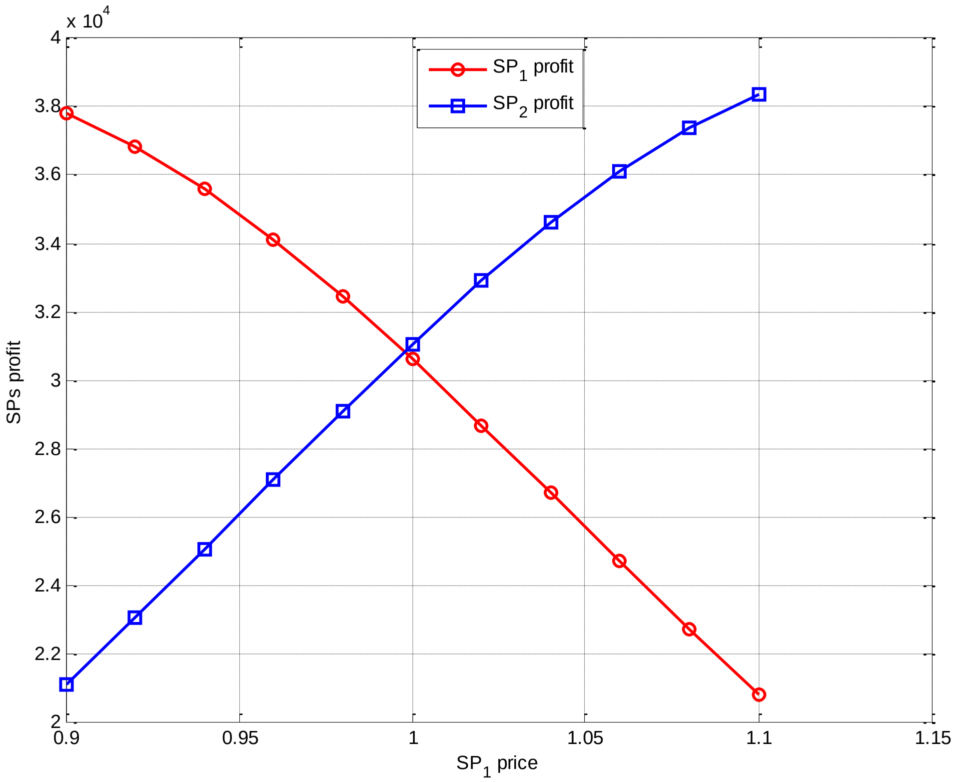

Figure 5- Providers' profit functions and Nash equilibrium prices forthe year 2030

We have picked the following years: 2016, 2023 and 2030, because they represent the most critical time in a life cycle of service: the initial time of service introduction, the service rapid growth and the service saturation, respectively. The output results suggest that with increasing *t*, the provider with smaller investment in the network (i.e. provider 1) will have to reduce the price to sustain its profit at the same level as its competitor, which has major investments in the network (i.e. provider 2). For t = 2016, the forecasted Nash equilibrium prices are P_1 = 0.976 and P_2 = 1.024 for provider 1 and provider 2, respectively (Figure 3). For t = 2023, the forecasted Nash equilibrium prices are P_1 = 0.983 and P_2 = 1.017 for provider 1 and provider 2, respectively (Figure 4) and for t = 2030, those prices are P_1 = 0.998 and P_2 = 1.002 (Figure 5). For each year the model computes the providers' profits and calculates a Nash equilibrium based on users' demand. Although a theoretic equilibrium exists, there will always be fluctuations, and it is possible to characterize the conditions under which oscillations can be avoided or converge towards the equilibrium.

7. CONCLUSION

Telecom service providers need to progress quickly and effectively to compensate the reduction of traditional revenue and meet users` demand for new services. In this paper we suggest GBM for long-term forecasting of a new broadband technology. The main advantage of this model is that it includes the marketing mix variables: price and advertising effects. It enables broadband providers to predict the number of users according to the price reductions as well as marketing investments. Also, the proposed model would enable providers to quickly make the right technology deployment decisions. We haveproposed this model for FTTH technology deployment in the case of Serbian market. We have analyzed several deployment strategies with different percents of price reduction and marketing efforts as well as market potential. In this way, managers can make the right technology investments and price strategies that are important to capture new broadband market shares.

Additionally, the paper analyzes providers' behaviour in a competitive market depending on their pricing strategies. We used Nash equilibrium concept for finding best pricing strategies for two providers in the game. The main advantage of this model is its capability to determine appropriate provider's service price according to the competitive provider. Also, this model can be useful for determining the trade-off between the prices and marketing investment. It gives possibility for a provider to optimize its profit by setting the price in order to compensate its lower marketing investment. In other words, the provider is able to obtain the best trade-off between its marketing strategy and service price.

The obtained numerical results show that provider's network investment has great impact on its pricing strategy, meaning that a provider with a better investment in a network infrastructure has a significant advantage in market positioning. This model gives the possibility to analyze possible deployment strategies that could happen in a market and thus reduce the business risk.

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REVERSE LOGISTICS WAREHOUSE PROCESS OPTIMIZATION

ABSTRACT

The basic warehouse processes of a forwarding part of the chain include goods receiving, storage, order picking and shipping and are designed to support accurate and fast response. To provide complete service, for a provider, it is necessary to include processing for reverse part of the chain, which if not continuously, or optimized at all, results with certain costs.

The paper deals with the problem of analyzing reverse logistics operations, in form of a case study, aimed to define warehouse activities conducted to process amounts in return, and finally suggests optimization possibilities for the benefit of reducing process time and reducing expected amounts of this significant part of the chain.

KEY WORDS

reverse logistics; warehouse processing; disposition time, case study

1. INTRODUCTION

Reverse logistics is the process of planning, implementation and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of origin to the point of consumption. Reverse logistics, if not well organized, increases costs. Good organization is needed to prevent bottlenecks, which is recommended to do already while planning distribution flow of goods. [1]

The paper describes the basics of reverse logistics and its role in the warehouse processes. It focuses on the warehouse activities, organization and lastly provides possible suggestions for optimization. It includes an overview of the reverse logistics case study in LDC (logistics and distribution center) at the Croatian market.

Analysis includes:

- current state analysis (forwarding processes, reverse logistics processes;
- reverse logistics activities measurement on certain sample;
- comparative analysis of statistical data.

2. REVERSE LOGISTICS

Reverse logistics is the process of moving goods from their typical final destination for the purpose of capturing value, or proper disposal while remanufacturing and refurbishing activities also may be included in the definition of reverse logistics. Reverse logistics also includes processing returned merchandise due to damage, seasonal inventory, restock, salvage, recalls and hazardous material programs, obsolete equipment disposition and asset recovery. The reverse logistics process can be broken into two general areas, depending on whether the reverse flow consists primarily of products, or primarily of packaging. [2]

Complexity of processing is result of differences of returned products in supply chain, not only regarding various types of products that makes manufacturers/providers hard to manage, but also diverse conditions of returns, as, damaged goods, unsold items, non-defective products, end-of-life products, and so forth.

Backward processes generally take longer time and are more complicated to operate than forward processes, since companies need to consider each returned product as issue at a time. However, having organized reverse logistics processing in companies is necessary because it provides a systematic product management and often is obligation because of various reasons for any part of the chain. Moreover, the benefits from optimization can be used for an organization as a strategy to minimize costs, improve customer satisfaction, and reduce waste unnecessarily directed to landfills.

The basic activities in reverse logistics processes, starts with a product that is returned to a subject of a supply chain from another subject, or by a consumer most often to a retail shop. A company has to determine the suitable disposal option for goods, if a product has perfect conditions to get a full refund from manufacturer, returning a product to a supplier may be a company first option disposition, or needs to react as is defined in contracts between subjects.

For return of unused product, reselling can be assured through outlet or secondary markets of any kind. If a product cannot be sold through these options because it has insufficient quality, it can also be exported to a foreign market by a salvage company, or properly disposed by using or not using parts or materials.

The following are the common activities of reverse logistics: [1]

- **Return to supplier** – products sent backwards through supply chain, decision often based on defined contracts.
- **Resell** – products may be sold again in the same or different channels.
- **Reuse** –products used again without any modification.
- **Recondition** –products repaired or renovated in good or satisfactory conditions.
- **Refurbish** – the process of adding value, painting, cleaning, etc.
- **Remanufacture** – to rebuild and repair part of products to be used again.
- **Reclaim materials** – to bring back usable parts from waste products.
- **Recycle** – a process of reclaiming materials (differently defined in different countries)
- **Disposal** – directing products to landfills.

Subjects of a supply chain in different surveys note that reverse logistics processes are complex and they have certain difficulties regarding those. In retail industry reverse logistics characteristics are that returns reduce the profitability by 4.3% while average amount returns reduce profitability among manufacturers is 3.80%. [2]

According to those, and many other conducted research companies that, previously, did not devote much time or energy to the management and understanding of reverse logistics have begun to pay attention. Companies have begun to benchmark return operations with best in class providers. Third parties specializing in returns have seen that demand for their services greatly increased. [3] Although this happened on developed markets, in developing still these issues are on high level.

Many authors highlight reverse logistics significance, as Kokkinaki who concluded that reverse logistics is necessary for the following reasons:

- **positive environmental impact:** legislations acts, also called “producer responsibility laws”, require manufacturers to develop a policy for the collection and reuse of products at the end of their lifecycle;
- **competitiveness advancement**: efficient handling of returns leads to reduced costs, increased profits and improved customer service;
- **regaining value:** efficient reverse logistics can capture values from reusing products or parts or recycling materials.[4]

The characteristics of reverse logistic systems at different logistics markets, in their basic structure are not significantly different, while the problems and ways in which the return flows are substantially different, and must be observed at an individual level. [5]

3. WAREHOUSE OPERATIONS

Warehousing is one of the most crucial part of activities in supply chain, as it plays an important role by running the core operations of logistics flows. Warehouse management has a mission to effectively process products at the right time, right place, and right quantity without damages or differentiation. [6] A good warehouse management needs to handle and encourage the operations in warehouses by reducing the distance movements and maximize capacity.

Warehouse operations are as follows: [9]

- **Receiving** – the process of goods and materials acceptance
- **Storage** – positioning of stock keeping units (SKU) at storage locations.
- **Order picking** –retrieving SKUs in accordance with customer orders
- **Shipping** – the process of packing, assembling, and preparing orders to be ready for outbound loading.

The necessity of warehouse process optimization includes observation of all processes mainly regarding process time, but also organizational issues. [7] Negative aspects often met at locations are issues regarding capacity and high level of unnecessary inventories.

Nowadays there are plenty of technologies which are support and decision-making tools for operations in warehouses as Radio Frequency Identification (RFID) which advantageously helps route optimizing, furthermore, as ERP and SAP that are widely used as key business function in organizations and logistics companies as well. [7]

Operations inside a warehouse operate a dual function for forward and reverse logistics, which means facilitation of warehouse operation must be efficient for shipping goods for forward logistics and receiving returned products for reverse logistics. [8] The operations in warehouse for forwarding flow take certain time, which is by companies often observed to be reduced to minimum, while processing of goods in return is mostly prolonged because process includes more activities for those goods. Subjects of a supply chain need to inspect products whether they are products from their chain before entering processing, items may be stored if the conditions and contract definition is set this way, for the purpose of directing to forward chain again; can be sent to recycling, secondary markets, manufacturers or properly disposed at landfills., etc. [8]

4. CASE STUDY OF REVERSE LOGISTICS IN LDC

To define processes for products in return, a research has been made at location of a logistics service provider at the Croatian market. Service provider is a significant company that offers full logistics service and some value added services. Services can be defined as tailor made, and include processes for goods in return in basic offer.

Observed warehouse receives returns from two main channels:

- final consumers;
- subjects of a supply chain (retail locations, LDCs).

As channels, the processing is common, with certain differences which is typical regarding return part of the chain and is as followed:

- return from the final consumers is accompanied by the document "List of delivery" containing a list of products in the return;
- the notice of the goods in return is given as an information to a provider in the form of a number of packages;
- the list is forwarded to the operator at the department of return;
- the courier positions goods that are being returned at the ramp dedicated for returns;
- after the returned goods receiving, the operator copies the „List of delivery" and retains a copy of the document.

Processing is done under two conditions:

- is being managed by two storage workers
- includes unwanted (unclaimed) goods and user complaints.

During the processing, the worker removes the label of packing, scans the account number, and in this way gets detailed information about the sources and product ID. After that, the worker opens packages and checks products. These returns are in 98% directed to forwarding, so to each of the products in the return is given a virtual location in the return zone, which is visible in the system and accessible to the warehouse workers for picking.

At the end of a shift, consolidated returned goods on a pallet are assigned to a position on the shelves of the distribution part. Specificity in positioning consolidated returned goods in the storage area is reflected in the fact that in the forwarding part the goods are stored by grouping them by types. Storing of non-grouped returned goods implies a cluster of different types of products.

In mentioned category of goods, the final consumers return, damage to the goods can only occur during transportation, where the distributor is automatically charged for the damages. Damaged goods are sold by the outlet stores, and if there is only damaged packaging and the goods are intact, they can be sold again in regular forwarding chain.

The return of goods from retail locations and LDCs includes goods returned as a result of failed sales, damage and unnecessary high inventories, goods are directed to the return flow. The process is as followed:

- provider is informed that in the supply chain items are being returned;
- return includes a "Return receipt" under a certain number;
- operator of the return zone checks the "Return receipt" and compares the details with the information in the system;
- products approved for return if all of the details are correct and match system data;

- if goods are coming from certain retail locations the status of the goods is defined at the retail location and the operator in the return zone will not check the condition of the goods. The goods which are coming from other retailers require a detailed review of the condition which can result with status of "damaged", "write-off" and "inventory”.

Additional note: The document often does not match, and the operator has to check item ID for those that do not have a label on them.

During the visual inspection the condition of the goods is determined. If the condition of the goods is labeled for „outlet“, they go on sale for workers of the logistics service provider and its customers. If the goods are labeled for write-off, the goods pass the standard procedure. Diagram presents mentioned processing.

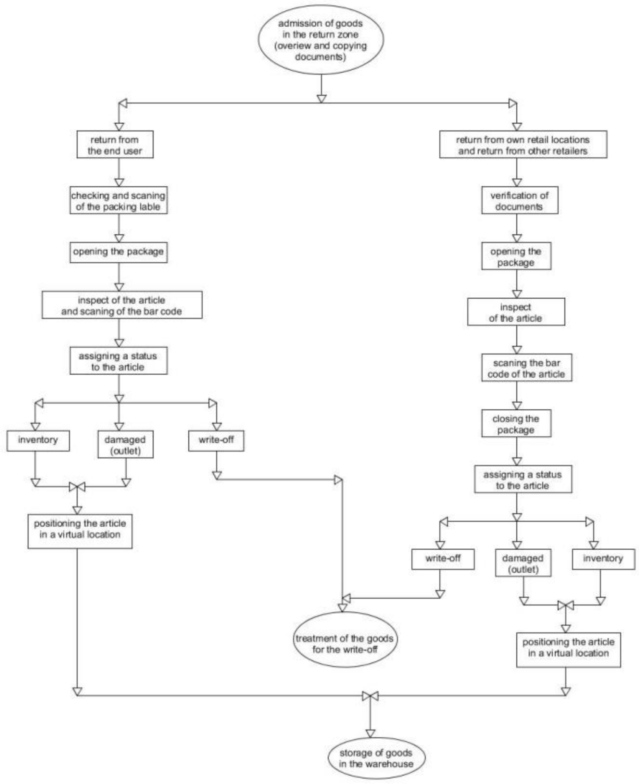

Figure1 - The block diagram of return
Source: created by authors

The study was carried out by collecting provider’s 2Q data and by measuring each activity within the processing regarding returns. For each activity obtained the average time is shown in table 2 and figure 3. Table 1indicatesdirection of goods to reverse logistics channels by the logistics service provider.

The first two graphs show that in the observed period all goods returned from the final consumers are in good condition and can be picked for distribution again. In the return channel from retail locations most goods, nearly 85 %, can be commissioned again, about 6 % is labeled for write-off and about 9 % for the outlet.

The next table indicates quantity of returned merchandise during measurement.

Table 1 -The quantities of goods in restitution by category

	Damaged (outlet)	Inventory	Write-off
Return from the final consumers	0	473	0
Return of own retail locations and other return retailers	25	227	17

Source: created by authors

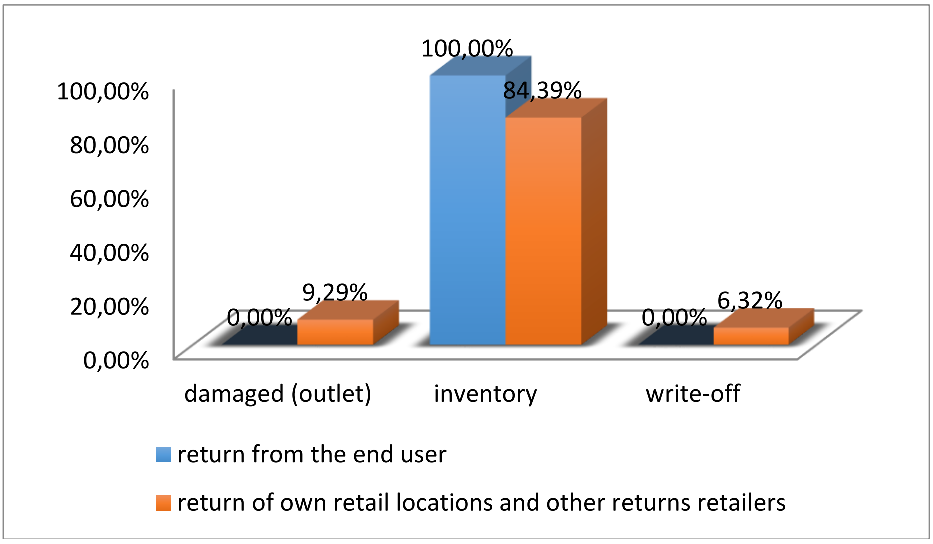

Figure2 - Status display of goods per channel return
Source: created by authors

Tables 2 and 3 demonstrate the average time for all activities while processing returned goods. Table 2 indicates also that most time-consuming activities in the processing of returned goods from the final consumers are verification and scanning of the products. While the most time-consuming activities in the processing of returned goods from retail locations are verification and sorting packages from the pallet. The reason for longer average times for verification of the products from other retailers is the larger amount of products in one package and necessity to check each product. Wrong packaging, incorrect color or size are issues that occur from time to time. Also, boxes are not well arranged on a pallets.

Table 2 - The average time for each activity of processing the goods in return from the final consumers

average time for document verification [s]	average time for opening the box[s]	average time for verification and scanning[s]	average time for positioning the productin the virtual location[s]
0:00:03	0:00:22	0:00:34	0:00:22

Source: created by authors

Table 3 -The average time for each activity of processing the goods in return from retail locations

average time for document verification and sorting packages [s]	average time for box opening[s]	average time for verification of the product[s]	average time for scanning the product[s]	average time for closing the box and placing the product in the virtual location[s]
0:04:31	0:00:12	0:01:18	0:00:55	0:00:09

Source: created by authors

5. PROPOSAL FOR REVERSE LOGISTICS PROCESS IMPROVEMENT

Based on conducted study and regarding return of goods, it is possible to propose certain directions for further optimization. The system can be optimized from the aspect of processing return of final consumers and also retail locations and LDC return. Conducted study implicated that each channel of reverse logistics has bottlenecks. These bottlenecks should be optimized to maximize the quality and speed of processing goods in return, and thus directly reduce costs of reverse logistics.

Some of the suggestions for optimizing relate to the observed processes:

- **sorting retail location and LDC's boxes**

During the research it was noted that employees spend too much time on sorting boxes in accordance to order, increasing the waiting queue. There is a possibility of optimization already at retail stores and LDC locations; stacking the merchandise on the pallet should be predefined, for the benefit of reducing the processing time when return enters provider's warehouse. If the retail and department of return collaborate, procedure of processing goods in return might benefit.

- **large quantities of return from final consumer**

The large amount of goods from the final consumers can be directed to inventory, shown on the graph, and proved by research. These are the unwanted goods that the users are not willing to accept, and are always undamaged in return. This return is common, thus the result is unnecessary processing because goods are repeatedly passing through the traditional flow. In order to prevent double manipulation, consumers could be contacted regarding purchase and finally if it happens the return of goods could be charged, in a case of non-acceptances. This way, users would be allowed to add complaints, but in the case of not accepting orders, manipulation of return goods would be charged.

- **the problem of locating returns**

Processing the goods to storage locations must for returns from the final consumer (because will be directed to distribution again) be the same as for forwarding chain according to type. It would not increase time significant, but would reduce the time for future picking process.

- **expertise of the workers**

Every operation requires supervision of expert to reduce time loss for eventual mistakes made by workers. At the location of observed provider has been recorded many system errors caused by human factor. As a result of system errors, time required for resolving problems has been in some cases extended up to few hours. Optimization of this segment proposes a person who is an expert in problem solutions related to reversed logistics.

6. CONCLUSION

Processing products in return needs to obtain high level of organization to prevent inevitable bottlenecks that can manifest in any part of the chain as a logistic cost. The most relevant shortcomings of reverse logistics organization are evident in a prolonged disposition cycling time, employee engagement, high costs, unorganized and non-existing activities and reverse logistics channels, amounts unnecessarily directed on landfills, etc. [5]

A good reverse logistics strategy by subject of a supply chain, is needed to cope with return to gain highest possible benefits. The benefit of optimization of reverse part of the chain often is not profit, but reducing costs.

During years of research on the Croatian market, found as developing one, logistics company's representatives always defined return processing as hard burden complex to handle. While many companies in Croatia haven't yet recognized the strategic potential of efficient reverse logistics, it is clear that the tide is beginning to turn.

Although worldwide companies have strategies to deal with this problem, many of them are not optimal (except those declared as "best in class") and can be improved. These strategies need supervision and continuous improvement to help companies build more competitive advantages.

As reverse logistics causes certain costs, often not measured and claimed to be unmeasurable, these costs are highly reflected while warehouse processing as well. Main difference between forwarding warehouse processes and those dedicated for product return, are number of activities provided and process time. Forwarding warehouse processes are on Croatian market often optimized to certain level, leaving some possibilities open for optimization. Some companies lack capacity, some have high inventory level or need to implement information systems. Regarding processes in return, at the same companies, they are:

- not defined in detail;
- of secondary matter in accordance to distribution chain;
- products not processed in FIFO method, but piling in non-current inventories;
- not located in predefined manner;
- not obtained by same/educated personnel;
- not measured for effectiveness.

Because of mentioned above, research has been made at location of a logistics service provider on the Croatian market. Observed provider, is one of the companies that has educated personnel regarding return and has basically defined processing. Although having some level of definition and certain level of supervision, processes result in prolonged disposition cycling time, ununiformed decisions, uncontrollable quality of items in return, unnecessary returns, high amounts with no possibility of reuse as a final product. Nevertheless, processes can be improved in certain ways suggested in paper.

All implementation of solutions regarding processes in return, as is in forward processing, needs to be provided as step at a time, leaving possible changes to be done during. Consulting warehouse workers, especially those educated and experienced in processing returns is obligatory while optimization. With these optimization proposals the observed company willpartly improve the processes of return and with continuous supervision can benefit in reducing warehouse costs.

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HAZARD IDENTIFICATION IN PART-145 APPROVED MAINTENANCE ORGANISATIONS: THE MANAGEMENT OF RISK ATTITUDE

PLEASE NOTE: This document has been prepared with the kind participation of an EASA registered Part-145 Approved Maintenance Organisation. The identity of the organisation is protected, and throughout this document, they are referred to exclusively as "Company A".

DISCLAIMER: "Company A" is an entirely fictitious reference intended solely for the purposes of this document. When using this term, any similarity to any actual company, registered or otherwise, is entirely coincidental and unintentional.

ABSTRACT

Risk is an unavoidable part of the aviation industry, and describes both an inherent uncertainty, and an appreciation of the degree to which this uncertainty matters [9]. It is a well-known aphorism that 'one cannot manage what one cannot measure', and so the identification of hazards is the first step towards the management of safety risk [11]. Unfortunately, different attitudes and perceptions mean that what appears hostile to some may appear benign to others, and basic human fallibility means that perception and risk attitudes are highly subjective because of "[exposure] to sources of explicit and implicit bias" [9].

In an effort to sustain airworthiness, Approved Maintenance Organisations (AMO) are one of the most regulated aspects of the aviation industry. This research has shown that a balance of compliance and flexibility is essential to the continued operation of "imperfect systems in an uncertain and dynamic world", and so aviation is reliant upon the management of risk attitude to provide an enveloping response to uncertainty, and so enhance the subjective management of safety risk [16].

Through analysis of the safety performance of an EASA registered Part 145 AMO, this project has shown that risk attitudes and perception play an integral role in the identification of safety risk. Whilst the scope and nature of the various risk attitude biases could not be fully quantified, further analysis has shown that safety performance monitoring and measurement is the first step toward this goal, whilst helping to reduce uncertainty and manage subjectivity across the operational environment.

Recommendations address the mitigation of conscious, subconscious and affective biases, and aim to enhance situational awareness and improve hazard identification. These include the standardisation of the risk assessment process, improved levels of quantitative performance monitoring, and the development of awareness amongst operational personnel of the potential impact of specific situational risk attitude influences.

Ultimately, this research has shown that the greatest asset to any AMO is its constituent staff members, and the promotion of risk attitude and error wisdom has been shown to assist *personnel in their understanding and management of their own limitations, whilst adapting their risk attitude to that required by the situation, the context and their skills.*

KEY WORDS

Safety management, safety risk management, safety risk, hazard identification, risk attitude, Part-145, approved maintenance organisation

1. INTRODUCTION

The aviation industry is one of the most complex socio-technical systems ever developed, and air travel is widely regarded as the safest mode of transport in the world [22].For many years, a key contributor to this enviable success has been the strategic utilisation of safety management systems (SMS); a toolbox for the systematic, proactive and business-like approach to the management of safety risk.

As one of the core components of any SMS, the correct identification of hazards is the first step toward effective safety risk management because “hazards that go unnoticed cannot be managed” or controlled [4]. Should assessment of the probability of the hazard or of the severity of its consequences be insufficient, then the reliability and effectiveness of mitigation strategies is reduced, and the value of risk management cannot be assured.

A key component in the identification of hazards is the process of perception; the fundamental ability “to see, hear, or become aware of something”. As risks are identified, assessed and managed by people, perception does not always mirror reality, and so what appears hostile to some may appear benign to others. This makes the hazard identification process highly subjective, and so in order to improve the management of safety risk and enhance underlying decision making, it is important to recognise and understand the values, attitudes and behaviours that subconsciously influence both defence and mitigation strategies.

In an attempt to manage the risks posed by actions and behaviour, aviation deploys a variety of strategies in an attempt to constrain and regulate both behaviours and their consequences. This has resulted in the widespread use of tools including checklists, training, and other “soft” mitigations. Unfortunately, whilst the importance of these risk management techniques is undeniable, they are often inherently flawed, because it is impossible to anticipate in a systematic or reliable manner “typical human frailties such as distraction, tiredness and forgetfulness”. Such frailties result in an unavoidable deviation from planned system performance, and so the effectiveness of soft mitigations is limited by their context of creation and their reliance upon human performance [11].

Thankfully, by recognising the limitations of rule-based defence and mitigation strategies, an SMS can provide a tailored and specific framework from where an organisation can manage risk within its own unique operational environment, alongside a reduction in the “contextual limitations” that beset sheer regulatory compliance [11].

Unfortunately, whilst the dynamic and flexible nature of an SMS can be of considerable benefit, it must be recognised that Approved Maintenance Organisations (AMO’s) remain one of the most regulated areas of the aviation industry. This regulation is essential to support the set, non-subjective standards necessary to attain airworthiness, and so determine whether an aircraft is safe for flight [20]. This means that to effectively promote safe operation, an AMO must balance the flexibility of safety management against the constraints inherent to compliance. An appropriate understanding of the true drivers behind the hazard identification process is therefore fundamental (Figure 1&Graph 1):

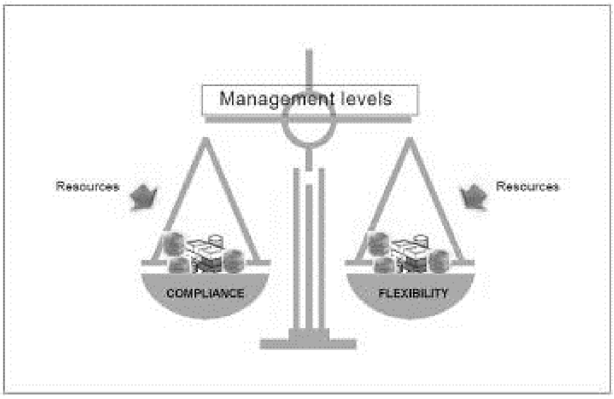
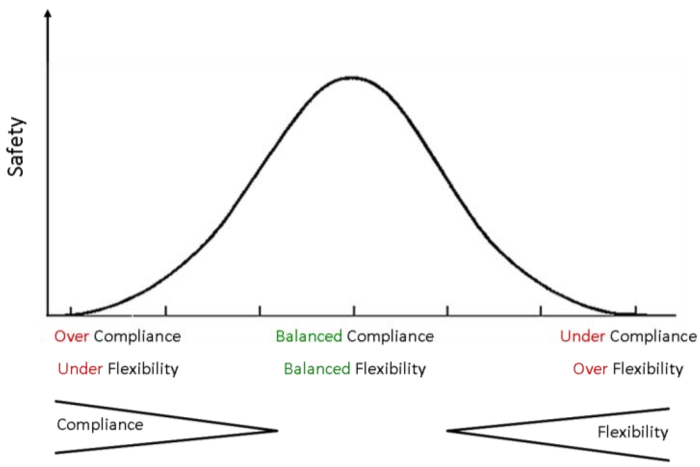


Figure 1 - The Balance of Resources
[Source: Created by author through interpretation of "The Management Dilemma" (The Dilemma of 2P's) from: International Civil Aviation Organisation (ICAO). "Safety Management Manual (SMM)". DOC 9859 AN/474. ICAO, 2009 – 2nd edition. (Page 3-3)]



Graph 1 - Compliance vs. Flexibility
(Source: Concept created by author)

2. METHODOLOGY

In order to investigate the underlying drivers of the hazard identification process, this study utilises primary safety occurrence data from a Part-145 AMO to produce a quantitative interpretation of safety performance. This organisation is referred to exclusively as "Company A".

The quantitative results are used to assess the attitudes toward the hazards, risks and threats that contribute to the creation of "Company A" defence strategies, supporting qualitative analysis of the complex influence of perception and risk attitudes on the hazard identification process. This is achieved through examination of the existing attitudes and perceptions of individuals, and the impact of general risk attitude situational influences, against comparison with the generic risk attitude spectrum.

Through analysis of various conscious and subconscious factors, this research aims to suggest practical recommendations to reduce the subjectivity between different attitudes and perceptions, improving the management and assessment of risk attitudes and safety risk. It is hoped that these strategies can foster improved situational awareness and increased process resilience, helping “Company A” to better understand and manage its unique operational environment whilst enhancing its safety defences.

3. RESULTS

To support the requirements of its safety reporting policy, “Company A” maintains an electronic database of all safety reports. A computerised software package is used to collate and process this data, and all reports are allocated the following criteria:

Occurrence Type	Occurrence Date	Occurrence Category	Occurrence Number
Location	Risk	Likelihood	Severity

Primarily, each report was correlated according to its “category”. “Company A” operates a fixed number of categories, and these include examples such as “damage through collision”, “installation error”, and “procedures not followed”. Within the database, each occurrence has a safety risk defined as either “low”, “medium”, or “high”, and this risk relates to the perceived potential impact of the occurrence on flight safety [1].

As the first quantitative assessment of the organisation’s safety data, “Company A” defined a fixed 10-month period for analysis. This period presented 197 occurrences, of which 4 were excluded as they did not contain values for risk, likelihood and severity. The remaining 193 occurrences concerned 44 occurrence categories, with the most common event type being “Installation Error”.

Overall, the average number of occurrences across the 62 categories was 4.48, and the standard deviation was 5.06. The range of occurrence quantities spanned from 1 to 22, and roughly 65% of all occurrences could be found in just 10 of the occurrence categories. This suggests that majority of occurrences are distributed over a narrow spread of event types.

A breakdown of the risk, severity and likelihood across the 193 occurrences may be observed as follows (Table 1):

Table 1 - Summary of Risk, Severity & Likelihood

x	Risk	n	% (0 d.p)	nx	Overall Risk Avg.
3	HIGH	1	1%	3	(nx / x)
2	MEDIUM	39	20%	78	
1	LOW	153	79%	153	
		193	(100%)	234	**1.21**

x	Severity	n	% (0 d.p)	nx	Overall Severity Avg.
5	Massive	2	1%	10	
4	Extensive	3	2%	12	
3	Major	41	21%	123	
2	Minor	135	70%	270	
1	Insignificant	12	6%	12	
		193	(100%)	427	**2.21**

x	Likelihood	n	% (0 d.p)	nx	Overall Likelihood Avg.
5	Common	0	0%	0	
4	Frequent	3	2%	12	
3	Occasional	14	7%	42	
2	Possible	124	64%	248	
1	Improbable	52	27%	52	
		193	(100%)	354	**1.83**

Source: Created by Author from “Company A” Safety Data

The results of Table 1shows that overall, approximately 80% of “Company A” events are low risk, whilst approximately 70% of all occurrences are insignificant/minor in severity, and 64% improbable/possible in likelihood.

Across, the period of analysis, “Company A” serviced 1261 aircraft, and to provide a supporting background to the initial data extracted, each aircraft was included in the dataset from the start of its maintenance input. This means that each aircraft was accounted for in only one monthly period, even if the aircraft’s stay was for an extended duration. In an attempt to enhance the reliability of the results, further information was not included owing to the complex and manual nature of the data extraction process.

By combining the results of the dataset with the total aircraft serviced, it is possible to produce a summary of the relationship between aircraft, occurrences, risk, severity and likelihood (Table 2):

Table 2 - Overall Safety Statistics

	Overall Results
Total Number of Aircraft	1261
Total Number of Occurrences	193
Average Occurrences Per Aircraft	0.16
Risk Average	1.21
Severity Average	2.21
Likelihood Average	1.83

Source: Created by Author from “Company A” Safety Data

(Please note: The values given for risk, severity and likelihood relate to the “x” values shown in column 1 of Table 1)

In order to provide additional contextual information and support enhanced conclusions, 20% of the dataset was extracted for qualitative analysis using stratified sample techniques. This method ensured that different events were given a different representation within the sample, proportionate to their frequency and contribution to the entire population.

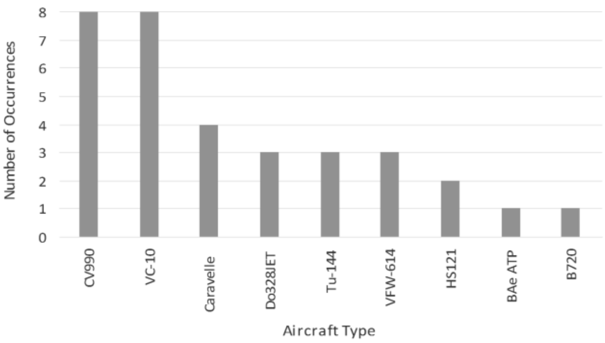
The top-5 occurrence categories were extracted from the whole population, and first sorted according to their frequency. They were then stratified again to provide a proportionate sample of occurrences according to their risk. Individual occurrence events were then extracted from the overall population using a random sampling technique. These results are as follows (Table 3):

Table 3 - Occurrence Extract

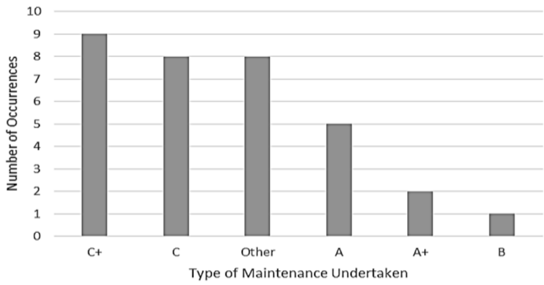
Category	**RISK**					**Subtotal**	**TOTAL**
	Low	**Subtotal**	**Medium**	**Subtotal**	**High**		
Installation Error	O2941-13 O373-14 O2436-13 O431-14 O1148-14 O3108-14 O3116-14	**7**	O3159-13 O95-14 O3104-13	**3**	O1131-14	**1**	**11**
Damage to Aircraft Components	O81-14 O2595-14 O137-14 O67-14 O2077-14 O2930-13 O261-14 O1289-14	**8**	O2850-13 O22-14	**2**	×	**0**	**10**
Collision/ Impact	O2608-14 O2441-13 O2844-14 O2362-14 O75-14	**5**	O2877-13 O2953-13 O804-14	**3**	×	**0**	**8**
Health and Safety Issue	O2909-13 O200-14 O2081-14 O3042-14 O2191-14	**5**	O729-14	**1**	×	**0**	**6**

Parts Damaged/ Unserviceable	O544-14 O3128-14				**2**	O1645-14 O2457-14 O2586-14				**3**	×				**0**	**5**
TOTAL	**7**	**12**	**6**	**2**	**27**	**2**	**4**	**3**	**3**	**12**	**0**	**0**	**1**	**0**	**1**	**40**

Of the 45 events in the stratified sample, 12 were excluded as they provided either inappropriate/insufficient evidence for analysis, or insufficient information to support an assessment of risk attitude. In order to support additional conclusions, the 33 remaining occurrences were then re-categorised by aircraft type, type of maintenance undertaken, and the type of safety report, a graphical extract of this data is shown below (Graph 2&Graph 3):



Graph 2 - Number of Occurrences per Aircraft Type



Graph 3 - Number of Occurrences per Maintenance Category

(Source: Created by author through interpretation of "Company A" Safety and Maintenance Planning Data)

For "Company A" operations, the modal results from the stratified sample conclude that a safety occurrence is most likely to involve a low-risk installation error during "Category C+" maintenance on "Vickers VC-10" or "Convair 990" aircraft**Error! Bookmark not defined.** In order to promote the reliability of research findings, it cannot be determined to what proportion these aircraft and criteria represent the overall operations of "Company A", because factors including increased aircraft exposure would increase the inherent probability of a safety event. This means that whilst the stratified sample is representative of the safety occurrence dataset, it is not necessarily representative of the **overall** "Company A" activity.

The most common resolution proposed within the population sampled was a basic reminder of procedural adherence. This resolution was deemed sufficient for approximately 30% of all events, and a further 20% suggested procedural re-design in an attempt to prevent re-occurrence. The final 50% of recommendations were split equally between events containing an assortment of context specific proposals, and others where no recommendations were provided at all.

Overall, the results within the stratified sample appear to demonstrate that "Company A" is reliant upon traditional "soft" mitigation strategies, in contrast to the mitigation of underlying causal factors such as inadequate human performance, distraction or fatigue. This traditional approach to risk mitigation suggests that by improving its understanding, management and recognition of the effects of risk attitude, there is significant potential for "Company A" to improve its safety defences by implementing strategies to target system-wide human performance deficits, whist continuing to balance compliance and system flexibility.

4. FINDINGS &DISCUSSION

By analysing the relationship between occurrence frequency and aircraft serviced, results show that for “Company A”, the relationship between occurrence frequency and safety risk is not proportional. This suggests that “Company A” operations concur with the accepted theory that the relationship between occurrence frequency and safety risk is non-linear, and there are a much greater number of high frequency-lower risk events than serious fatal accidents. This occurs because statistically, “millions of operational errors are made before a major safety breakdown occurs” [11 & 22].

The inherent uncertainty involved in the management of risk makes it “important to understand [the] factors capable of influencing individual risk attitudes, so that their effect[s] can be countered and managed proactively where they lead to inappropriate responses to uncertainty”. The assessment of “how well people understand the chances that they take, and whether they embrace the consequences” is inherently different for different individuals, and this makes it possible to assign “headlines to describe alternative positions adopted by people when faced with uncertainty” [8 & 9].

Of the events within this study, the results of the stratified sample showed that:

- Approximately 50% of events provided evidence of an active decision making process
- Approximately 60% included an inappropriate or <u>“low” perception of hazard probability</u>. A further 20% showed a “medium” perception, and 20% could not be assessed.
- Approximately 40% included an inappropriate or <u>“low” perception of a hazard’s impact magnitude</u>. A further 35% showed a “medium” perception, and 15% could not be assessed.
- Approximately 40% of events contained a <u>“high” degree of control or choice</u> over the active situation. A further 15% were “low”, and 30% could not be assessed.
- Approximately 40% had an accurate assessment of the closeness of the risk in time.
- Approximately 40% had a “high” perception of the potential for direct consequences. A further 30% showed “low” perception, and the remaining 30% were split between “medium” and “unable to assess”.
- Overall, 28% of occurrences contained insufficient information to support analysis in at least one of the categories required.
- Over 90% of the sample were “error reports”, less than 10% were “hazard reports”.
- Over 70% of events resulted in “tangible” evidence, such as aircraft damage, which could not be ignored.

When combined, results show that the “average” occurrence within the stratified sample contains a low/inadequate perception hazard impact magnitude, and an inadequate perception of theprobability or frequency of occurrence. When combined with the control/degree of choice over an active situation, these results suggest that subconcious perception and risk attitude play a significant role in the occurrence sample, in contrast to examples of active, conscious risk taking.

As a key element in the recognition of uncertainty, perception is integral to the management of safety risk. Unfortunately, basic human fallibility means that perception and risk attitudes are “exposed to sources of explicit and implicit bias, since all elements of the risk management process are performed by individuals”. The three main categories of bias are referred to as conscious, subconscious and affective [9].

The inherent existence of all three biases means that each factor must have its own consequences, and so effective quantitative safety performance monitoring and measurement (SPMM) is vital if their effects are to be monitored, and active and latent and hazardous conditions are to be detected. This means that by facilitating causal chain analysis, SPMM is capable of looking past the outcome, and so provide an invaluable insight into the true causal factors of an event. By recognising the widespread applicability of such factors as distraction, SPMM can then support the necessary frame work to mitigate the same potential contributory factors in future, unrelated events [11].

For "Company A", the lack of detailed or reliable information contained within the stratified sample of occurrences means that the influence and existence of risk attitude situational influences, and various individual and group based heuristics cannot be assessed in a quantitative manner. For this reason, it is not known to what extent the various biases influence risk attitude, perception and the underlying the hazard identification process.

5. CONCLUSION

The results of this study have demonstrated the significant relationship between risk perception, risk attitude, and the efficacy of the hazard identification process. A considerable number of conscious, subconscious and affective influences are known to affect the management of perceptions and risk attitude, and so the management of this subjectivity is essential if the appropriate balance between system compliance and flexibility is to be ascertained.

Whilst the results of this study are extracted from a much larger summary of around 20 specific recommendations, the results of the stratified sample have shown that it is not yet possible to reliably quantify the risk attitude and perception biases that are present within "Company A" operations because of the variable and subjective nature of the current SPMM process. This means that "Company A" must recognise that an explicit decision making process, optimised communications, and an increase in situational awareness are essential in reducing bias and uncertainty, because central to the achievement of any goal is a "clear understanding of the nature of the [risks involved] as well as the ability to determine the influence of risk attitude on decision making" [8].

Situational awareness is key to reducing uncertainty and understanding "how people's actions and assessments actually made sense at the time". "Progress on safety comes from understanding and influencing these connections" and this can only be achieved through the continual monitoring of operational performance using human-centric reporting methods, safety surveys and internal safety investigations whilst continuing to create contexts and situations in which the correct perception and risk attitude are most likely to be adopted by both the system and an individual [2].

The importance of SPMM means that "Company A" should continue to develop its safety database and recording categories, and so improve its collection of the high-frequency, low-consequence event data capable of providing large quantities of information devoid of the contextually limited conditions of an accident or incident. This information has the potential to provide "Company A" with the quantitative data necessary to reliably monitor and mitigate the effect of various risk attitude influences, whilst continuing to improve learning potential and manage operational risk.

"Company A" should attempt to increase the proportion of proactive and non-punitive hazard reporting, and reinforce its importance across the entire organisation. This should be supplemented by an anonymous reporting system, and a receptive safety attitude whereby feedback is provided to individuals who report their concerns, and material is safeguarded so that it used solely for the enhancement of system safety. Importantly, the success of any reporting culture can only be achieved alongside an appreciation of the essential foundations necessary to support a "just", proactive and generative safety culture [11].

Further monitoring of maintenance planning data could also be incorporated to include factors such as the distribution of aircraft across an annual maintenance period, the ratio of scheduled/unscheduled maintenance, aircraft age and familiarity, and the recording of any delays to the maintenance timetable. This information could be used to support additional quantitative conclusions, and additional personnel information could continue to monitor other human factors including staffing levels, personnel experience, and task allocation alongside other latent individual and group risk attitudes.

In addition, whilst "Company A" currently assesses risk against the potential impact on flight safety, this strategy is not without limitations. Risk is a complex entity, and it must be acknowledged that different events will carry inherently different levels of different risk types, including personnel safety, aircraft damage and potential business risk. "Company A" should therefore consider the benefits of incorporating different risk categories in order to increase the value of its SPMM.

In order to enhance its latent system understanding and improve situational awareness, "Company A" should also acknowledge the potential benefits of both risk attitude diagnosis and assessment. By helping to "diagnose the presence and strength of various drivers of risk culture", such assessment would help to facilitate minor and routine adjustments to operations, and make the organisation "alert and responsive to both upside and downside uncertainty". For this reason, "Company A" should consider the adoption of a strategic audit of risk attitudes as part of a strategy for both new and existing employees [9].

Such audits could utilise scenario based assessments, and both individual and group based questionnaires could be developed to expose a hypothetical risk(s), and then assess and evaluate participants chosen responses. This would allow the comparison and assessment of both individual and group risk attitudes, and "Company A" could utilise factors such as the framing effect to influence survey design, and so recognise the implications of question wording and form. In addition to operational changes, a strategic audit also has the potential to allow "Company A" to monitor and improve the performance of its safety culture, minimise threats and maximise opportunities [13].

The greatest asset to any AMO is its constituent staff members. Responsible for both system design and operation, it is these individuals who make the "moment-to-moment adjustments" necessary to ensure that operation is successful in an environment vulnerable to "unidentified effects". This means that a mindful organisation recognises that "there is variation in [routine activities], but there is stability in the cognitive processes that make sense of this activity". The monitoring, management and understanding of these cognitive activities is therefore integral to the management of safety risk [16].

By providing "instruction[s] on error-provoking conditions", it is possible for "Company A" to provide" frontline professionals [the] mental skills necessary [to make] rough and ready assessment of the error risk in any given situation". This assessment can be compared against a scale devised by and appropriate for "Company A" operations, and so allow personnel to further their appreciation of their own perceptions and risk attitude. If utilised correctly, examples of error wisdom methodology have the potential to promote mitigating actions, and the avoidance of situations where a high error or risk potential is perceived [16].

In conclusion, this study has helped to demonstrate that risk attitude is an essential component in the hazard identification process, and for a human-centric system, the individual is not only capable of being a system's single greatest weakness, but also its single greatest asset. Ultimately, this means that despite complex defence and mitigation strategies, safe and sustainable operation can only be achieved by having the right person, in the right place, with the right response, at the right time, and it is only through enhancement of its management and understanding of risk attitude that "Company A" can take one step further toward this illusive and virtuous goal.

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MARS – A FRESH LOOK AT RISK ASSESSMENT MODELLING AND EFFECTIVE SAFETY DATA COMMUNICATION

ABSTRACT

Aviation industry's safety management is strictly regulated since the introduction of Safety Management System (SMS) concept and it is propagation through the industry and literature. Safety and Risk are in the focus of the constant research ranging from strictly technical and technological to organisational influence. Still effective and practical assessing and communicating the risk is a challenge thus diminishing optimal enhancing of organisations' safety level. The paper will analyse the literature for the SMS in aviation for their ability to account for the complex dynamics from which safety in these kinds of systems tends to emerge – or not. Evolution of safety assessment methods and methodologies (including) the systemic models (RAG, FRAM, STAMP) will be presented. After this, it will introduce MARS as a model by describing the general features and their connection with biometrics for varied practical and theoretical reasons. Conceptual description and presentation of the model will be followed by presenting mathematical approach in the model. General presentation of mathematical approach will be applied to a case study involving aviation organisation and related data (related to Human, Technical and Environment factors). Finally one of these factors will be defined and analysed more in detail demonstrating the effectiveness and application of the MARS on the operational data.

KEY WORDS

Air Traffic Control, Training, Safety Management Integration, Risk Modelling, Safety Management System, Human Factors, Safety Data

1. INTRODUCTION

High reliability Organizations (HRO) are complex socio-technical systems where the correct functioning is guaranteed only in case of an efficient and coordinated functioning of each system component, i.e. aviation, railway, nuclear plants, healthcare. In addition, in HROs, any failure may have a catastrophic effect on the environment, on the operators and on people not directly involved in the process, too. In these complex systems, the Safety

Management System (SMS) provides a systematic way to identify hazards and control risks while maintaining assurance that these risk controls are effective permits to manage safety, ranging from initially reactive to proactive and finally predictive approaches. Aviation is one of the HRO where safety methodologies are in continuous evolving process. Conditions for work in aviation significantly changed over the past decades. In detail, between 2009 and 2014, revenue in the global aviation industry grew at a compound annual growth rate of around 7.4 percent, reaching $9 billion U.S. dollars net profit in 2014 [1]. Aircraft movements in terms of aircraft departures and aircraft kilometres flown for the period 2005-2025 have been expected to increase at average annual rates of 3.6 and 4.1 per cent, respectively. The growth of passenger traffic on the major international route groups has been expected to range from 3 to 6 per cent through the year 2025. In detail, at European level, the flight growth stabilizes at around 2.6% increase per year, showing higher rates in 2016 and 2020, as demonstrated in [2] for the EUROCONTROL Statistical Reference Area (ESRA) analysis.

It has been more than 120 years since the start of accident causation analysis, aiming at prevent them or minimizing their effect. The classic view of safety aims at decomposing systems into basic functions and evaluates in detail each component failure probabilities. Along with this point of view, decomposition of systems in their components allows a detailed and stable description, enabling an accurate analysis of the causes of events. By the way, as socio-technical systems, such as HRO, are continuously developing, work environments have gradually become more difficult to understand, with reference to their complexity.

As a result, since the classical safety analysis assumes that systems are tractable in the sense that they are well-understood and well-behaved, classical models and methods become [3] progressively unable to describe and properly focus on safety. The probability of occurrence of a safety event is due to several factors, depending on technical and procedural aspects, operating system conditions, human factors and service level constraints that the system has to guarantee. It is then possible to link these conditions to a risk level, which indicates a safety event probability of occurrence. This view perfectly fits with the aviation needs, where large numbers of human operators interact with procedures and technical systems, in a variety of locations, with the common target of flying safely and efficiently [4]. Considering the high service levels required and the recent evolution in traffic volume, aviation becomes one of the most critical HROs, where the need for enhanced safety assessment techniques is very important.

This paper focuses on safety in aviation, developing a model, i.e. the MARS, which takes into account the safety features of an organization in the aviation context (ANSP, airline, ground handling, etc.). The MARS addresses the organization criticalities in order to give high-level information to the decision-makers and thus enhance the organization' safety level. The contribution of the paper are as follows. In the first section, this paper shows a literature review on the evolution of safety assessment techniques over the past decades. Then it presents the conceptual framework of MARS and it basic mathematical approach. In the third section, the paper shows an application of MARS to evaluate the safety performance of an airline. In the conclusions, the paper discuss on the possibility to evolve the proposed model, paving the way for further research.

2. LITERATURE REVIEW

Accident analysis and risk assessment methods have usually been developed in response to problems following major technological developments or to cope with "new" type of accidents. As shown in Figure 1, it is noteworthy that human factor methods came onto the scene after the accident at Three Miles Island in 1979 and that organizational methods were developed following the Chernobyl and Challenger accident in 1986 [5]. Systemic model arises, according to current system safety needs, where inter-related connections and tight coupling between functions lead to consider a system-wide perspective.

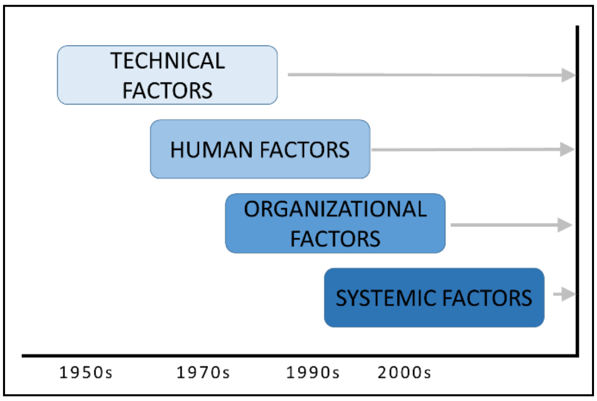

Figure 1 - The evolution on safety assessment [36]

Risk has been under scrutiny as early as the 17th century. Roelen [6] makes the point that it was mainly the financial risk that has been studied and analyzed. Initial approach to accidents as sporadic events with "Act of God" nature has been modified so contemporary research about accident causation in industrialised society has been developed by end of19th and early in 20th century. Griffin states that the initial approach to explain accidents solely by the characteristics of their participants has changed by the introduction of the "Domino Theory" in early 1930s [7]. In this model, Heinrich has connected different elements in the chain of events that lead to an injury or accident. Among these latter, there were societal circumstances, human error, operator's background as well as the accident trigger event. The focus of all early models on accident circumstances originated from military and industrial organisations where they were developed and applied initially to reduce the number of injuries and financial losses generated by mishaps and unsafe acts. Towards the mid-20th century, initial causation theories were enriched by new elements and some models for conflict predicting have been added to mainly reactive methods in use.

Netjasov and Janić stated that one of the first models that International Civil Aviation Organisation (ICAO) attempted to tackle safety and capacity over the North Atlantic was "Machol-Reich" in late 1960s [8]. Still the number of accident investigation models superseded the number of accident prediction (by risk assessment and management) until 1970s. Improvements in systems safety due to the shift in understanding the influences on systems operations and safety from technological to human and organisational factors have gradually diminished. Hence, as Netjasov and Janić stated, new elements had to be introduced to develop models that are more advanced. For example, management and management related influences were introduced by Weaver [9] initially followed by Bird and Loftus [10]. The initial three elements from the "Domino Theory" have been linked when Adams [11] introduced organisational error as an element. Finally the 90s "Generic Error

Modelling System" developed by James Reason [12] has been enabled through Johnson [13] and his barriers to error discussion. James Reason's widely accepted accident causation "Swiss Cheese" model (RSCM) is represented by rotating cheese slices: when the threat makes it all the way from its origin through aligned "cheese" holes, it materialises and accident happens. Provided any of the slices blocks the path, the threat cannot develop further to a mishap. Despite the fact that this theory has helped to develop others, e.g. TRIPOD [14] and DELTA [15] it does not offer practical guidelines to modelling safety, rather it propose a qualitative evaluation. In addition, starting from RSCM, ESARRs [16] propose a set of indicators that could be combined by the Aerospace Performance Factor (APF), in a quantitative Safety Index [18-19].

The end of the 20th and early 21st centuries have brought new challenges in understanding accident causation in aviation. Contemporary systems have commanded the need to adjust our "common" modelling to their advanced and new logics. Papers and books from the late 90s indicate several attempts to design over encompassing and comprehensive SMS models. Rasmussen's [20] early overview of safety in complex socio technological systems established the basis of related research areas focused on factors contributing to an accident within those systems. "Normal Accident" theory introduced by Perrow [21] explains system accident by complexity and interrelation between systems. This is reinforced by Reason's study [12] of organisational factors and the structure that contributes to accidents. Following this approach the HRO name has been introduced to describe management of complex systems as in Rijpma [22]. Focused attention to organizational factors and conditions contributing to system safety resulted in Hollnagel et al. introducing the notion of resilience [3]. This has allowed for formal analysis of systems' organizational structure, conditions and their response to developing safety issues. Alongside these developments. Aviation has addressed issues and adopted recommendations through SMS [23]. Leveson confirmed that models originating from the end of the 20th century did not reflect the complexity of accidents entirely [24].

This is very much so when they deal with systemic factors, e.g. limits in the organizational structure, inefficient management or limited safety culture of the company or the industry in general. Thus, it would be of an utmost importance to understand how the system, with all relevant organizational and societal components, may induce accidents [25]. In addition, Leveson makes a point about how, in systems managed by human as well as computer software, errors do not occur separately. They are even more affected by the management or procedural flaws, which are not taken into account in traditional models. Roelen [6] agrees and adds to that how the value of probability of the occurrence that works for technical components cannot be the same if a human component has a role in the event. Finally, reflecting on "The Event Analysis of Systemic Teamwork (EAST)" model characteristics, Griffin [7] concludes that new models should address the system in its entirety not as the sum of isolated events or participants [26].The authors agree that accident modelling should encourage a holistic view on accident causation even before the mishap. There are more than 22 threat assessing models and software packages as per FAA [27]. Focusing on operators, physical components failures or weak elements in technological procedures can potentially cause missing some of the vital factors in future accident prevention.

According to Griffin, new models should enable the study of the systems' behaviour as a whole in both normal and out of normal state to be able to study their performance indicators. They should be based not only on linear dependency of the elements, but take into account other types of dependencies such as feedback between model elements. Different model levels connected either directly or indirectly should be able to influence and exchange feedback between each other.

Problem analysis through systemic approach advocated by Rasmussen made Leveson conclude that understanding the intention, purpose and the decision for system design is crucial for successful accident prevention. Focusing on operator's actions, system failures or technological flaws could lead to serious omissions in capturing some of most influential future accidents' prevention factors. Risk modelling should address more than the accident mechanism only for more comprehensive investigation practice. On this path, the probability of failures at "sharp end" and organization structure at higher levels are interconnected. A stabile state, input and output variables together with their functional relationship are crucial for assessing the level of management's influence on risk. Finally, impartial risk assessment following modifications to system (either due to new technology or regulations) provide for more general application of new models.

Netjasov and Janić state that the complexity of models that can cater for characteristics mentioned above require a modular approach that would simplify the process. Simplification is the reason for having models that can be used by general users. Replication of the calculation and results validation are next in line of the desired characteristics of the models. The representation of complex systems by models inadvertently results in their complexity and lengthy calculation process. Identified by Roelen that positions the usability of the model over the complexity of the same. According to Griffin the very exact and unforgiving nature of aviation as an industry drives requirements for replication of results and knowledge transfer from model designers to their users. They vary from "sharp end" operators across management and regulators to academia. As Stoop [28] states, different users require different information to be able to identify systemic challenges. Operators need information for safe operations. Management and regulators need indications and means for safety system design. Finally, academia seek to understand system's nature and the effect of suggested modifications or the need for different ones. Finally as Netjasov and Janić state, the effective and transparent use of module results would be possible only if their output is presented by units that can be validated objectively [8].

In the industrial context, several methods have been developed, or are currently under an improvement process (e.g.) the Functional Resonance Analysis Method (FRAM) [29] and the System Theoretic Accident Modeling and Processes (STAMP) [24], the Resilience Analysis Grid (RAG) [30], which agree that a system-wide evaluation is strictly necessary to consider resilience performance of an organization. Resilience acquires, indeed, a fundamental role in the ATM system, where large numbers of interacting human operators and technical systems, acting at different levels in a variety of locations, must control air traffic safely and efficiently in the context of uncertainty and disturbances [4]. These models, however, offer a reliable conceptual framework and qualitative evaluations. On the contrary, the model proposed in this paper, i.e. the MARS, shares the systemic perspective of STAMP, FRAM and RAG. In addition, however, the MARS shows the possibility of developing a quantitative holistic index capable of defining the safety features of the system. This index could help the decision-maker in assigning resources and find the criticalities in the process in order to enhance the safety level of the organization.

3. THE MODEL: "MARS"

3.1.The General Features of the Model

In the process of risk management, today risk assessment at the level of isolated events is relatively simple and common. The problem is how to assess and monitor risk at the level of individual safety cases or the entire system such as an airline or Air Navigation Service Provider (ANSP).The creation of a safety case reduces the visibility of the numerous events resulting in smaller effect, compared to the relevant individual cases where the realisation of the threat can have catastrophic consequences for the system.

3.1.1. Conceptual Description of the Interaction between Model's Elements

Suitable choice of the methodology and presentation in an appropriate model would enable that the risk, which in itself is not easy to grasp and display, can be effectively assessed and presented in the system that is being observed.The diversity and complexity of world and systems requires the representation of complex processes or situations through models. The basis of each model are its constituent elements and relationships between them.The overall risk of the system consists of all the risks that are involved. It is very difficult to predict all the potential risks in the system. This is even more difficult if the incidents had not yet developed into a serious accident or an unexpected event, and therefore there has been no formal investigation about the same.The reason for this is that the complex interactionsamong individual system's elementscannot be described in precise mathematical terms. Therefore the construction of an appropriate model containing elements of the level of risk and their interpretation in line with the nature of observed aviation system's stakeholder is suggested. Such a model would be able to assess the level of risk in the system observed at a given point of time or the level of its development. Along the lines of previous discussion, the ease of use and accurate reflection of current state would be benefits to the model as well.

3.1.2. The Lumbar Spine and Model Construction

Biomechanics characterises the study of the characteristics of movements of man and their impact on the human body. The lack of appropriate models to assess and control the risk at safety cases level, together with works from biomechanics by authors such as Sušić [31], indicated that the possibility of finding solution for modelling the risk in biomechanics. The analysis of forces and moments in motion of the human body faces comparable problems to those in complex systems such as aviation. For example, the elements of lumbar spine (as in Figure 2) with its loin vertebrae and discs, dorsal and ventral muscles and intra-abdominal pressure are in some functional interrelation that provides lumbar spine functioning and physiological capabilities. Hansen confirms this idea [32]:" Both systems are characterised by the interaction of their subsystems and features that do not allow the examination of the level of risk and effective proactive action to risk using the method of trial and error (or invasive methods in medicine)". Therefore given the above discussion the analogy with the system of lumbar spine will be used for the transport system (i.e. transport stakeholders).

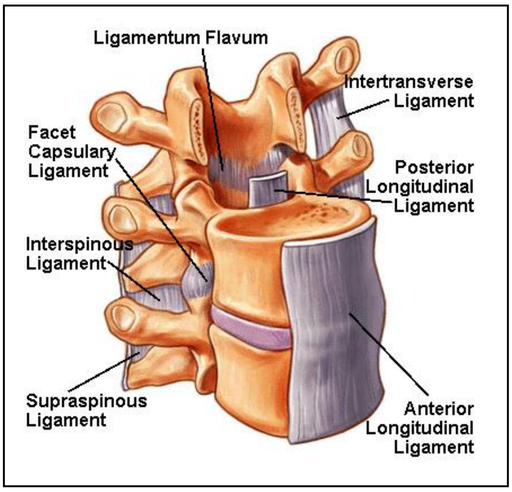

Figure 2 - Lumbar Spine Model [37]

3.2 Identification of Human, Technology and Environment Macro-Factors

Namely, everyday tasks which the human body is exposed sometimes, just like an accident or crash of an aircraft, bring the system into a state in which the upper limitsare exceeded when it moves from a stable state to an unstable one. This case reflects on a human body as an injury or illness, and is not acceptable. Similarly, in the transport system an accident, even incident, is not an acceptable result.

Talking about the system of the lumbar spine, a problem arises because of the impossibility of direct measurement of all parameters within the system. Permanent and real risk of injury requires compensation and internal countermeasures which body uses to bring the system into a safe form. In the absence of information on compensating values in cases when the system is brought back before a critical condition, the problem is then assessed analytically and biomechanics modelling is used as a method. Likewise, the fact that an accident or even a serious accident did not occur in the company or the system does not diminish the importance of information that can be obtained from them. When information available within the system are plugged in the appropriate model, it should collect and feed them forward for decision making. Focusing the attention to essential issues, the model should serve to identify the effective forms of action and generate warnings when situations lead to something more than an incident [32].Definitions of all three categories of aviation mishaps (i.e. incidents, serious incidents and accidents) involve technological (and technical), environmental and human macro-factors (as in Figure 3.). Therefore, the modelling approach links the level of risk and outcome of emergency taking into account the characteristics of comprehensive aviation system and its stakeholders. Assessing the level of risk of individual stakeholder or safety case is done with regard to the above three elements that describe undesired events. The model name is "The Model of Aviation Risk Study" or abbreviated “MARS” [33].

The level of risk in the system will present an analytical model that consists of three macro-factors (as seen in see Figure 3). They are technology, human and environment (i.e. legal environment and regulations) in which the stakeholder (i.e. air carrier, ANSP, or airport) exists and operates. The dynamic characteristics of the transport system and its vertical structure (i.e. macro-factors of the model) are a source of diverse influences.

Therefore the risk level of a stakeholder represented by this model is influenced by the characteristics of its three constituent macro-factors. Concurrently the same stakeholder acts on these three macro-factors modifying them more or less (as indicated by arrows pointing from the risk towards each macro-factor). Note that the interaction between each macro-factor individually, represented by full and dashed line arrows, generates the change in their characteristics (aggravating or alleviating in relation to the level of risk). The consequence of changes in characteristics of macro-factors is the change in their impact on the risk of the stakeholder (indicated with arrows pointing from them towards the risk). At the same time they change in the way in which they react to the impact that company (i.e. stakeholder) has on them.

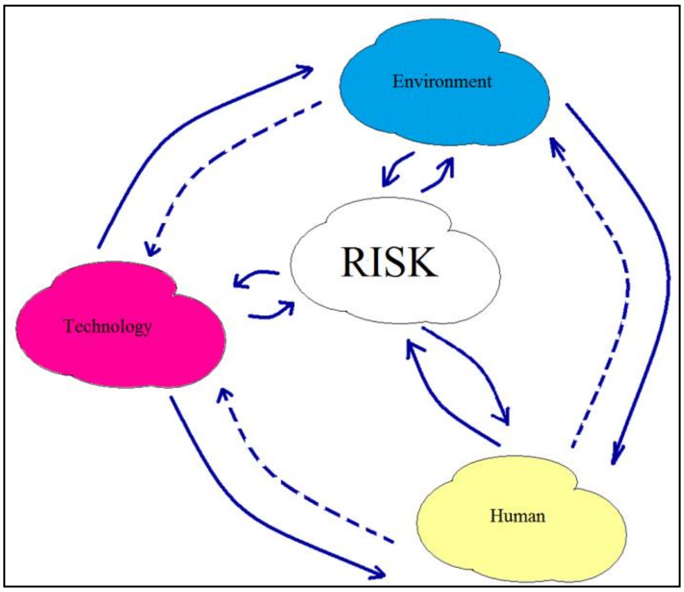

Figure 3 - Conceptual Description of the Interaction Between Human/Technology/Environment as a Basis for MARS Modelling Approach [33]

If one considers, for example, the risk of Controlled Flight into Terrain, the availability of certain technology (e.g. Enhanced Ground Proximity Warning System) leads to prescribing its mandatory installation by organisations such as ICAO, US FAA or EASA in Europe. All of these results in changes that introduce new technologies in the legal environment of the country in which an airline operates. By incorporating this technology in aircraft it is necessary to adapt procedures and training of the crew in order for technology to be used most efficiently. The result of all these activities is the total reduction in the level of risk in the system.

3.3 Define the Conceptual Mathematical Approach in MARS

Keeping the analogy with the system of the lumbar spine, the safe state of the air transport system (or each of its stakeholders) corresponds to the resistance to injury. According to Sušić ([31]., p.1), this is "the result of the continuous process of the internal control, always striving to influence the distribution of internal forces by a process that aims to optimise the allocation of roles and load through physiological logic in order to reduce the risk of injury to the spine." [26, p.1]

Physical interpretation of certain macro-factors of the model (see Figure 4) consists of blocks of a specific shape and weight that can rotate around the shaft. It is important to emphasise that the physical representation of the model is primarily to support our analogy aiming at presenting the features that are important in discussion of certain macro-factors and the method to calculate risk using MARS eventually. Following this interpretation the risk in the system can be represented by a single value obtained using equations 1, 2, and 3. below [33].

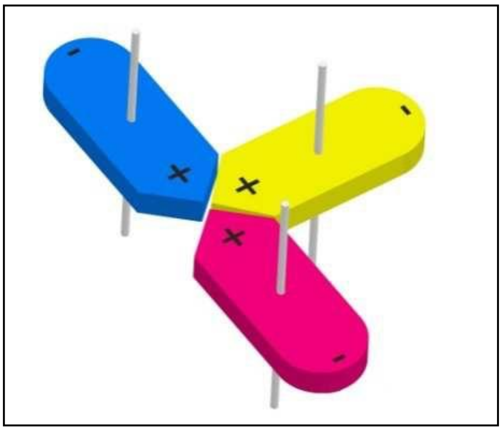

Figure 4 - MARS Model Physical Representation [33]

The value of risk within the system observed is expressed as Equation 1:

$$R = \frac{1}{W_E \cdot \eta_E + W_H \cdot \eta_H + W_T \cdot \eta_T}, R \in \boldsymbol{R} \qquad (1)$$

Where:

R the total risk of the system,
W_E the weight of Environment macro-factor,
W_H the weight of Human macro-factor,
W_T the weight of Technology macro-factor.
η_E the total efficiency of influence for Environment macro-factor,
η_H the total efficiency of influence for Human macro-factor,
η_T the total efficiency of influence for Technology macro-factor.

The mass of each block (representing macro-factor) in (1.) is:

$$W_i = 1 - \left(\frac{C_{O_i}}{C_{TTL}}\right), W_i \in [0,..,1], i = E, H, T \qquad (2)$$

$W_i \in \boldsymbol{R}, C_{O_i} \in N, C_{TTL} \in N$

With:

C_{TTL} the total number of events with reduced level of safety,
C_{O_i} the number of events where destabilisation was observed due to one specific macro-factor (indicated by index).

Total efficiency of influence for each macro-factor (i.e. block of the model) is given by Equation 3:

$$\eta_{MF} = \max\{0, \frac{(\eta_{MFP_1} \cdot k_{MFP_1} + \cdots + \eta_{MFP_n} \cdot k_{MFP_n}) - (\eta_{MFN_1} \cdot k_{MFN_1} + \cdots + \eta_{MFN_m} \cdot k_{MFN_m})}{\left(\sum_{i=1}^{n} k_{MFP_i} + \sum_{j=1}^{m} k_{MFN_j}\right)}\} \qquad (3)$$

Where:

$\eta_{MF} \in \boldsymbol{R}$, $MF = (E, H, T)$,

k_{MFP_i} and k_{MFN_j} are order of influence for positive and negative impact factors related to one macro-factor. The values selected are related to a particular stakeholder or safety-case under study, η_{MFP_i} and η_{MFN_j} efficiency of influence for positive and negative impact factors related to one macro-factor. The values in range from 0.1 to 0.9 as discussed in the text (see §4).

The maximum value for equation 3 is 0.9 while the minimum is 0. Although there might be cases where the solution of the equation 3 might be less than 0 we will assume that for all those cases the solution is 0. This is the case when the total efficiency of influence for negative impact factors is larger than for positive hence we conclude that the concerned macro-factor does not contribute to risk resilience and this is in line with the assumptions for MARS.

With all three equations presented we conclude that the risk value is a number from 0.37 to 10.More precisely speaking there is no upper limit for the risk value. When each and every block weight is close to or at 0, the value for risk is moving towards the infinity regardless of total efficiency of influence. At the other end the value of 0.37 indicates the optimal values of macro-factors' weight and efficiency of influence. In that case each mass is 1 and corresponding efficiency of influence is 0.9.

4. MARS APPLICATION IN A CASE STUDY

Following conceptual discussion of the model, and the presentation of the mathematical representation of the risk value generated by the same model, a safety case study of missed approach risk is presented. In order to accomplish that MARS has been integrated into the real data from the flight operations of an airline. The risk of Missed Approach operations reported is to be evaluated by MARS in a specific organization.The input data for the model are the total number of observations, the number of observations related to each macro-factor of the model, the order of influence, and the efficiency of influence for each individual macro-factor. A missed approach is a normal form of flight operations. Flight crews are prepared and trained for it, if needed. However, as it does not happen too often, the crew usually report them and indicated the problems that they had at some of these events.

Lumbar spine as well as the observed system, experience the transition from steady state in unstable as a result of insufficient capacity to resist the destabilizing influences with all possible means. This will also make the use of analogies between their mechanical capacities possible. Mechanical capacity of an assembly, including the system of the lumbar spine, and in each macro-factor of MARS model corresponds to the difference of the total capacity of the system and that part of the capacity that is spent on losses.Hence difference between the total number of observations (i.e. missed approach flights performed) and the number of flights where the destabilization of one of macro-factors has been reported represents the ability of the system, or its capacity, to resist destabilization due to the effect of that macro-factor (as in Equation 4.)

$$C_{MF} = C_{TTL} - C_O \qquad (4)$$

where:

$$C_{MF} \in [0, C_{TTL}]$$

and where:

C_{MF} the number of events that did not result from destabilization due to one specific macro-factor studied.

C_{TTL} the total number of events with reduced level of safety,

C_O the number of events where destabilization was observed due to one specific macro-factor, i.e. the inertia of the block has not been enough.

Although with this approach one cannot be certain about which of the remaining two macro-factors may have contributed to the steady state in the safety case considered this is not critical. Their direct impact on the resilience of the system will be assessed when events related to their effect will be considered.

The total number of flights and the number of flights related to the destabilisation of each macro-factor are taken from Flight Data Monitoring system across January 2006 and February 2011. In this period, there were 2786 observed cases. This period also cases within it are divided into two adjacent periods. Sample 1 covers the period from January 2006 to March 2009, and Sample 2 period from April 2009 to February 2011. The number of missed approaches in these periods are 1741 and 1045 respectively.

Following one of the most common classification of safety related events (i.e. IATA STEADES) one has to break down safety cases in their elements that map to the one of macro-factors in MARS. Thus let us consider technical macro-factor to discuss in more details the elements of the Equation 1. Technological macro-factor is represented by a purple block on Figure 4. It may include events related to the technical means and the technological procedure applied in the process of transportation. The weight of the blocks is different and varies depending on the size of the financial investment in particular element. Each block has its own mass. Note that for the sake of this presentation the masses of blocks are not taken together as a system of mass.

Following its physical meaning, weight block affects its inertia, and thus his behaviour when in operating environment exerts torque through the shaft on which it is located. The weight of 0 represents the moment when the block is the lightest and does not provide any resistance to change. The weight of 1 represents the greatest resistance to change in that block (e.g. human or technical or environment macro-factor of the system).Following Equation 4 and the physical interpretation of the mechanical capacity, one can divide the entire equation by the total number of observations C_{TTL}. This leads to the Equation 5 that describes the inertia and the mass of a macro-factor (i.e. block) that is under consideration.

$$W_{MF} = 1 - \left(\frac{C_O}{C_{TTL}}\right) \qquad (5)$$

where:

$$W_{MF} \in R, W_{MF} \in [0,..,1]$$

Analogue to the discussion of block's mass one can conclude that the inertia of the block is 0 when all observed events were due to the destabilisation of the particular block. Consequently if none of the observed events can be associated with the block under consideration, then the inertia is 1. This way the weight of the block has been measured. The weight results in block's inertia that is, on the other hand, important to determine the total resistance of a system to destabilisation. Above discussion prove that the usage of analogy from biomechanics has allowed operational evaluation of the level of risk. The assessment of the blocks' masses has been independent of the knowledge of the amount of investment in a particular block with respect to a nominal maximum investment that would lead to the maximum mass of the block and the greater resistance to destabilisation consequently.

Numerically for the proposed case study the total number of missed approach events has been classified as per macro-factor and the time they happened. Taking in the account the total number of missed approach flights (C_{TTL}) as well as those that have been observed to depend on a particular macro-factor (C_O) the inertia (W) of each macro-factor has been calculated using Equation 5(see Table 1.)

Table 1 -Mass values for each macro-factor in both case study samples

	Sample 1 ($\boldsymbol{C_{TTL} = 1741}$)			**Sample 2** ($\boldsymbol{C_{TTL} = 1045}$)		
	T	E	H	T	E	H
$\boldsymbol{C_O}$	603	448	267	341	279	182
$\boldsymbol{C_O/C_{TTL}}$	0.35	0.26	0.15	0.33	0.27	0.17
$\boldsymbol{W}$	0.65	0.74	0.85	0.67	0.73	0.83

One can conclude that resistance to destabilization increases with mass and reduced number of events observed associated with the macro-factor under consideration. Having calculated W using Equation 5, one would continue finding out the order of influence (k) for each macro-factor of MARS as presented in Equation 3.

Quantifying k is the important step to describe the system completely. Using biometric analogy k represents measurements that describe a human body for the sake of analysis. Total values of k on the risk for each of the macro-factors are the final element of the model used to characterise the level of risk of the system under consideration (i.e. an airline in case studied).Adopting the assumption of Reason that the safety space as constant change [34] MARS cannot assume a condition in which there is no positive nor negative activities (i.e. blocks must touch each one at their ends). Mathematically the absolute value of $k$determines the shape of the end of each block in MARS model (round or sharp). As seen on Figure 3, the shape depends on whether at any particular moment in time there are activities, (i.e. control decisions) that organization performs as a response to the realistic risk.

Binary information on whether there is an influence or not is not good enough to quantify the value of risk. Qualitative representations of impact on the risk from each macro-factor have to be converted to quantitative values in an appropriate manner for the model to reflect the characteristics of the system. Converting qualitative into quantitative values has been addressed in the works related to the Multi-objective Decision Making that discuss problems in which experience and knowledge of the organization or system should be considered when making decisions.

One of the most challenging phase [35] in the process of multi-criteria analysis would be the identification problems and it has been accomplished by understanding the impact on the risk while developing model MARS. The overall impact is thus decomposed in sub-problems (i.e. macro-factors).

Positive and negative impacts are taken into account for the purpose of objective assessment of the overall impact on risk. This is not the only approach to selecting the set of factors that could significant impact. By changing the conditions to be taken into account one modifies the focus of model.

Assigning a higher k value to a positive impact or to a negative impact results in higher effect on the risk value in the final assessment. Hence assigning relevant $k$values is of real importance. Therefore this task should be accomplished very carefully. Initial setup can be based on relevant standards (e.g. ICAO STEADES or similar). Additional k adjustments can result in a more accurate assessment of the level risk corresponding to the conditions within the company or companies compared using MARS. Table 2 demonstrates the order of importance (i.e. rank) for various positive and negative impact for each of macro-factors in the case studied. Note that Table 2 is based on a research activity with a group of subject matter experts, following the approach developed by Sikora in [33].

Table 2 - Order of importance for specific macro-factors

Rank	Influence					
1	TP5	TN3	EP3	EN4	HP5	HN5
2	TP2	TN1	EP6	EN3	HP1	HN7
3	TP3	TN2	EP5	EN6	HP3	HN4
4	TP1	TN4	EP7	EN2	HP4	HN1

Having Equation 3 as the means to establish the total efficiency (η_{MF}) of a macro-factor what remains to be calculated is efficiency of each and every positive or negative impact factors within that macro-factor. Nominally, they can assume values as per Table 3.

Table 3 - The efficiency of macro-factor (η_{MF}) ranges [32. p.86]

η_{MF}	Characteristics
0.90	Extremely High
0.75	High
0.50	Sufficient
0.25	Insufficient
0.10	Negligible

The value of η_{MF} can go up to 0.9 because once can never be sure that the organization has fully exploited the potential impact of a factor. Likewise the lowest value is 0.1 because even in the case that the degree of efficiency is negligible one has to take into account this little potential impact.

Note that this is only one of the possible choices for η_{MF} intervals. These can be based on decisions within companies, adopted standards or using the experience of comparable organisations.

Observing the activities of the company for the period in which the risk is assessed one can determine η of impact factors (see table 4.).

Table 4 - The efficiency of macro-factor impact factors in case study periods

	TTL i	Sample 1		Sample 2	
TP2	23	15	21.4%	8	11.0%
TP3	2	1	1.4%	1	1.4%
TP1	38	19	27.1%	19	26.0%
TP4	80	35	50.0%	45	61.6%
ttl TP_i	143	80		73	

	TTL i	Sample 1		Sample 2	
EP3	44	16	19.0%	28	28.3%
EP6	64	26	31.0%	38	38.4%
EP5	75	42	50.0%	33	33.3%
ttl EP_i	183	84		99	

	TTL i	Sample 1		Sample 2	
HP2	49	25	29.4%	24	25.0%
HP3	22	11	12.9%	11	11.5%
HP1	99	40	47.1%	59	61.5%
HP4	11	9	10.6%	2	2.1%
ttl HP_i	181	85		96	

For example case study's $\eta_{MF}$of impact factors for technological macro-factor for two observation periods is given in Table 5.

Table 5 - The efficiency of technology macro-factor's impact factors calculation

		Sample 1		**Sample 2**	
Impact Factor	k	η	$\eta \cdot k$	η	$\eta \cdot k$
TP2	9	0.21	1.93	0.11	0.99
TP3	5	0.01	0.07	0.01	0.07
TP1	3	0.27	0.81	0.26	0.78
TP4	1	0.50	0.50	0.62	0.62
		η_T=	0.18	η_T=	0.14

Similarly once established for each macro-factorη_{MF} allows us to find risk value in the system using Equation 1. (see Table 6 below)

Table 6 - The Value of Risk for Two Periods in Case Study

	Sample 1			**Sample 2**		
	T	E	H	T	E	H
	603	448	267	341	279	182
C_O/C_{TTL}	0.35	0.26	0.15	0.33	0.27	0.17
W_i	0.65	0.74	0.85	0.67	0.73	0.83
η_i	0.18	0.28	0.27	0.14	0.32	0.26
R	**1.804407**			**1.839594**		

The case study in question has resulted in two discrete values of risk representing the two periods observed. By using the input data the level of risk has been calculated for the two periods under observation in case study using Equations 1, 2, and 3.The overall level of risk in our case for periods represented by Sample 1 is 1,804, and those by Sample 2 is 1,840. Figure 5 depicts them in areas that are at the moment acceptable for the organization observed.

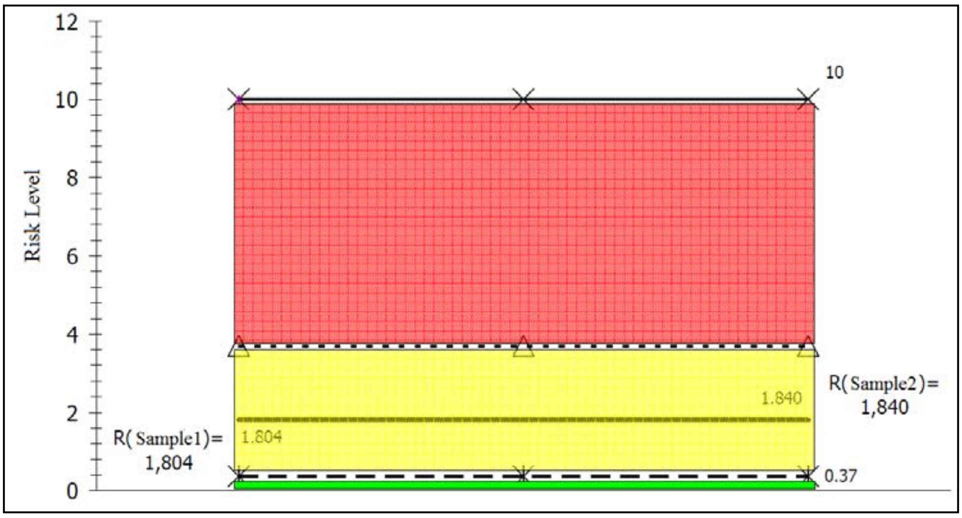

Figure 5 - Overall risk level in the two samples [33]

The acceptable of risk ends with 3.7 in this case study, as prescribed by the airline policy. Similarly it has been established that activities to reduce risk should be taken if its value is in the range of 3.7 to 10. Reference risk level limits depend on the individual stakeholder and indicate its attitude towards risk. Thus, the generative companies' levels of acceptable risk will probably be lower than those in pathological or bureaucratic.

5. CONCLUSION

This paper focuses on safety in aviation, presenting in its first part a review of applicable literature in terms of aviation safety management, accident investigation and modelling of the risk. Modelling of the risk literature review encompassed work outside the aviation as well to cater for risk assessment and management in general. Having presented the state of the art general features of the actual available models, the paper shows the potentiality of MARS as a potential candidate to fill some of the gaps identified.

MARS takes into account the safety features of an organization in the aviation context (airport/ ground handling, an airline, or air navigation services provider, etc.). Due to the complexity of accident causation in contemporary systemic thinking an analogy to biometrics has been utilized to harvest the holistic view on accident causation even before the mishap addressing the system in its entirety. Hence, MARS is offered as a tool to utilize systems' performance indicators for behavior in and out of the steady and normal state. Interconnected nature of model elements with feedback as a dependency between master-factors has been discussed and accounted for in conceptual as well as mathematical interpretation of the model.

Modular nature of MARS with possibility of adding or taking away positive or negative influences on risk related to each macro-factor has been introduced in order to simplify the process of reaching a measurable risk value holding a meaning for a variety of potential users of the model. This high-level information for decision makers is intended to enhance the organization's safety level by giving them the feel on their actual influence on risk. The possibility of developing a quantitative holistic index capable of defining the safety features of the system could help the decision-maker in assigning resources and finding the criticalities in the process in order to enhance the safety level of the organization. At the same time the flexibility of defining input variables and reconfiguring the setup of the model allows for MARS to be used widely regardless of the stakeholder where it is applied.

A case study has been presented for an airline safety case (Missed Approach) supported by data captured from Flight Data Management system and official company communications. Elements needed for specific case risk evaluation has been calculated from data captured until two discrete risk values has been reached (one for each study period observed).

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OVERVIEW OF THE WORLD MARITIME FLEET AND FLOWS WITH REFERENCE ON THE FLEET AND PORTS IN THE REPUBLIC OF CROATIA

ABSTRACT

In today's interdependent and globalized world, efficient and cost-effective transportation systems that link global supply chains are the engine of fueling economic development and prosperity. With 80 per cent of global merchandise trade by volume carried by sea and handled by ports worldwide, the strategic economic importance of maritime transport as a trade enabler cannot be overemphasized. The trade competitiveness of all countries – developed and developing, and including landlocked countries – depends heavily on effective access to international shipping services and port networks.

This paper presents the structure of world merchant fleet, maritime cargo flows and container traffic in the biggest container ports in the world. The paper also discusses role of the Republic of Croatia as a maritime country, with emphasis on the role and structure of maritime fleet and total maritime cargo traffic in seaports.

KEY WORDS

structure of merchant fleet, merchant cargo flows, maritime cargo, seaports

1. INTRODUCTION

Maritime transport handles over 80 per cent of the volume of global trade and accounts for over 70 per cent of its value [1]. Since 1970, global seaborne trade has expanded on average by 3.1 per cent every year, reaching an estimated 9.84 billion tons in 2015. At this pace, and assuming no major upheaval in the world economy, global seaborne trade is expected to increase by 36 per cent till 2020 and to double by 2033 [2]. While bulk trade accounts for the largest share of global seaborne trade by volume, the containerized cargo contribution grew more than threefold between 1985 and 2010. Developing countries are driving growth in global merchandise trade. Africa and Latin America are increasingly becoming suppliers of China's primary commodity needs. In return, consumer goods from China are exported more and more to these regions. These developments are shaping the configuration of maritime transportation.

Maritime transport acts as the main carrier and driver of the world trade. It connects large industrial, transport and trade hub and its port. The intensity and amount of marine cargo flow today is a measure of the effectiveness and usefulness of traffic as well as a certain degree of economic development of a region or country. Since about 2/3 of the total international trade of goods are transporting by ships, the intensity and direction of maritime cargo flows are relevant indicators of the concentration of world's centers of production and consumption [3].

With regard to the object of transportation, two basic types of maritime shipping should be considered, freight and passenger shipping. Freight shipping, as the biggest and most important part of maritime shipping can be divided into free (tramper), liner and tanker shipping [4]. Every type of shipping requires specific type of ships. Free shipping requires bulk carriers, liner shipping container or general cargo ships and tanker shipping different types of tankers.

Explanation of the structure of maritime fleet and concept of maritime affairs as one of the most important traffic branches is presented in this paper. After a brief review of the ships history, as well as the geopolitical circumstances that affected types or sizes of a ships, the structure of world merchant fleet and the world's major routes are shown, with an emphasis on the most important world maritime canals that are in very close relation with the world's goods exchange.

As container traffic today occupies a leading position in the maritime trade, leading container traffic ports by regions are analyzed. In connection with the world fleet structure, international seaborne trade by type of cargo will be presented.

The structure of merchant fleet of the Republic of Croatia and its ports are analyzed as well. For comparison, position of container traffic for port of Rijeka and satellite ports, with port of Shanghai and port of Trieste will be shown.

2. THE STRUCTURE OF THE WORLD MERCHANT FLEET AND MARITIME CARGO FLOWS

Since early period of 19th century, precisely in 1807, when the first steam ship was built, over the invention of propeller and diesel engine a new era in the development of the maritime world began [5].

Today at the world seas different types of ships are sailing, equipped with a modern technology, in different sizes, speed, shape, purpose, etc. Some of them have over 320,000 tons deadweight. The most famous Ultra Large Crude Carrier (ULCC) tankers have carrying capacity up to 564,650 tones. The longest ship ever built, ULCC "Sewise Giant" was built in 1976 in Japan, with length of 458.45 m, width of 68.8 meters, draft of 8.29 m, speed of 13 knots (6.5 m / s) and capacity of 564,650 tons [6].

The world fleet in 2014 grew only by 3.5 per cent, what is the lowest annual growth rate in over a decade [2]. In total, at the beginning of the year, the world's commercial fleet consisted of 85,094 vessels, with a total tonnage of 1.16 bill. GT (Table 1). For the first time since the peak of the shipbuilding cycle, the average age of the world fleet increased slightly during 2014. The natural aging of the fleet for given delivery of fewer newbuilding, combined with reduced scrapping activity and newer tonnage, cannot be compensated.

Greece continues to be the largest ship-owning country, followed by Japan, China, Germany and Singapore [2]. Together, the top five ship-owning countries control more than half of the world tonnage. Five of the top 10 ship-owning countries are from Asia, four are European and one is from the America [2]. Table 1 presents the World trade merchant fleet at the end of 2014.

Table 1 - The structure of the world trade vessels fleet 2014.

Type	Number	(%)	GT (in 1000gt)	(%)
Oil and chemical tankers	12,363	14.5	296,896	25.5
Gas tankers	1,703	2.0	56,654	4.9
Other tankers	851	1.0	1,606	0.1
Bulk carriers	10,996	12.9	409,915	35.1
Container ships	5,084	6.0	206,128	17.7
General cargo ships	16,218	19.1	58,209	5.0
Specialized cargo ships	267	0.3	3,858	0.3
Ro-Ro cargo ships	1,482	1.7	47,333	4.1
Passenger ships	6,612	7.8	36,547	3.1
Offshore vessels	8,030	9.4	34,685	3.0
Service ships	4,795	5.6	9,947	0.9
Tugs	16,693	19.6	4,681	0.4
Total	**85,094**	**100**	**1,166,459**	**6.9**

Source: [7]

The most numerous are tug boats while fleet of bulk carriers have the highest percentage in total Gross Tonnage (GT). Tugs are smaller ships, whose main characteristics are related to engine power and maneuverability and not cargo capacity. Those types of vessels represent only 0.4 % of total GT. Tanker fleet with share of 30.2% takes almost one third of GT world fleet. Due to fact that tankers are mostly large ships, ratio between GT and number of ships is as per expectations. As per Table 1, containerized cargo can be loaded on a fleet that takes 27.1% share of world GT.

Emerging developing economies, China and India, generate need to have large capacity of bulk carriers, container ships and tankers and this is the main driver of growth in dry bulk, containerized and liquid cargo shipments.

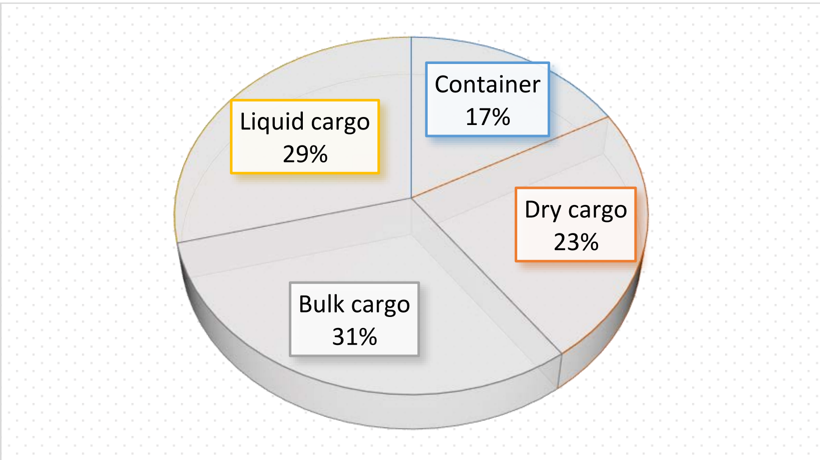

Figure 1 - International seaborne trade by type of cargo
Source: [2]

In Figure 1 total share of cargo by type in maritime traffic is presented. Containerized cargo has share of 17%, while 29% is liquid oil and gas cargo. Main bulk cargo; iron ore, coal, grain, bauxite/alumina and phosphate rock take 31% of the world trade by sea [2]. Dry cargo, mostly general cargo, break bulk, etc. has 23% share of total cargo transported by sea.

Containers transport different types of goods and this fact contributes to the growth and constant increase in container traffic, so the focus of research will be on container traffic.

Tanker trade is greatly determined by global energy production and aggregate demand, the world economy, demographics, urbanization, industrialization and, more importantly, by the "geography" of global energy surpluses and deficits. While crude oil prices are an important market signal, that has directly impact on tanker business, other factors like policy decisions by members of the Organization of Petroleum Exporting Countries (OPEC), geopolitical developments, and political tensions, have a lot of influence on crude oil price and consequently on tanker merchant fleet.

Total GT of bulk carriers in 2014 was 35.1%, with total turnover of 22%. While these kind of ships do not have common routes and are sailing around the world in a search for cargo, the proportion of these types of ships in foreign trade is more than satisfactory.

As already mentioned, approximately two-thirds of total international trade in goods is carried out by sea, forming the strong maritime cargo flows between the production areas and consumption area. Throughput of marine corridor is almost unlimited, the size of the ships allow transport of extremely large amounts of goods. Large amounts of a variety of goods could not be carried by any other mean of traffic than by maritime traffic. Due to the high capacity and cost efficiency, shipping enables global economic connections and therefore is the basis of the world's commodity-trading exchanges.

Maritime flows are connecting all parts of the world and the map with common used maritime routes is shown in Figure 2. In the past, most used sailing points were around South Africa (Good Hope) and South America (Magellan passage). The reason to build Very Large Crude Carriers (VLCC) and ULCC vessels was to carry large amount of liquid cargo around these two points.

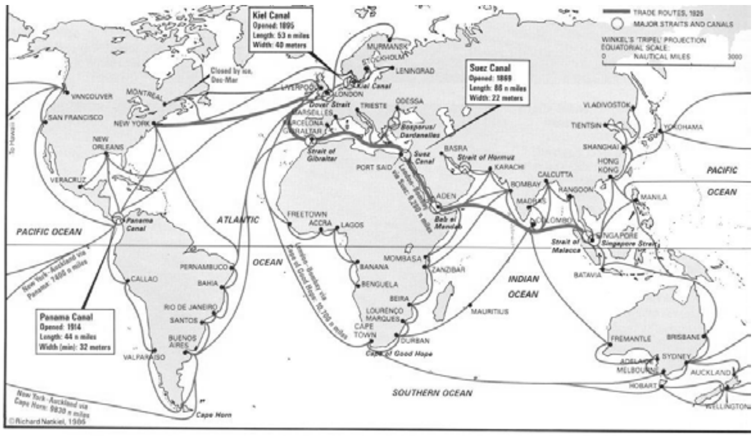

Figure 2 - Major global trade routes and geographic choke points
Source: [8]

In order to shorten distance between Far East and Europe and shorten sailing time to transport crude oil from Middle East to the West, in 1869 Suez Canal long 163 km were dug. Every year approximately 19,000 ships and over 700 mil. tons of cargo is passing through the Suez Canal [9, 10]. In order to connect Pacific and Atlantic oceans, in 1914, Panama Canal long 77 km were dug. This channel shorten distance between two American coasts for 14,000 nautical miles and approximately 45 days of steaming between two coasts. On annual basis through the canal is passing up to 15,000 ships and over 300 mil. tons of cargo [11]. These two canals are most important worldwide canals. It must be noted that canals or passages like Gibraltar, Kiel, Corinth, Bosporus-Dardanelles, Malacca, St. Lawrence, etc., also have very important role in maritime trade flows with the purpose to shorten distance and save sailing time and money for a ships and companies.

As per Figure 3. the world merchant marine container traffic, except for 2009, has permanent growth. In 2015, 180,000,000 containers was transported by sea. In 2014, global containerized trade have increased by 5.3 per cent and reached 171 million TEUs.

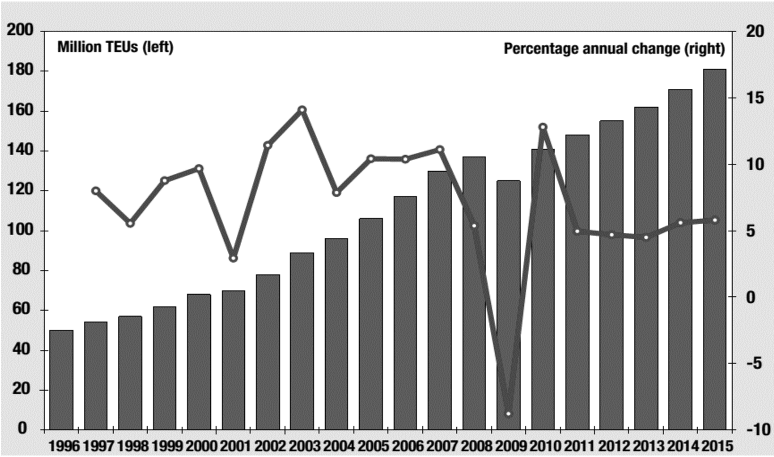

Figure 3 - Global containerized trade, 1996-2015 (mil. TEUs and percentage annual change)
Source: [2]

Global growth was boosted by the recovery of the major East–West transpacific and Asia–Europe trade lanes.

Table 2 - Containerized cargo flows on major East-West container trade routes, 2009-2014 (million TEU's and percentage annual change)

	Transpacific		**Europe Asia**		**Transatlantic**	
	Asia-North America	**North America- Asia**	**Asia-Europe**	**Europe-Asia**	**Europe-North America**	**North America-Europe**
2009	10.6	6.1	11.5	5.5	2.8	2.5
2010	12.3	6.5	13.3	5.7	3.2	2.7
2011	12.4	6.6	14.1	6.2	3.4	2.8
2012	13.1	6.9	13.7	6.3	3.6	2.7
2013	13.8	7.9	14.3	6.9	3.6	2.7
2014	14.7	7.5	15.4	7.0	3.9	2.7
Percentage change 2013-2014	**6.3**	**-4.5**	**7.5**	**1.3**	**8.3**	**0.0**

Source: [2]

Partly reflecting the recovery in the United States and the improved prospects for Europe, containerized trade volumes carried on the Asia–Europe and trans-Pacific lanes are estimated to have increased by 7.5 per cent and 6.3 per cent respectively. In comparison, and reflecting a weaker import demand in Asia, trade volumes on backhaul journeys remained weak. Weaker demand for imports from Europe and North America does not necessarily reflect a drop in the overall import demand, as imports into Asia often include waste and other residual products. Volumes on the westbound lanes of the trans-Pacific route contracted while shipments on the eastbound lanes of the Asia–Europe trade route increased only marginally (Table 2).

The recovery on the East–West routes does not reveal the changing patterns of global demand. The total container trade on main lanes is estimated to have grown by 9.0 per cent between 2007 and 2014 while trade volumes on the nonmainlane trades are said to have expanded by 45 per cent during the same period. Consequently, the share of world trade held by the mainlane trades fell from 36.0 per cent in 2007 to 30.0 per cent in 2014. At the same time, intraregional (led by intra-Asian trade) and South–South trade accounted for 40 per cent of global containerized volumes in 2014, followed by flows on the mainlane East–West (30 per cent), North–South (17 per cent) and secondary East–West trade routes (13 per cent). Despite the recovery on the main East–West trade lanes and the lower oil prices and bunker fuel costs, the practice of slow steaming in container shipping continued and appears to be the norm as there is no outright increase in vessel speeds. In the meantime, ship owners continue to order very large container ships, as illustrated by the very recent ordering of 11 second generation Triple-E container vessels with a capacity of 19,630 TEUs each [2].

Table 3 shows the world's 20 leading container ports for the period 2012–2014. The top 20 container ports accounted for approximately 45.7 per cent of world container port throughput in 2014. These ports showed a 4.5 per cent increase in throughput compared to 2013, the same as the estimated increase for 2013. The list includes 16 ports from developing economies, all of which are in Asia. The remaining four ports are from developed countries, three of which are located in Europe and one in North America. All of the top 10 ports continue to be located in Asia, signifying the importance of the region as a manufacturing hub.

Table 3 - World top 20 container terminals and their throughput (TEU), 2012-2014

Port name	2012	2013	2014	Percentage change 2012-2013	Percentage change 2013-2014
Shanghai	32,529,000	36,617,000	35,290,000	12.57	-3.62
Singapore	31,649,400	32,600,000	33,869,000	3.0	3.89
Shenhzen	22,940,130	23,279,000	24,040,000	1.48	3.27
Honh Kong	23,117,000	22,352,000	22,200,000	-3.31	-0.68
Ningbo	15,670,000	17,351,000	19,450,000	10.73	12.10
Busan	17,046,177	17,686,000	18,678,000	3.75	5.61
Guangzhou	14,743,600	15,309,000	16,610,000	3.83	8.50
Qingdao	14,503,000	15,520,000	16,580,000	7.01	6.83
Dubai	13,270,000	13,641,000	15,200,000	2.80	11.43
Tianjin	12,300,000	13,000,000	14,060,000	5.69	8.15
Rotterdam	11,865,916	11,621,000	12,298,000	-2.06	5.83
Port Klang	10,001,495	10,350,000	10,946,000	3.48	5.76
Kaohsiung	9,781,221	9,938,000	10,593,000	1.60	6.59
Dalian	8,064,000	10,015,000	10,130,000	24.19	1.15
Hamburg	8,863,896	9,258,000	9,729,000	4.45	5.09
Antwerp	8,635,169	8,578,000	8,978,000	-0.66	4.66
Xiamen	7,201,700	8,008,000	8,572,000	11.20	7.04
Tanjung Pelepas	7,700,000	7,628,000	8,500,000	-0.94	11.43
Los Angeles	8,077,714	7,869,000	8,340,000	-2.58	5.99
Jakarta	6,100,000	6,171,000	6,053,000	1.16	-1.91

Source: [2]

For the last two years, most of ports having growth in container traffic (Table 3). Only three ports from twenty in 2014 have drops in turnover. Shanghai port, as leading port in container traffic, has strong growth in 2013 but in 2014 traffic has fool for 3.62% what is traffic loss of 1,327,000 containers.

3. MERCHANT MARINE FLEET AND PORTS OF THE REPUBLIC OF CROATIA

The Republic of Croatia as a maritime country should strive to become important part of the world merchant cargo flows. For that purpose, it is important for Croatia to focus on technologically development of merchant fleet and ports that will be able to receive a new generation of ships.

Table 4. shows the structure of the merchant marine fleet in the Republic of Croatia. Total number of ships is 138 with 1,689,258 GT. Bulk carriers represents 60.5% deadweight of total fleet but different owners. Most of ships fly convenient flags due to tax exemptions.

Two biggest cargo ship-owners, today, in Croatia are Tankerska plovidba d.d. from Zadar and Atlantska plovidba. They owns entire crude oil tankers fleet and some of bulk carriers There are a few product tankers owned by Uljanik plovidba d.d.. Passenger fleet, except of four ships from Rapska plovidba is concentrated in Jadrolinija d.d. from Rijeka.

With bankruptcy of Croatian line from Rijeka, the liner shipping or container fleet practically disappeared from the structure of the Croatian merchant fleet.

Table 4 - Merchant marine fleet of the Republic of Croatia

								%	
	Ship's type/Owner	Number of ships	GT	DWT	Grain (m³)	Vehicles	Passengers	**GT**	**DWT**
A)	**Bulk carriers**								
1	ATLANTSKA PLOVIDBA	16	552.609	983.826	1.176.713				
2	JADROPLOV	6	168.402	292.933	364.114				
3	TANKERSKA PLOVIDBA	7	147.262	228.163	307.202				
4	ULJANIK PLOVIDBA	3	91.382	157.462	195.714				
	Total:	**32**	**959.655**	**1.662.384**	**2.043.743**			**56,80**	**60,50**
B)	**Tankers**								
1	TANKERSKA PLOVIDBA	8	406.243	749.442					
	Total:	**8**	**406.243**	**749.442**				**24,05**	**27,28**
C)	**Product tankers**								
1	ULJANIK PLOVIDBA	4	122.552	209.884					
2	TANKERSKA PLOVIDBA	2	61.276	104.489					
	Total:	**6**	**183.828**	**314.373**				**10,88**	**11,44**
D)	**Passenger ships**								
1	JADROLINIJA	3	873				1.200		
	Total:	**3**	**873**				**1.200**	**0,05**	
E)	**Catamaran**								
1	JADROLINIJA	9	3.458				2.644		
	Total:	**9**	**3.458**				**2.644**	**0,20**	
F)	**Ferryboats**								
1	JADROLINIJA	37	109.208			3.824	23.651		
2	RAPSKA PLOVIDBA	4	2.118	0		166	1.080		
	Total:	**41**	**111.326**	**0**		**3.990**	**24.731**	**6,59**	
G)	**Commercial yacht**								
1	BRODOSPLIT PLOVIDBA	1	1.212	232			12		
	Total:	**1**	**1.212**	**232**		**0**	**12**	**0,07**	**0,01**
H)	**Tugboat**								
1	BRODOSPAS	10	2.305						
2	JADRANSKI POMORSKI SERVIS	11	2.823						
	Total:	**21**	**5.128**					**0,30**	
I)	**Supplier ship**								
1	BRODOSPAS	7	12.488	11.636			84		
	Total:	**7**	**12.488**	**11.636**			**84**	**0,74**	**0,42**
J)	**Other ships**								
1	BRODOSPAS	5	2.953	6.232			110		
2	JADRANSKI POMORSKI SERVIS	4	2.084	3.178					

3	RAPSKA PLOVIDBA	1	10				12		
	Total:	**10**	**5.047**	**9.410**			**122**	**0,30**	**0,34**
TOTAL 31.12.2015.		**138**	**1.689.258**	**2.747.477**	**2.043.743**	**3.990**	**28.793**	**100%**	**100%**

Source: [12]

With regard to seaport in Croatia, although in the past decades a number of studies and activities to improve business of cargo ports were carried out, the cargo seaports in the Republic of Croatia are still not competitive in relation to the cargo seaports in the Adriatic and Mediterranean seas.

The Republic of Croatia has six international seaports [13]. The biggest cargo port is port of Rijeka and with satellite ports (Bakar, Omišalj and Raša), transfer more than half cargo in the Country. In 2012, the port of Rijeka and satellite ports had 8,554,001 t of cargo turnover what is almost 60% of total cargo traffic in Croatia. In the same year, total cargo turnover in the Country was 14,623,885 t. Container traffic in the port of Rijeka and satellite port is only 42% of traffic in the biggest port at Adriatic Sea, port of Trieste [14, 15]. Comparing transferred TEUs of the port of Shanghai, the biggest container port in the world, with the port of Rijeka, it is significant that port of Rijeka and its satellite ports realize 90% of total container traffic in the Republic of Croatia but only 0.6% TEUs of Shanghai port.

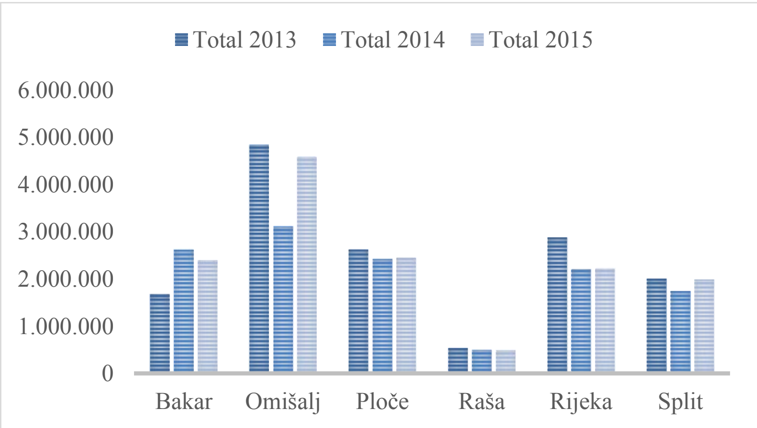

Figure 5 - Total maritime cargo traffic (t) in Croatian ports, 2012-2015

The Figure 5. gives total maritime cargo data for six cargo ports in the Republic of Croatia for period 2012-2015. Statistical data are taken from [16]. For this period, cargo transfers have decrease of 1.5 mil. tons of cargo. Except of port of Bakar, 2013 was year with highest cargo turn over in Croatia. Omišalj is crude oil and oil product terminal, equipped to receive even VLCC tankers. Capability to receive such large vessel is positioning the port as leading port in the Country. Port of Ploče is more important for the Republic of Bosnia and Herzegovina, while port of Split, Zadar and Šibenik are more focused on passenger transfers [17]. Port of Dubrovnik is purely passenger port and is not analyzed in this paper.

The merchant fleet of Republic of Croatia takes only 0.14% of total world fleet in GT. Container ships fleet, as world maritime progress indicator, does not exist. As opposed to container shipping, a tanker shipping trying to keep world technology progress. Seaports in the Croatia, hold minor role in the world wide maritime traffic.

4. CONCLUSION

In todays with globalized world, efficient maritime traffic and transportation systems are the main conditions for economic development and prosperity of the countries and regions. The fact that nearly ¾ of all goods is transported by sea reflects the importance of maritime affairs in a global sense. Geopolitical factors have direct effect on the size of ships and international trade. The construction of the world famous canal directly affected the reduction of sailing costs around the African and South American continents. The sea routes have directly connection with the exchange of goods between all parts of the world. Any other form of traffic could, not transport the amount of goods that can be transported by sea. Due to its large, practically unlimited capacity, relative simplicity and speed in cargo handling and cost effectiveness of transportation, shipping, and maritime cargo flows today are the basis of commodity-trade. Today, the prevailing transport of cargo by sea are containers. The highest intensity of maritime cargo flows exercised the countries with a developed container traffic and built modern terminals for handling containers. In particular, it relates to the country's East Asian continent and the countries of Western Europe. Considering the traffic position of the Republic of Croatia, maritime tradition and more intensive economic globalization, and the associated inland-sea route singled out the port of Rijeka in the national framework. In the Adriatic Sea still dominate Italian ports, but with proper guidance, the port of Rijeka can be made as one of leading North Adriatic transit port and would contribute to economic stimulus not only for this region but also for the country as a whole.

With its know-how, proper strategic planning as well as adjustment to the global economic business requirements the shipping trade of the Republic of Croatia has an excellent opportunity to come forward as a leader in the sector related to the sea and maritime affairs in a country with a centuries old maritime tradition.

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POSSIBILITIES OF INTERCITY INTERMODAL DISTRIBUTION DEVELOPMENT ON SHORT DISTANCE

ABSTRACT

Intermodal transport is often considered as alternative approach regarding to congestion caused by road freight transport while its implementation in practice in most cases refers to the long distances (over 300 km). Until recently research did not pay much attention to the connection between intermodal (road-rail) transport and urban distribution, relying on a fact that intermodal transport is not achievable at distances less than 300 km. This paper will explore the possibility to develop the concept of intercity intermodal distribution at short distance as well as preconditions for the development of this concept. Intention is to show that the cooperation between intermodal transport and urban distribution is possible. By using case studies, process of intercity intermodal distribution will be described, which will lead to a conclusion regarding the future development of the concept of intercity intermodal distribution.

KEY WORDS

Intermodal transport; urban distribution; intercity intermodal distribution; preconditions for intercity intermodal distribution

1. INTRODUCTION

Economic development is closely connected with the transport demand and the increasing demand for freight transport occurs still largely by road transport, which has negative consequences for society, economy and environment. Although intermodal transport is often presented as a prospective solution for reducing a pressure of road freight transport, until recently the concept of the intermodal (road - rail) transport it is beginning to explore more. The final destinations of transported goods are urban areas, which represent the connection between urban distribution and intermodal transport. According to some authors, it is considered that the intermodal transport is competitive at distance more than 300 km, and therefore it is not considered that intermodal transport is applicable in respect of the distribution of goods. Urban freight and intermodal road-rail transport are still handled as separate policy concerns and this paper will try to show the connection between them. This paper presents intercity intermodal distribution as innovative approach on short distances (less than 300 km) with a goal to determine the preconditions necessary for its implementation at a cost-effective, sustainable and competitive way.

2. POSSIBILITIES OF USING INTERMODAL TRANSPORT ON SHORT DISTANCE

European Conference of Ministers of Transport (ECMT) [1] defines Intermodal transportation as movement of goods (in one and the same loading unit or a vehicle) by successive modes of transport without handling of the goods themselves when changing modes. ECMT defines multimodal transport as the "carriage of goods by at least two different modes of transport". Intermodal transport is therefore a particular type of multimodal transport.

United Nations Convention on International Multimodal Transport of Goods [1] defines international multimodal transport as "the carriage of goods by at least two different modes of transport on the basis of a multimodal transport contract from a place in one country at which the goods are taken in charge by the multimodal transport operator to a place designated for delivery in a different country".

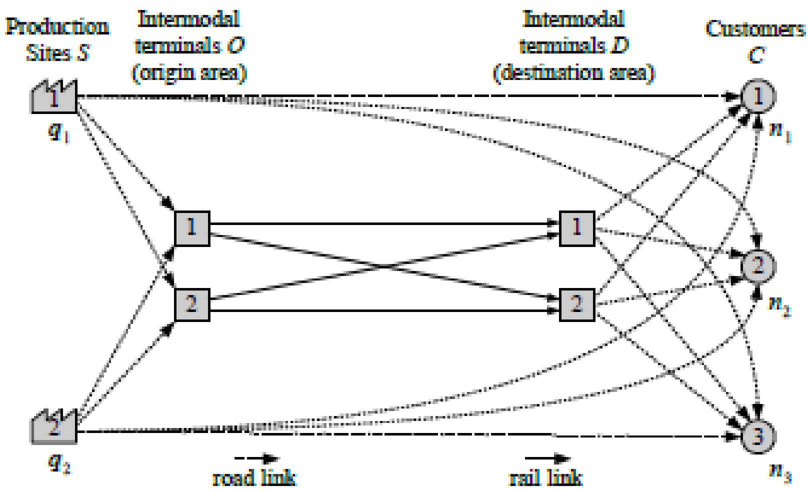

Figure 1 - Distribution of goods using intermodal transport
Source: On Transport Service Selection in Intermodal Rail/Road Distribution Networks, BUR (2012)

Figure 1 shows the concept of distributing goods where the railway is used for long distances while road vehicle is used for local collection and delivery of goods.

One of the aims of European transport policy is to achieve a balance between modes of transport through the development of intermodality. Authors have different opinions regarding distance on which goods should be transported using intermodal transport. Van Klink and Van den Berg (1998) considered competitiveness of intermodal transport at distances more than 500 km while the operator Kombiverkehr achieved breakeven point at distance of 350 km [2]. European Conference of Ministers of Transport (1998) states that the intermodal transport on shorter distances is competitive over 300 km [3]. Limbourg, S. and Jourquin, B. considered that intermodal transport should occur at distances more than 343 km [3].

According to the European Commission (2002) 50% of the total transport occurs at a distance of 150 -500 km [2].

That intermodal transport can be sustainable on short distance (less than 300 km) presents a project developed by the logistics operator Samada and large supermarket chain Monoprix, which supplies shops in Paris area using the railway. This mode of transportation was implemented in 2007 and is used to transport goods from the warehouse of Combs-la-Ville and Lieusaint (Seine et Marne) located outside the city to Monoprix store in Paris. An important point when launching the project was that supermarkets will not suffer losses in terms of service quality, delivery time and frequency of delivery. The train runs on the rail distance of 30 km and for transport is using the same railway infrastructure as passenger trains and the final distribution of goods is carried out by CNG delivery vehicles. The average number of wagons is 16 and the maximum 20, depending on orders and seasonal oscillations with train daily runs (Monday-Friday) [4].

Figure 2 presents the process of intercity intermodal distribution of Monoprix that takes place in a way that goods are stored on pallets and placed in the wagon (phase 1), after formatting the train leaves Monoprixov terminal at 7:30 pm and comes to the terminal Paris Bercy at 8:20 pm (phase 2) where is performed cross-dock (phase 3). The last stage of the process refers to the final distribution, which takes place from the Bercy terminal to the supermarkets using CNG vehicles (phase 4).

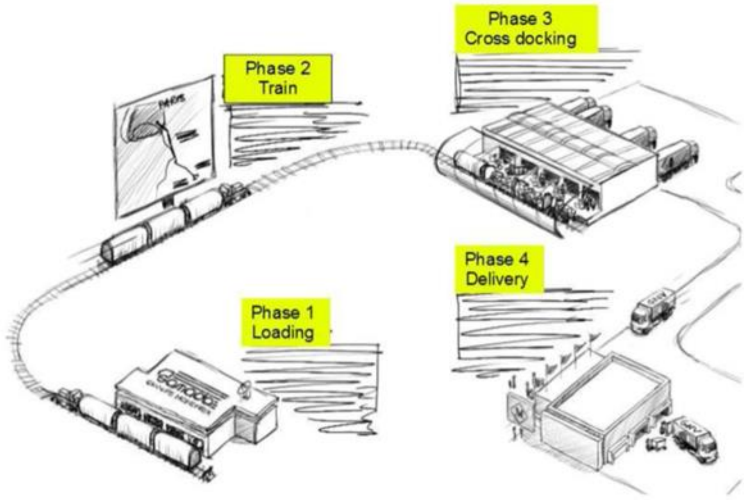

Figure 2 - Process of intercity intermodal distribution of Monoprix
Source: Turblog D3.1: Urban Logistics practices- Paris Case study (2011)

Every working day is transported 460 tons of goods [4]. Based on the data in this study it will be made a calculation for the specified route using 40'containers (FEU) instead of conventional railway wagons that Monoprix is using.

- Model of using Rail-CNG vehicles: € 9400
- Model of using road vehicles for distribution of goods (used vehicles 5.5 tons): € 10 920

Based on these prices it can be concluded that the model Railway - CNG using 40'containers compared to a model of using road vehicles creates a saving of 1520 euro / day. The calculation is bases on a prices from 2015.

The goal of implementing this project was to show:

- possibility of using railway for transport (distribution) of goods on short distance (inter-city distribution) as well as the possibility of entering a freight train in the city center
- possible compatibility between passenger and freight rail traffic using the same infrastructure in the urban areas
- finding solutions to reduce traffic congestion on the highway and access roads in the city center
- reduction of environmental pollution caused by daily road shipments
- introduction of railway in distribution process in a way that doesn't interfere with the current process supplying stores for reasonable prices [4].

3. PRECONDITIONS FOR DEVELOPMENT OF INTERCITY INTERMODAL DISTRIBUTION

According to the authors [4, 5, 6, 7, 8, 9, 10, 11, 12] and based on the case study that will be explained further in the paper it led to the following criteria that affect the development of intercity intermodal distribution:

- client interested for transporting the goods by intermodal transport
- clients demand is important because client decides regarding to a market or types of goods what is the most important thing for him (transport price, service reliability, delivery time, the environmental side or subsidies for the selection of a particular mode of transportation)
- large volume of goods (minimum between 400-500 tons / day)
- country policy (referring to the price of fuel, fuel tax that for rail transport should be lower than the tax on fuel for road transport, electricity prices should be free of tax, local authorities responsible for land, legal restrictions relating to the operation of commercial vehicles in urban areas)
- investing in intermodal terminals should be considerate as precondition for the future growth of intermodal transport
- connection between logistic facilities and railway network/intermodal terminal (important existing infrastructure in the place where we plan to develop a terminal)
- location of the terminal as well as the location of the consignor and consignee in urban area (significantly affect the cost of intermodal transport)
- the competence of intermodal transport depends on the time and cost of PPH, which are important factors
- developed railway infrastructure in terms of availability
- technical characteristics of railways
- concept of connecting several terminals which are located along the route of intermodal transport in the way that intermodal train stops between stations which covers more markets
- development of areas where intermodal distribution will take place
- subvention (they can remove the biggest obstacle to the development of intermodal transport)
- introducing the concept of sharing transport equipment which excludes concept of private transport (the reason for is lack of goods volume of individual clients) which will require cooperation between clients and operators of public and private sector
- development of ecological vehicles to reduce the cost of PPH
- company that can fulfill the requirements of the market in terms of reasonable price and good quality services.

4. POSSIBILITY OF INTERCITY INTERMODAL DISTRIBUTION DEVELOPMENT – CASE STUDY SLOVAKIA

This chapter will explore the possibility of developing and implementing intercity intermodal distribution on short distance between Slovakia and Hungary. The route is chosen based on the client and for potential client is chosen one of the largest manufacturers of electronic products in the world. The goods of potential client is different from the goods earlier described in the paper and it will be explored the possibility of transporting electronic products by intermodal mode in a short distance. Distribution center of the potential client is located 60 km from the capital city Bratislava and supplies markets of: Hungary, Slovakia, Czech Republic, Austria, Switzerland, Slovenia, Romania, Bulgaria, Croatia, Serbia, Montenegro, Bosnia and Herzegovina, Macedonia, Kosovo, Albania, Italy, Polish, Germany, Greece and Latvia.

Goods are divided into two modes:

- "Finish goods" (FG) which include: TV, laptop, refrigerator, washing machine, dishwasher, printer, speakers, cameras, air conditioners, vacuum cleaners, oven, microwaves, SD card
- HHP (high-value goods), which includes: mobile phones and tablets
- "Finish goods" also referred to as "cheaper goods", while the HHP considered "high-value goods".
- The division is not based on a single product value it is based on a value of the pallet in a way that in one palette fits more product HHP in relation to FG.
- Transport of goods takes place by road vehicle, and there are three types of transport:
- FTL ("Full truck loading") direct transport that takes place between the distribution center and a single consignee, refers to the transport a shipment which consists of two or more items of the same category (FG or HHP).
- ST ("Small truck") / MR- direct line of consignments takes place in a way that goods sent from the distribution center to more consignee. Transporting the 2 or 3 shipments for at least 2 or more consignees.
- Group shipments: goods from DC is sent to the terminal in the destination country where is performed cross dock and goods are still transported along with shipments of other clients. If a large volume of goods needs to be transported it is sent directly from the distribution center to the terminal.

As shown in Figure 3 required investments of potential client are related to infrastructure, it is necessary to connect the existing railway network to the terminal. In these case there is not PPH cost (pre-post haulage)[1] because distribution will be carried from the sender terminal.

Figure 3 - Distribution center of potential client
Source: Google maps

[1] PPH (pre/post haulage)- defines "pre haulage" which involves giving empty containers to the sender as well as transport of the container to the terminal while "post haulage" includes the distribution of full container to the recipient and return of empty containers to the terminal

For the purposes of this research it will be calculated the required number of FEU containers and reason for using them is port Bratislava. Only data related to the FG will be used.

Research for the specified route is presented in two ways:

- that the final destination of cargo transported is Hungary in order to see whether intermodal transport is competitive on the specified distance due to the volume
- that the final destination of transported cargo are mentioned countries (Hungary, Slovenia, Romania, Bulgaria, Croatia, Serbia, Montenegro, Bosnia and Herzegovina, Macedonia, Kosovo, Albania, Greece) to see the impact of PPH in the total cost of transportation.

The total distance of a railway rout from DC of potential client- Budapest is 161 km. Average travel time is one working day. The specified route is shown in Figure 4.

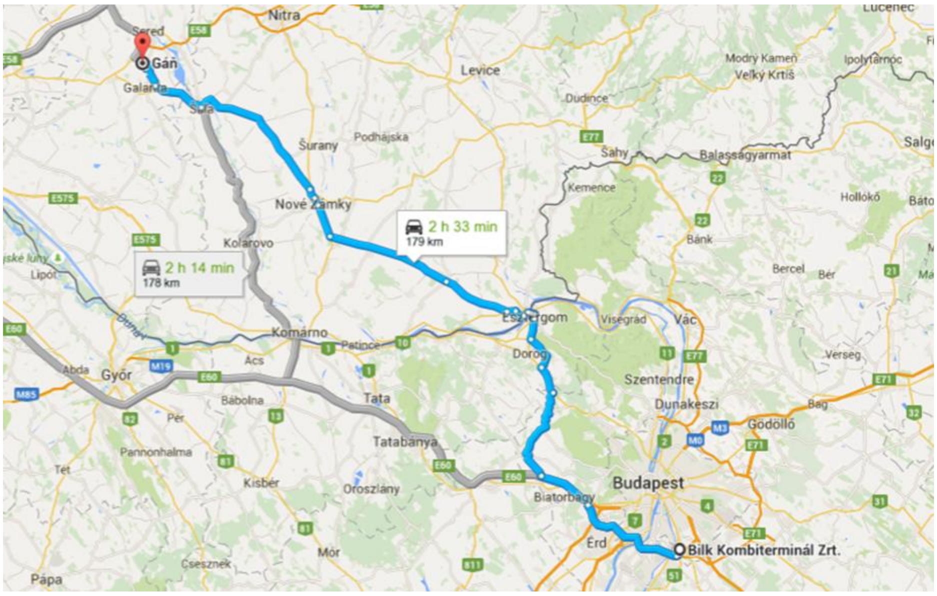

Figure 4 - Intermodal route DC potential client- Budapest
Source: google maps

Considering the volume of 765,93 m^3 /day on a daily basis is needed 30 containers or 19 trucks.

When we take into account the cost of:

- renting containers: 5 €/day *30 containers= 150 €/day
- price of the train, the cost of handling the transport unit, operators price= €7500

Total price of intermodal transport for the route DC of potential client- Budapest is €7650[2].

Transport cost for road vehicle is € 5320[3].

When the price of intermodal transport is compared with a price of road transport it comes to conclusion that intermodal transport at distance of 161 km is more expensive on a daily basis then road transport for 2330 euros. The reason for this is the amount of goods transported. Earlier in the paper it is mentioned that intermodal transport is profitable for

[2] The price is calculated by authors on the basis of data gathered by logistics operator from Slovakia.

[3] The price is calculated by authors on the basis of data gathered by logistics operator from Slovakia.

transportation more than 400 t / day that is precisely the lack of potential client. The lack of a potential client is considered to be in daily tonnage that amounts 153 t[4].

On the other hand, it will be explored the impact of PPH costs on intermodal chain, goods are transported from DC of potential client to Budapest by using intermodal mode of transport than in Budapest is made cross-dock and continues to the final destination (previously mentioned countries) by road transport.

The total cost of road transport from the terminal in Budapest to the capitals of mentioned countries is 21 200 euros. To this amount is added the cost of transportation by rail of €7650 and the total cost of intermodal transport is 28 850 euros[5].

Price of transportation by road vehicle from the distribution center of potential client in Slovakia to the major cities of mentioned countries is €26 990[6].

If we compare the price of road transport with the cost of intermodal transport for supplying mentioned markets, it comes to conclusion that intermodal transport is more expensive for €1860. The reason for that in this example of PPH costs. Reason is that the consignee is distant from the intermodal terminal more than 100 km. This proves statement that the recipient's location affects the cost of transportation which increases PPH costs that affect the total cost.

Based on the above can be concluded that potential client of intermodal transport on short distance from Slovakia in the concept of private transport currently does not have enough amount of goods on a daily basis that would serve mentioned markets. Cargo handling costs at the terminal presents obstacle to the development of efficient intermodal transport. Important point for future development of intermodal transport is existence of a client who is willing to transport their goods by intermodal transport, obstacle referred to delivery time. Since delivery time is important criterion for client followed by transportation costs.

The solution proposed is a collaboration between public and private sectors in a way that the goods intended for different clients for the same market consolidates, this will increase the daily volume of goods as well as better utilization of means of transport.

5. PRE-POST HAULAGE (PPH) PROBLEM

Earlier in the paper was mentioned the concept of PPH. According to research of Sandberg Hanssen, Mathisen & Jørgensen (2012) "pre haulage" can be defined as a process which involves giving empty containers to the sender as well as transport of the containers to the terminal while "post haulage" includes the distribution of full container to the recipient and return of empty containers to the terminal [13]. The competitiveness of intermodal transport largely dependent on the costs of PPH. According to some studies PPH costs account for between 25% and 40% of the total cost of intermodal transport [13]. On the cost of PPH affects the location of the terminal as well as the possibility of "sharing" means of transport, which would reduce the costs of PPH.

The best indicator of the impact of PPH cost to the entire intermodal chain can be seen from the examples of the potential client explained previous in the paper. Example of the potential client from Slovakia showed the statement given earlier in the paper that the location of the terminal and the sender/recipient significantly affect the cost of intermodal transport. Example of potential client from Slovakia show that total intermodal transport

[4] The price is calculated by authors on the basis of data gathered by logistics operator from Slovakia.
[5] The price is calculated by authors on the basis of data gathered by logistics operator from Slovakia.
[6] The price is calculated by authors on the basis of data gathered by logistics operator from Slovakia.

mode was €28 850 of which PPH expenses were €21 200[7]. It should be mentioned that the advantage of the potential client is the fact that transport is carried out from his distribution center (has a connection with the railway infrastructure) which does not have "pre haulage" costs, only "post haulage" which is not the case for other clients. Distance between intermodal terminal and recipient results in higher transportation costs because the final part of the transport still takes place by road transport, while increase in the price of fuel increases the price of PPH. According to the mentioned can be concluded that the competitiveness of intercity intermodal distribution in relation to road transport depends on PPH.

6. CONCLUSION

Connection between intermodal transport and distribution of goods in the concept in which the railway subsystem is basic subsystem for freight transportation while logistic company is responsible for collecting /distributing of goods in the city it corresponds to the requirements of a modern transport system. A key element in the concept of intercity intermodal distribution is client. Client is the one whose demands determines a way of transport.

Based on the case study presented in this paper can be conclude that the future of intercity intermodal distribution is in transport "sharing" (cooperation between local authorities, different clients, logistics operators or better said private and public sector). The concept of private train for one client between two terminals (without including other terminals on the route) is achievable for individual clients, which limits the choice of other clients, is thereby a weak sustainable concept. It is necessary for the clients who do not satisfy requirement daily volume (minimum of 400-500 t) for profitability intercity intermodal distribution to enable the use of intermodal transport, which will include in the transport chain less developed areas.

Implementation, sustainability, competitiveness and profitability of an innovative concept of intercity intermodal distribution at a short distance is achievable through research. There is no "scheme" by which all clients can apply the concept of intercity intermodal distribution, so it is necessary to observe each client separately by preconditions for the development of intercity intermodal distribution given in this paper. Through research we open the "door" for intermodal transport first on a global level and therefore on a local level.

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ALLOCATING DELIVERY VEHICLES WITHIN THE TRANSPORT NETWORK BY APPLYING MATHEMATICAL MODEL

ABSTRACT

This paper presents possibilities of applying mathematical models in daily allocation of delivery vehicles and routing operations. Two mathematical models are designed for solving vehicle allocation problem and vehicle routing problem, respectively. The models are tested on real system data, obtained from Croatian Postal Company. The vehicle allocation model reduces the number of delivery vehicles needed, while the vehicle routing model optimizes delivery routes. Advantages of mathematical modeling are quantified by comparing the results obtained by applying mathematical models against the solutions given by the Company operators.

KEY WORDS

delivery vehicle allocation; delivery vehicle routing; mathematical models

1. INTRODUCTION

Express service (pickup and delivery), also called express delivery services, and today is common service requested from more and more customers. It started in the United States in 1960's. In its short history, express services have experienced a rapid growth and have expanded all over the world. Nowadays, there are many express service companies playing important roles in the field of express service. The modern express services are not only the rapid goods delivering, but also the financial and information exchanging. Development of information technology and computer science will benefit this industry. Express delivery services industry is still growing today and probably will keep growing in the near future.

Part of logistical problems in those companies are related to the optimization of the delivery vehicles allocation and routing. Quality operational decisions in short time period for allocation and routing is prerequisite for efficiency of operations. Since these problems are NP hard problems, generating optimal solution is very demanding and time consuming. For this reason, the problems are approximated by linear programing mathematical models, however the optimal solution is obtained by using heuristic algorithms. In the term linear programing, programming refers to mathematical programing, which refers to a planning process that allocates resources in the best possible way [1].

Large companies today (like DHL, UPS) for solving these problems use different custom-made software, which are not cheap. For small regional companies that software represent a negligible financial cost and they are not willing to invest if they do not see operational benefit.

For this reason, they prefer to rely on dispatcher experience in delivery vehicle allocation decision-making.

One of such small regional companies in express delivery service business is Croatian Post Company. Croatian Post delivers every second parcel today in Croatia. In other words, by the volume of delivered mail and the quality of its service Croatian Post is the market leader in parcel and express mail delivery. HP express is Croatian Post's express delivery service, covering the entire territory of Croatia. It is an express package delivery and pickup service in defined time windows. They use 3PL information system for collecting customer service requests, but company dispatcher based on his experience does allocation and routing.

Completing delivery and pickup processes in the defined time windows is the primary demand that has to be fulfilled. Failing to do so, results in a negative effect on the level of customer service, which leads to loss of customers and potential earnings. Optimization of vehicle allocation in delivery systems reduces operational costs, and increases the level of customer service while allocating vehicles in a non-optimal way generates higher operational costs, and can create a negative effect on the level of customer service.

The solution of the problem is obtained by optimizing mathematical model of the real system, which is entered into Microsoft Excel spreadsheet. Additional software tools are used, Evolver Add-on, which uses genetic algorithm for finding heuristic solutions and Google Maps add-on, which is used for finding the travel time distance between locations. Compared to exact algorithms, heuristics procedures take less computation time but do not guarantee optimal solutions [2]. In order to facilitate the solution process, two separate but related mathematical models (vehicle allocation and vehicle routing) were designed.

Solving the major problems in the program tool Excel is not the best solution because there are specific software tools for solving logistics problems, but the solution obtained Excel may indicate the need for changes in the operational activities. Comparing the results obtained by solving mathematical models, and solutions given by the dispatcher, it is possible to evaluate improvements.

2. DESCRIPTION OF THE LOGISTIC PROBLEM

Costumers, either via call center or web based application, generate the demand for the package pickup and delivery process. After the demand has been created, the call center forwards the request towards to the dispatcher. The dispatcher decides to which delivery vehicle the pickup process will be allocated. All of the delivery operations are grouped by postal region (sector) and allocated to delivery vehicles.

Every vehicle/driver in the delivery network has an assigned delivery book, which consists of a list of costumers for delivery and pickup. Also, the delivery book contains information about every delivery process (package information, delivery address and the defined time window), and the order in which the operations are to be executed [3].

The order in which delivery and pickup processes are executed is defined by two influence factors. The prime influence factor is the delivery window in which the process must be completed, which means that the processes with the sooner time window-deadline (e.g. 8 am) must be completed before any processes with a latter of a time window-deadline (e.g. 10 am). The secondary influence factor is the priority right, which defines that key costumers of the delivery service provider will be serviced before the other costumers.

The decision method, which the dispatcher uses, is based on the area of the pickup process and the postal region of the delivery vehicle. Processes execution order in the delivery book is created using computer solutions by dispatcher. Computer solution in use does not include the allocation and routing algorithms. The dispatcher according to his/her experience allocates the delivery vehicles for each demand area or postal region (sector). Delivery vehicles driver himself does vehicle routing in each given sector.

Since the allocation and routing of vehicles are based on the dispatchers experience and evaluation, they may not be optimal. Also, since the allocation of pickup processes can occur during the day, when delivery book is already created and in use, there is need for reallocation of the pickup processes to vehicles in an optimal way and also for rerouting.

3. MATHEMATICAL MODELS FOR VEHICLE ALLOCATION AND VEHICLE ROUTING

Creating and solving mathematical models for vehicle allocation and routing, can help the dispatcher in making optimal decisions, which could lead to increasing system performance and the level of customer service.

The proposed solution for described problem consists of two separate, but linked mathematical models. Those models are:

- Mathematical model for vehicle allocation
- Mathematical model for vehicle routing

First, it is necessary to allocate delivery vehicle for each demand area (sector). The mathematical model for vehicle allocation defines which sectors will be allocated towards the delivery vehicle, and therefore creates delivery routes. After the delivery vehicle has been allocated to demand sector, vehicle routing according to influence factor has to be done. The mathematical model for vehicle routing optimizes created routes for each sector. Each of mathematical models is described as follows:

Mathematical model for vehicle allocation

Objective function – minimize the number of allocated vehicles

$$\min F = \sum_{k=1}^{m} y_k \tag{1.1}$$

$$y_k = 1 \Leftrightarrow \sum_{i=1}^{n} x_{ik} \geq 1 \quad \forall \quad k = 1, \dots, m \tag{1.2}$$

$$y_k = 0 \Leftrightarrow \sum_{i=1}^{n} x_{ik} = 0 \quad \forall \quad k = 1, \dots, m \tag{1.3}$$

Subject to the Constraints

$$T_{i+1} \geq T_i \qquad \forall \quad i = 1, \dots, n \tag{1.4}$$

$$T_i \geq b_{ik} + s \; \forall \, i = 1, \dots, n \qquad \forall \quad i = 1, \dots . n; \quad k = 1, \dots . . m \tag{1.5}$$

$$\sum_{k=1}^{m} x_{ik} = 1 \qquad \forall \quad i = 1, \dots . n; \quad k = 1, \dots . . m \tag{1.6}$$

$$x_{ik} \in \{0,1\} \qquad \forall \quad i = 0, \ldots . n; \quad j = 0, \ldots n; \quad k = 1, \ldots . . m \tag{1.7}$$

$$m_{i-1,k} + x_{ik}(P_i - R_i) \leq q \qquad \forall \ i = 1, \ldots, n \, ; \ k = 1, \ldots, m \tag{1.8}$$

$$m_{0k} = \sum_{i=1}^{n} x_{ik} R_i \qquad \forall \ k = 1, \ldots, m \tag{1.9}$$

$$\sum_{k}^{m} \sum_{i=0}^{n} \sum_{j=0}^{n} x_{ik} \left(t_{ik} + s\right) \leq D \qquad \forall \, i = 0, \ldots . n; \ j = 0, \ldots n \ k = 1, \ldots . . m \tag{1.10}$$

Where:

- y_k = binary variable, if the vehicle k is allocated (at least one costumer is allocate; the variable K_i = variable gets the value of 1, otherwise the variable gets the value 0
- x_{ik} = binary variable, value 1 if the costumer is allocated towards the vehicle k, value 0 if it's not allocated
- m = total number of vehicles
- n = total number of clients
- b_{ik} = the time of beginning of the service for costumer i, by the vehicle k
- i = 1,…n; k = 1,…m
- R_i = mass of the package for delivery on the location of the costumer i
- P_i = mass of the package for collection on the location of the costumer i
- t_{ij} = travel time distance from location i towards the location j
- q = vehicle capacity k
- T_i = time window for executing the service on location i
- $y_k =$ decision variable: if the vehicle is allocated the variable has a value of 1, if it's not allocated the value is 0
- $D =$ drivers work time
- m_i = sum of the mass of packages on board delivery vehicle k after finishing the service on location i

The inequity (1.4) defines that the order for visiting costumers is defined trough subsequent time windows. The inequity (1.5) defines that the time for completing the service must be lower or equal to the time windows for that costumer. The equation (1.6) defines that every costumer is serviced only once. Equation (1.7) defines the decision variable x_{ik} as a binary variable. The equation (1.8) defines that the total mass of the packages in the vehicle *k,* after completing the service at the location *i,* does not exceed the vehicle carrying capacity. The equation (1.9) calculates the total mass of the packages for delivery at the distribution center. The equation (1.10) expresses that the overall time of all operations completed by the driver, does not exceed his working time.

Mathematical model for vehicle routing

The model is based upon the general VRPDP *(„Vehicle Routing Problem with Deliveries and Pickups")*[4]. The original model is modified to include time based values and constraints.

Objective function:

$$\min F = \sum_{i=0}^{n}\sum_{j=0}^{n} x_{ij}\,(t_{ij} + s) \tag{2.1}$$

Subject to the Constraints

$$T_j \geq T_i \qquad \forall \; j \geq i \tag{2.2}$$

$$T_i \geq b_i + s \qquad \forall \; i = 1, \dots n; \tag{2.3}$$

$$\sum_{i=0}^{n}\sum_{j=0}^{n} x_{ij}(t_{ij} + s) \leq D \qquad \forall \; i = 0, \dots . n; \quad j = 0, \dots n; \tag{2.4}$$

$$b_j = b_i + s + t_{ij} \qquad \forall \; i = 1, \dots . n; \quad j = 1, \dots n; \tag{2.5}$$

Where:

- x_{ij} = decision variable: value 1 if the delivery vehicle travels from costumer i towards costumer j, otherwise the value of the variable is 0
- b_i : moment of starting the service on location i; i = 1,...n
- t_{ij} : travel time distance between location from location i towards the location j
- T_i : time windows for completing the service on location i; i = 1,...n
- s : time needed for completing the operational processes on a location
- D : drivers work time

The inequity (2.2) defines that the costumers with earlier time window-deadline (e.g. 10:00), are serviced before the costumers, which have a later time window-deadline (e.g. 12:00). The inequity (2.3) defines that all of the customers are serviced before exceeding the time window value. The equation (2.4) expresses that the overall time of all operations completed by the driver, does not exceed his working time. The equation (2.5) defines the starting time of the service on the location *j*, which consists of starting time of the service at the previous location *i*, time needed to complete the service at the location *i*, and the travel time between locations *i* and *j*.

4. DISCUSSION OF THE RESULTS

In order to indicate possibilities and advantages of mathematical modeling in dispatcher daily operational decisions, two solutions were analyzed:

- Solutions made by dispatcher, and
- Solutions made by help of mathematical models.

The procedure for comparing the solution made by the dispatcher and the solution gained by solving the problem via mathematical models is shown in the Figure 1.

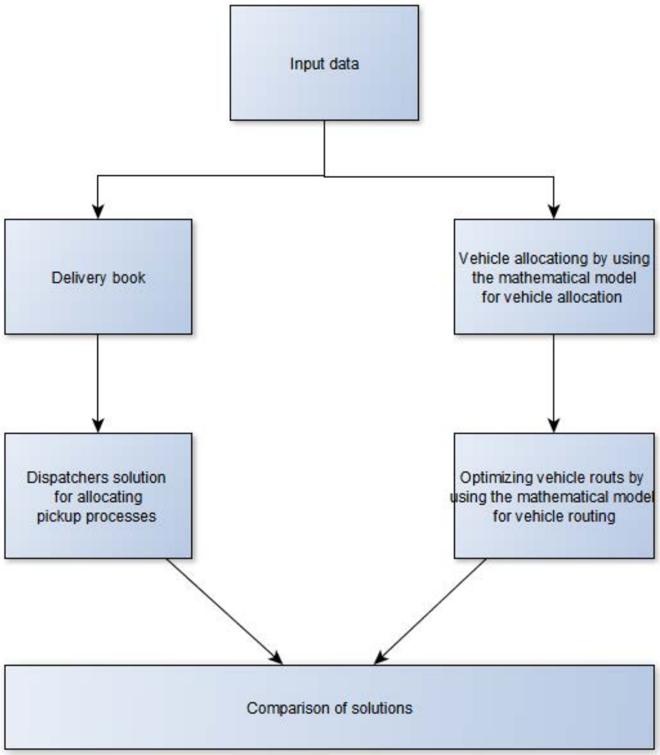

Figure 1 - Flowchart of problem solving phases

Dispatcher solution for observed demand in particular area and data is taken from HP express service department. As there are differences in amount and frequency of demand as well as traffic congestions between urban and suburban area, solutions for both areas are analyzed.

Using the same input data as the dispatcher, firstly the mathematical model for vehicle allocation is used for allocating costumers to the delivery vehicle. Afterwards, the mathematical model for vehicle routing is used for creating optimal delivery routes.

The input data is based on the following information:

- Name and surname of the Costumer
- Address of the Costumer
- Type of process (delivery, pickup or both)
- Time window
- Mass of the package for delivery to the costumer
- Mass of the package for pickup from the costumer

The two problems, the problem of delivery and pickup in an urban area and the problem of delivery and pickup in a suburban area, differentiate one from other in multiple characteristics. Most notably, the density of costumers and the average travel time between two costumers.

For the purpose of presentation in this paper, only one demand sector for each area is taken, demand sector in urban area with 102 customers and one demand sector in suburban area with 50 customers.

Steps of creating solutions by the use of mathematical modeling are presented further in text. Based on the information of costumer addresses, the travel time matrix is created using the Google Maps plugin function *"GetGoogleTravelTime",* which uses navigation functions of the Google Maps server for calculating the shortest route between locations. The matrix shown in the *Table 1* contains travel time distances between all locations, which are street addresses of costumers and the LDC. The values of time distance are in the HH:MM format. Only one segment of the table is shown due to insufficient space.

Table 1 - Travel time matrix

Distance between the LDC and customers				Distance between the customers										
	0				1	2	3	4	5	6	7	8	9	10
1	00:08			1	00:00	00:15	00:15	00:13	00:15	00:12	00:08	00:11	00:27	00:17
2	00:09			2	00:15	00:00	00:05	00:08	00:09	00:10	00:11	00:06	00:23	00:05
3	00:12			3	00:12	00:03	00:00	00:06	00:07	00:14	00:09	00:07	00:22	00:05
4	00:14			4	00:13	00:08	00:04	00:00	00:04	00:16	00:07	00:10	00:18	00:10
5	00:16			5	00:20	00:13	00:09	00:08	00:00	00:23	00:14	00:17	00:14	00:11
6	00:07			6	00:11	00:12	00:14	00:17	00:19	00:00	00:13	00:08	00:30	00:15
7	00:08			7	00:08	00:10	00:09	00:07	00:08	00:11	00:00	00:06	00:21	00:12
8	00:05			8	00:08	00:07	00:06	00:08	00:10	00:11	00:05	00:00	00:23	00:09
9	00:27			9	00:28	00:22	00:18	00:17	00:15	00:30	00:22	00:24	00:00	00:20
10	00:12			10	00:17	00:04	00:06	00:09	00:10	00:12	00:13	00:08	00:25	00:00
11	00:15			11	00:16	00:04	00:06	00:09	00:10	00:14	00:12	00:10	00:23	00:02
12	00:05			12	00:09	00:08	00:11	00:13	00:15	00:05	00:10	00:04	00:26	00:11
13	00:29			13	00:25	00:25	00:21	00:20	00:18	00:30	00:22	00:28	00:18	00:23
14	00:08			14	00:08	00:14	00:12	00:10	00:12	00:11	00:03	00:10	00:22	00:16
15	00:13			15	00:13	00:10	00:07	00:05	00:06	00:15	00:07	00:09	00:21	00:12
16	00:11			16	00:12	00:08	00:07	00:07	00:09	00:13	00:06	00:07	00:22	00:10
17	00:11			17	00:09	00:12	00:10	00:08	00:10	00:13	00:04	00:11	00:20	00:14
18	00:07			18	00:09	00:08	00:07	00:09	00:11	00:11	00:05	00:04	00:23	00:10
19	00:13			19	00:14	00:04	00:04	00:06	00:08	00:15	00:11	00:09	00:22	00:05
20	00:10			20	00:11	00:18	00:16	00:14	00:16	00:15	00:09	00:14	00:26	00:20

Due to size of excel sheet presented results in table 1, 2 and 3 shows only 20 customers, but the calculation is done for all 102 and 50 customers.

The mathematical model for vehicle allocation, shown in chapter 3, is transferred in MS Excel, and is solved by using a mathematical software tool Evolver. The solution given by the solving tool is given in *Table 2***.**

As shown in Table 2, vehicles 1 and 3 are allocated. Costumers allocated to vehicle 1 are the following: 3, 4, 7, 8, 9, 10, 11, 13, 18, 19 and 20. Costumers allocated to vehicle 1 are the following: 1, 2, 5, 6, 12, 14, 15, 16 and 17.

Table 2 - Optimal solution generated by solving the vehicle allocation model

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
24	Vehicle start time		7:00																										
25	Time windows		08:00	10:00	12:00																								
26			Decision matrix																										
27				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Vehicle allocated (YES=1/NO=0)	(Vehicle capa	(Vehicle c	Vehicle capacity [kg]	Total mass [kg] of delivered packages	Total mass [kg] of packages for picku
28			Vehicle 1	0	0	1	1	0	0	1	1	1	1	1	0	1	0	0	0	0	1	1	1	1	113	60	850	737	79
29	Reset the		Vehicle 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1000	0	
30	decision matrix		Vehicle 3	1	1	0	0	1	1	0	0	0	0	0	1	0	1	1	1	1	0	0	0	1	1898	2950	3000	1102	5
31				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2				1839	84
33	Mass of packages for delivery on locati			50	2	300	0	200	10	3	5	0	2	10	10	10	50	30	50	700	2	5	400						
34	Mass of packages for pickup on locatior			0	10	10	20	10	0	0	4	20	2	400	0	30	0	0	20	10	4	0	300						
36	Vehicle 1	Used capacity [kg]	737	737	737	447	467	467	467	464	463	483	483	873	873	893	893	893	893	893	895	890	790						
37	Vehicle 2	Used capacity [kg]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
38	Vehicle 3	Used capacity [kg]	1102	1052	1060	1060	1060	870	860	860	860	860	860	860	850	850	800	770	740	50	50	50	50						
40			750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750						
41			1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000						
42			3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000						
44	Customers allocated		Vehicle 1	0	0	3	4	0	0	7	8	9	10	11	0	13	0	0	0	0	18	19	20						
45	to the delivery vehicle		Vehicle 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
46			Vehicle 3	1	2	0	0	5	6	0	0	0	0	0	12	0	14	15	16	17	0	0	0						

	Vehicle 1 route	Time distance	bij	Time window	Vehicle 2 route	Time distance	bij	Time window	Vehicle 3 route	Time distance	bij	Time window
49			7:00				0:00				7:00	
50	3	0:17	7:17	8:00	#NUM!	0:00	0:00	23:59	1	0:13	7:13	8:00
51	4	0:11	7:28	8:00	#NUM!	0:00	0:00	23:59	2	0:20	7:33	8:00
52	7	0:12	7:40	10:00	#NUM!	0:00	0:00	23:59	5	0:14	7:47	8:00
53	8	0:11	7:51	10:00	#NUM!	0:00	0:00	23:59	6	0:28	8:15	10:00
54	9	0:28	8:19	10:00	#NUM!	0:00	0:00	23:59	12	0:11	8:26	10:00
55	10	0:25	8:44	10:00	#NUM!	0:00	0:00	23:59	14	0:15	8:41	12:00
56	11	0:12	8:56	10:00	#NUM!	0:00	0:00	23:59	15	0:14	8:55	12:00
57	13	0:26	9:22	12:00	#NUM!	0:00	0:00	23:59	16	0:10	9:05	12:00
58	18	0:32	9:54	12:00	#NUM!	0:00	0:00	23:59	17	0:14	9:19	12:00
59	19	0:13	10:07	12:00	#NUM!	0:00	0:00	23:59	#NUM!	0:00	9:19	23:59
60	20	0:22	10:29	12:00	#NUM!	0:00	0:00	23:59	#NUM!	0:00	9:19	23:59

Allocating costumers to delivery vehicles creates delivery routes, which then need to be optimized. A new distance matrix is created containing only locations of costumers allocated to the respective delivery vehicle. The mathematical model for vehicle route optimization is transferred to Excel, and is solved by using the mathematical software Evolver. The proposed solution is shown in *Table 3*.

Table 3 - Optimal solution generated by solving the vehicle routing model

Route	0	1	4	3	2	11	10	12	6	8	5	9	7	13	17	20	14	16	18	19	15	0
Time distance [HH:MM]		00:08	0:18	0:09	0:08	0:14	0:07	0:13	0:10	0:13	0:15	0:19	0:27	0:27	0:23	0:10	0:11	0:12	0:12	0:13	0:15	00:13
bij	7:00	7:08	7:26	7:35	7:43	7:57	8:04	8:17	8:27	8:40	8:55	9:14	9:41	10:08	10:31	10:41	10:52	11:04	11:16	11:29	11:44	11:57
		8:00	8:00	8:00	8:00	10:00	10:00	10:00	10:00	10:00	10:00	10:00	10:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00	
Total mass of packages in vehicle	642	592	612	619	627	617	617	607	597	596	606	626	623	643	653	553	503	473	475	470	440	
Mass of packages for delivery		50	0	3	2	10	2	10	10	5	0	0	3	10	0	400	50	50	2	5	30	
Mass of packages for pickup		0	20	10	10	0	2	0	0	4	10	20	0	30	10	300	0	20	4	0	0	
Vehicle capacity	700																					
Total operational time	4:57																					

As shown in *Table 3*, the delivery schedule is 0, 1, 4, 3, 2, 11, 10, 12, 6, 8, 5, 9, 7, 13, 17, 20, 14, 16,18,19,15 and 0.

Note that the location with the indicator 0 is the LDC, which is the starting and ending location in the delivery route. The higher priority costumers with a sooner time window-deadline (e.g. costumer with identification number 2), are serviced before the costumers which have a later time window-deadline (e.g. costumer with identification number 11). The total time needed for completing delivery processes, pickup processes and the return to the LDC is 4:57. Time window and vehicle capacity conditions are met.

After calculating solution via respective mathematical models, results of both solutions are compared. *Table 4* shows the results of the solutions given by the dispatcher and by using mathematical models, for problems set in the urban and suburban area.

Table 4 - Comparison of generated solutions

Problem type	Urban	Urban	Suburban	Suburban
Solution obtained by	Dispatcher	By using mathematical models	Dispatcher	By using mathematical models
Number of customers	102	102	102	50
Number of delivery processes	78	78	32	32
Number of pickup processes	24	24	18	18
Number of allocated vehicles	3	2	2	1
Number of costumers allocated to vehicle 1	26	51	27	50
Total time needed to complete all processes allocated to vehicle 1 [HH:MM]	4:09	5:23	3:57	5:23
Total mass of packages delivered by vehicle 1 [kg]	33,7	75,5	159,8	232,7
Total mass of packages picked up by vehicle 1 [kg]	46,5	33	66,1	78,2
Number of costumers allocated to vehicle 2	40	51	23	0
Total time needed to complete all processes allocated to vehicle 2 [HH:MM]	5:14	6:12	4:01	N/A
Total mass of packages delivered by vehicle 2 [kg]	63	54,1	72,9	N/A
Total mass of packages picked up by vehicle 2 [kg]	5,9	50,4	12,1	N/A
Number of costumers allocated to vehicle 3	36	0	N/A	N/A
Total time needed to complete all processes allocated to vehicle 3 [HH:MM]	4:29	N/A	N/A	N/A
Total mass of packages delivered by vehicle 3 [kg]	33	N/A	N/A	N/A
Total mass of packages picked up by vehicle 3 [kg]	31	N/A	N/A	N/A
Total time of all allocated vehicles [HH:MM]	13:52	13:35	7:58	5:23

Type of delivery vehicle used in both problems is a medium size delivery van, which has a carrying capacity of 1490 kg. The urban type problem consists of 102 processes, which consist of 78 deliveries and 24 pick-ups. The suburban type problem consists of 50 processes, which are dived to 32 deliveries and 18 pick-ups. Since the density of customers is higher in the urban area, the average traveling time distance is lower in comparison to the suburban area, which means that a higher number of customers can be served in urban area, than in a suburban for the same amount of time.

In case of the urban area, the solution gained by solving the mathematical model for vehicle allocation allocated 2 delivery vehicles, which is an improvement of 33%, in comparison to dispatcher's solution which allocated three delivery vehicles. Customers allocated to delivery vehicle 1 are the following: 1, 4 ,5, 6, 7, 9, 11, 12, 13, 15, 18, 19, 22, 24, 25, 26, 28, 30, 33, 34,35, 37, 38, 39, 40, 41, 42, 43, 45, 48, 49, 51, 56, 59, 62, 66, 67, 68, 69, 71, 72, 81, 82, 83, 85, 89, 90, 92, 99, 100, 101 and 102. Customers allocated to delivery vehicle 2 are the following: 2, 3, 8, 10, 14, 16, 17, 20, 21, 23, 27, 29, 31, 32 ,36, 46, 47, 50, 52, 53, 54, 55, 57, 58, 60, 61, 63, 64, 65, 70, 73, 74, 75, 76, 77, 78, 79, 80, 84, 86, 87, 88, 91, 93, 94, 95, 96, 97 and 98. After optimizing delivery routes of two allocated vehicles, the total time needed for serving all costumers is 13:35, which in comparison to the dispatcher time of 13:52 is an improvement of 2%.

In case of the suburban area, the solution generated by solving the mathematical model for vehicle allocation allocated only one delivery vehicle, which is an improvement of 50%, in comparison to two allocated delivery vehicles by the dispatcher. After optimizing the delivery route in the vehicle routing model, the total time needed for serving all costumers decreased to 5:23, which is an improvement of 32%, in comparison to dispatcher's solution. The mass of packages did not exceed the carrying capacity of allocated vehicles in both types of problem. The highest total mass of delivery packages was allocated towards the vehicle 1 in the suburban area with a value of 232.7, which equals to only 15 % of the vehicles maximum carrying capacity. It should be noted that the HP express did not provide the volumetric mass values for the packages, therefore their influence is neglected in the solution.

5. CONCLUSION

Operator's solutions for assigning and routing delivery vehicles that was analyzed, didn't fully meet the demands of efficiency and effectiveness (allocation based on operator's assessment and experience). For this reason, logistic costs of the company are not minimized, while the highest service level isn't achieved. The optimal solutions of the vehicle assignment problem and the vehicle routing problem were obtained by applying software tools on the mathematical models of the real system.

In order to quantify the improvements, the solutions implemented by the operator were compared to the solutions generated by software tools, in optimizing mathematical models of the problems. In almost every iteration, the optimized solution was better than the operator's solution, only in few iterations the solutions were similar.

Methodology outlined in this paper enable reducing the number of allocated vehicle and the total distance vehicles travel at deliveries and pickups, which results in better utilization of the fleet and increase of the service level. Due to simplicity of use, flexibility and quick problem solving, this methodology is particularly suited for daily use in real-life situations, especially when subsequent modifications are required.

The software tools that were used have certain limitations which makes them insufficient for problems with high number of deliveries and pickups, however the same methodology still could be implemented for such problems, but facilitated by more advanced software tools.

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OPERATIONAL RECOMMENDATIONS AND RESTRICTIONS FOR REDUCING NOISE AT AIRPORTS

ABSTRACT

Sudden development of airports and the urbanization of the surrounding areas results in the increase of noise level and air pollution. Therefore, it is necessary to define and implement operational procedures characteristic for certain airports with the aim of reducing both noise level and air pollution. The operational procedures must be implemented in a manner to insure a harmonized development and modernization of air traffic and to reduce negative effect of aircraft noise in the airport area.

This paper presents an overview of operational procedures that can additionally reduce the negative effect of aircraft noise at an airport and its surrounding population. A visualization of certain operational procedures has been made on the example of the Zagreb Airport in order to emphasize the advantages that would be achieved by their implementation in order to reduce the noise level.

KEY WORDS

noise reduction, noise sources, Zagreb Airport, aircraft, operational procedures

1. INTRODUCTION

Even today, when great attention is directed to environmental protection and ecology, one of the most negative elements in the environment, as well as in traffic, is noise. With the increasing number of flights and in accordance with the expansion of airports, air traffic is becoming a serious problem of the present time. Air transport is the youngest branch of transport, which began to develop rapidly in the fifties of the last century, and the introduction of turbo-jet engines is responsible for its rapid growth. The implementation of such engines in aviation resulted in the construction of larger, safer and faster aircraft.

A negative side effect of the high efficiency and power of turbo-jet engines is noise. The sudden increase in air traffic contributed to the overall noise level which became unbearable. By analysing traffic data, it can be stated that air traffic is constantly growing and the number of produced aircraft in the world is rising fast due to open market (especially in Europe) and entrance of low-cost airlines. In this rapid traffic increase the aircraft noise presents a serious problem, which affects not only the comfort and efficiency of a relatively small number of people in the aircraft, but also the population living close to the airports.

Due to constant expansion of the cities and inhabited areas around the airports, there are more complaints regarding the impossibility of living in these regions. These complaints refer to disturbances, insomnia, and impossibilities of communication. Nowadays, it is clear that each airport and citizens around it have been affected by some kind of noise level or disturbance. Although, there are lots of operational procedures which can reduce noise around airports, most of the airports which are not primary ones or have HUB status do not have these measures implemented or they are not familiar with their benefits.

In this article all operational and technological measures for noise reduction at airports will be presented.

2. BACKGROUND

There are a number of papers that examine the theme of the negative impact of noise on people and the environment. Only several of most significant papers on this subject is mentioned below.

There are different factors that impact aircraft noise perception - one of them is the number of flights (a number of aircraft noise events). Jagniatinskis et al. [1] researched the influence of number of flights' on applicability of the usually used environmental noise metrics: equivalent L_{eq} and maximum L_{max} sound level for the long-term interval of their observation. The correlation between Leq and Lmax levels is considered against duration of observation interval. As a result the definition of representative duration is obtained. Ozkurt et al. [2] researched noise impacts of İzmir Adnan Menderes Airport on public health. The research showed that the number of people who are potentially exposed to high noise levels and threatened by several illnesses, such as hypertension and sleep disturbances, is significant in the surrounding area of the airport. The same author used SoundPLAN software for noise modelling to estimate the noise exposure levels both for current flight operations and for future capacities at the example of Ankara Esenboğa Airport. Bentes et al. [3] analysed airport noise exposure around Viracopos International Airport by quantifying the proportion of people highly influenced by the noise in the surrounding zones using simulations, integrated noise models and geographic information systems. Integrated Noise Model (INM) was used [4] for the estimation of the noise impact produced by the airport and for the evaluation of exposed population. The paper showed that the utility of AIS (Automatic Identification System) data and their specific elaboration to draw up noise abatement measures in order to reduce the noise impact on population and allow the airport development. Another paper [5] analysed the effects of aircraft noise on residential satisfaction and the study showed that the most important determinants of residential satisfaction are: road traffic noise annoyance, age and neighbour noise annoyance. Zachary et al. [6] described a multi-indicator assessment and minimization problem focused on aviation community noise.

In the second type of papers the authors analyse the operational measures that can contribute to reducing noise at airports and their surroundings. In order to determine the most influential factors for the introduction of noise abatement measures in airport surroundings, the research [7] examined 248 European airports. By analysing the correlation of specific characteristics related to airports (number of runways and aircraft operations, distance from the city and the population of the city that it serves, gross domestic product-GDP- per capita) and the number of introduced noise abatement measures, the authors proposed noise abatement measures. A non-homogeneous Poisson model was used to study the behaviour of airport noise levels. The model was used to count the number of times that the noise level exceeded a given threshold in a time interval of interest [8]. In the research [9] airport noise insulation programs for reducing the amount of noise, which people are exposed to, without impacting the operating capacity of an airport were analysed. In the paper [10, 11] a complete Strategic Noise Mapping research and Action Noise Plans assessment and evaluation are presented with the aim to access land use management as an effective tool for protection from aircraft noise. Prats et al. [12] presented the optimization of aircraft noise abatement procedures by using a multi-objective optimization strategy that employs goal, lexicographic-egalitarian and hierarchical optimization techniques.

What sets this paper apart from the majority of the above-mentioned ones is that it provides an overview of all the known procedures that are nowadays applied in order to reduce noise at airports and around them.

3. DEFINITION OF AIRCRAFT NOISE MEASURING VALUES

In view of the fact that the aircraft noise is one of the major environmental problems of the modern air transport, it is necessary to be familiar with the basic theoretical knowledge which primarily comes from the key definition of sound. By definition, the sound is a periodic change of pressure which spreads through an elastic fluid at a specific rate [13]. The sound can be registered by the hearing sense, i.e. by the physiological characteristics of the ear and by interpreting the auditory information within the brain. It can also be detected subjectively and/or physically (objectively). The negative feeling of an increased sound level can be called noise although the definition has a much more refined character. Noise can be defined as a complex range of different sound waves of different frequencies, the hertz (Hz), and intensities, the decibel (dB). The hertz is the unit of frequency in the International System of Units (SI); it is defined as one cycle per second. The decibel is a logarithmic unit used to express the ratio between two values of a physical quantity, often power or intensity. The frequency range of an average normal human hearing is from 16 Hz up to 16 kHz, depending on the age, years of service and the person's job description [14]. The measure unit for the determination of the noise is called decibel. Decibel is defined as ten times the logarithm of the ratio of two intensity power values, the measured intensity value and the commonly used intensity reference value of 10^{-12} W/m^2 (watts per square meter). The number of decibels of intensity is calculated by using the formula below [13]:

$$\mathrm{Li} = 10\log\left(\frac{I}{I0}\right) \tag{1}$$

Where:

- L_i - stands for the level of intensity (a value in dB),
- I - stands for the measuring intensity (a value in W/m^2),
- I_0 - stands for the intensity reference value of 10^{-12} W/m^2.

The A-weighted curve is used for easy evaluation of the relative intensity of different sounds which consist of several different frequencies. The level of sound pressure measured through such filter is called the A-weighted sound level or A-weighted decibel (dBA) which contains an additional dimension of environmental noise that varies with time. In case of the aircraft approaching, the sound level increases and in the case of the aircraft distancing, it decreases. Due to such variations, a particular *"sound event"* is often described as its maximum sound level value or the maximum noise level (L_{max}). The formula for calculating the maximum noise level is listed below [14]:

$$Lmax = \max\ (L(t) \Big|_0^T) \tag{2}$$

Where:

- L_{max} - stands for the maximum noise level (dB),
- T - stands for the final time period, from zero time, in which the maximum noise level occurs,
- L - stands for the level of pressure, intensity or power (dB).

For the accurate and comprehensive measuring of the noise level in aviation it is also necessary to specify the measure of the cumulative exposure to a noise level of an event called sound exposure level (SEL) and the equivalent sound level measure (L_{eq}). SEL is defined as the accumulation of sound energy for the duration of an event, where the duration is defined as the period when the A-weighted sound level exceeds, for the first time, the threshold level until it drops back below the threshold level. The equivalent sound level measure (L_{eq}) is defined as the average sound level that has emerged during a certain observed period such as one hour, during the night or a 24 hour period. The formulas for SEL and L_{eq} are listed below [14]:

$$SEL = 10 * \log_{10} (\textstyle\sum_{i=1}^{n} 10^{Li/10}) \tag{3}$$

$$Leq = 10 * \log_{10} (\tfrac{1}{T} \textstyle\sum_{i=1}^{n} 10^{Li/10}) \tag{4}$$

It is also necessary to define the community noise equivalent level (CNEL) which represents the noise level over a 24-hour period. During the aircraft certification the effective perceived noise level (EPNL) is used. It represents the effective perceived noise level by a human as prescribed under the International Civil Aviation Organization (ICAO) Annex 16. The additional data required for further calculations and analysis of noise level is the average noise day-evening-night level (L_{den}). Within the L_{den} there are three periods that are commonly defined by the following periods [16]:

- the day (from 07:00 until 19:00) with no penalties to add for the measured dB level,
- the evening (from 19:00 until 23:00) with 5 dB penalty addition,
- the night (from 23:00 until 07:00) with 10 dB penalty addition.

The formula for calculating the L_{den} with the specific time periods for Croatia is listed below [15]:

$$\mathrm{Lden} = 10 * \lg\frac{1}{24} * \left(12 * 10^{\frac{\mathrm{Lday}}{10}} + 4 * 10^{\frac{\mathrm{Levening}+5}{10}} + 8 * 10^{\frac{\mathrm{Lnight}+10}{10}}\right) \tag{5}$$

Where:

- L_{day} - the average noise level for the period from 07:00 until 19:00 (dB),
- $L_{evening}$ - the average noise level for the period from 19:00 until 23:00 (dB) + 5 dB penalty addition,

- L_{night} - the average noise level for the period from 23:00 until 07:00 (dB) + 10 dB penalty addition.

4. AIR TRANSPORTATION NOISE SOURCES

Airport noise results from the various operations of the air transport and combined transport. There are two main sources of airport noise: the noise created by the flight operations [17] and the noise resulting from ground handling operations on the land [18]. While observing the aircraft in flight, the main sources of noise are:

- **Noise produced by the propulsion of the aircraft:**
    - <u>Turbo-jet engines</u> - noise caused by the turbo-jet engine consists of the compressor noise, noise caused by the vibration of the motor housing and the exhaust noise. The exhaust noise also contains the turbine noise and fuel combustion noise. The intake noise is a distinct noise component; it consists of a broadband noise and tonal components caused by the compressor blades. The level of exhaust noise during normal conditions is much higher than the other components. The engine noise is caused by the turbulence that occurs in the mixing zone of very fast and hot exhaust gases with the calm cold air from the environment. During the flight, the exhaust noise is 3 to 5 dB lower than the exhaust noise level during the same operating mode on the ground. The cause of this difference is the smaller relative velocity of the exhaust compared with the surrounding air, which results in less intense turbulence [16].
    - <u>Turbo-fan engines</u> - this aircraft engine model is similar to the turbo-jet engine. It was created as a result of efforts to reduce the noise level and to increase the efficiency of the turbo-jet engine. It consists of blades and a smaller turbo-jet engine that comes with an extension and runs the blades. A part of the airflow from the blades passes through the engine where it additionally burns and gives thrust. The majority of commercial aircraft use this type of engines because they are very efficient and relatively quiet during operation. The noise level of the turbo-fan engines during operation with maximum power dominates next to the broad-frequency aerodynamic exhaust noise [16].
    - <u>Propeller-driven engines</u> - the propeller drive is not so represented among commercial aircraft nowadays. The propeller is defined as a rotor with at least two blades which can be either with a fixed or variable pitch. The blades are designed to create a low pressure area on one side and a high pressure area on the other side of the blade. The resulting force runs the air mass among the axis of rotation, creating thrust. The source of the propeller noise is very tonal and spatially directed. Mechanisms for the creation of propeller noise are primarily associated with the blade thickness and with the aerodynamic pressure on the blades which cause thrust and torque. One of the sources of propeller noise is also the turbulence on the boundary layer of the blades within the incoming air stream, but the broadband range and the noise level are generally low. The level and noise spectrum caused by the propeller is determined by a series of factors, such as: peripheral and progressive speed of the top of the blade on the propeller, the shape and numbers of the blades, etc. The propeller noise sources can be divided into fixed, variable and random sources.

- **Aircraft structure noise** - it is defined as unwanted sound that occurs during the airflow along the aerofoil. The noise caused by the aerofoil is the result of the pulsing aerodynamic forces on the wing, the existence of a turbulent boundary layer and a vortex which occurs when the air flow passes the surface of the wings, fuselage and the tail, as well as the current around the landing gears, flaps and various protrusions on the hull. During the take-off, the noise level caused by the aerofoil is insignificant, while the noise level during the approach and the landing has a great importance, and by its intensity it is comparable to the noise caused by the propulsion of the aircraft. The noise created by the aerofoil can be called structural noise and it is defined as a noise that is not caused by the propulsion of the aircraft during the flight. The structural noise sources are: the landing gear, slats, flaps, wing surface that moves and the vertical stabilizer. The noise made by flaps is produced on the outside and lateral edge of the flaps. The appearance of the vortex (because of the opening and closing of the flaps) is the main cause of generating noise around the side portion of the flaps. For this reason turbulence appears, as well as a flow of pressure which increases the aircraft noise. It is proven that all of the elements that are moving and acting during the take-off and the landing produce lower noise level in small and medium-sized aircraft and higher noise level for larger aircraft. The most important source of aircraft structure noise is the landing gear. The cause of such noise is the airflow around it, taken into account that the landing gear has so many sharp curves that it increases the complexity of the airflow, and therefore it increases the noise level. The noise effect produced by the landing gear occurs during the approach and the landing where the greatest resistance occurs around the landing gear parts [19].

5. OPERATIONAL PROCEDURES FOR BECOMING ”QUIET” AIRPORT SYSTEM

Aircraft are 75% more quiet today than 40 years ago [20]. However, this progress has not been correlated with a decrease in community pressure to further reduce exposure to aircraft noise.

The reduction of noise at its source is the first element of the ICAO “Balanced Approach to aircraft noise” [21], adopted back in 2001 (ICAO Annex 16 (Vol. I and Vol. II.), Doc 9829 [22, 23]). This Guidance was incorporated into EU law in 2002, with the adoption of Directive 2002/30 [24]. In parallel, the decision was made to withdraw completely from operations at EU airports Chapter 2 aircraft, bringing significant noise benefits to the local communities.

Since then, a progress was made on two fronts when it comes to the reduction of noise at its source:

- Directive 2002/30 [24] has been revised and includes the possibility to phase-out those aircraft that are compliant with Chapter 3 by a margin of less than 10 dB, after a cost-effectiveness analysis on an airport-by-airport basis;
- A new noise standard, Chapter 14, was adopted in February 2013. It represents a 7 dB improvement compared to Chapter 4.

Although there are lots of measures for noise reduction which can be used at airports, it is important to understand that each airport has its own specialties and characteristics which directly affect the possibility of realizing such procedures. Following that, it is necessary to understand that, for noise reduction, it is mandatory that communication and development of procedure is maintained between ATC, Airline and Airport. The list of operational procedures and their benefits for noise reduction after the implementation are listed as following:

- **Continuous Descent Operations** (CDO): 55 L_{eq} contour for a typical night could be reduced by about 18% by the use of CDOs; noise reduction on ground can vary from 3 to 12 dB; CDA angle 3° (more pleasant for passengers); fuel savings = reduction of emissions;
- **Continuous Climb Operation** (CCO) - Noise Abatement Departure Procedures (NADP) – Benefit: rapid aircraft climbing to twice the height, which ensures fast noise reduction on the ground below that path; retracting flaps occurs at high altitude, and almost horizontal segment is much less distressful to the settlements below the corridor;
- **Modified approach angle or displaced landing thresholds** – an increase in ILS glide slope results in a reduction of noise on the ground as the aircraft are higher during the approach. This measure is usually implemented for obstacle clearance rather than noise mitigation;
- **Low power/low drag approach** profiles - this approach procedure implies delayed extension of flaps and gear, so the aircraft stays in a clean, quieter configuration longer; this leads to a reduction of thrust and reduces both noise and fuel consumption;
- **Minimum use of reverse thrust** after landing (when it is possible due to safety reason);
- **Curved Approach** (advanced CDA) - on a curved approach procedure, aircraft do not have to turn into the landing direction before the final approach segment, thus providing greater flexibility in the distribution or direction of noise; no international regulations and certifications have been developed so far; in combination with a CDA this is also referred to as ACDA (advanced CDA).
- **Noise preferred arrival and departure routes –** routes which will be at a larger distance from populated areas;
- **Flight track dispersion or concentration**;
- **Preferential runways** – the use of preferential runways reduces noise impact in a certain area by directing all, or just the noisiest, traffic to an alternative runway; a different runway may have to handle more operations, which increases the noise; this procedure is mainly applied during the night time when noise mitigation is crucial - usually nonpeak hour traffic allows the use of preferential runways;
- **Displaced threshold** - a displaced threshold moves the touchdown position inwards along the runway; aircraft is higher above the ground at any given point along the approach path; for a 3° glide slope, a displacement of 300 m results in a height difference of about 15 m and a noise reduction of 0.5 dB where the aircraft is at 300 m; displaced threshold reduces the usable runway length for landing;
- **Avoided using reverse thrust** in night periods.
- **Taxi power control** (single or dual engine taxi) and taxi queue management;
- **Ban on aircraft engine testing or training flights at certain times**;
- **Controlling time for Engine Run-ups**, (required for different aircraft maintenance tasks) noise events are less predictable - a variety of restrictions may be applied, e.g. time period for possible run-up, run-up duration, number of run-ups per day or per aircraft type;
- **Limited use of Auxiliary Power Unit** (APU) or use Ground Power Unit (GPU) Electricity from GPUs and pre-conditioned air (PCA) are provided in order to enable APUs to be shut down, allowing for a reduction of ground noise.

Following the above mentioned list of procedures, the visualization of all operations is shown below, which most airport use during arrival, handling, departure (Figure 1) and how it will look if airports implement all the possible noise reduction procedures (Figure 2). Both figures were made as a visualization of Zagreb Airport using Google Earth Pro software. The Figure 1 presents current situation at Zagreb Airport related to the operational procedures.

As far as Zagreb Airport is concerned, the most problematic part is departure of aircraft from the runway threshold 05 as aircraft closely overfly villages, causing complaints about the noise. In addition to that, it must be emphasized that Zagreb Airport is a mixed airport, which means that its traffic consists of commercial and military aircraft, and the military aircraft are not covered by the Croatian Noise Protection Act. On the other hand, the majority of the houses overflown by aircraft have been illegally built, so that legally speaking, those citizens cannot complain about the noise.

In line with the Croatian Noise Protection Act, each airport which reaches over 50.000 operations must have a permanent Noise Monitoring System. Although it was not mandatory, Zagreb Airport implemented a permanent Noise Monitoring System in 2006, and has been monitoring noise in its surroundings since then. According to the Croatian Law, if the noise threshold is over 65 dB L_{den} over a year, the airport should implement corrective measures and activate its Environmental Action Plan. For now, Zagreb Airport does not need to do this since all the indicators are below the legal requirements, but an Action Plan was made and is ready to be used if needed.

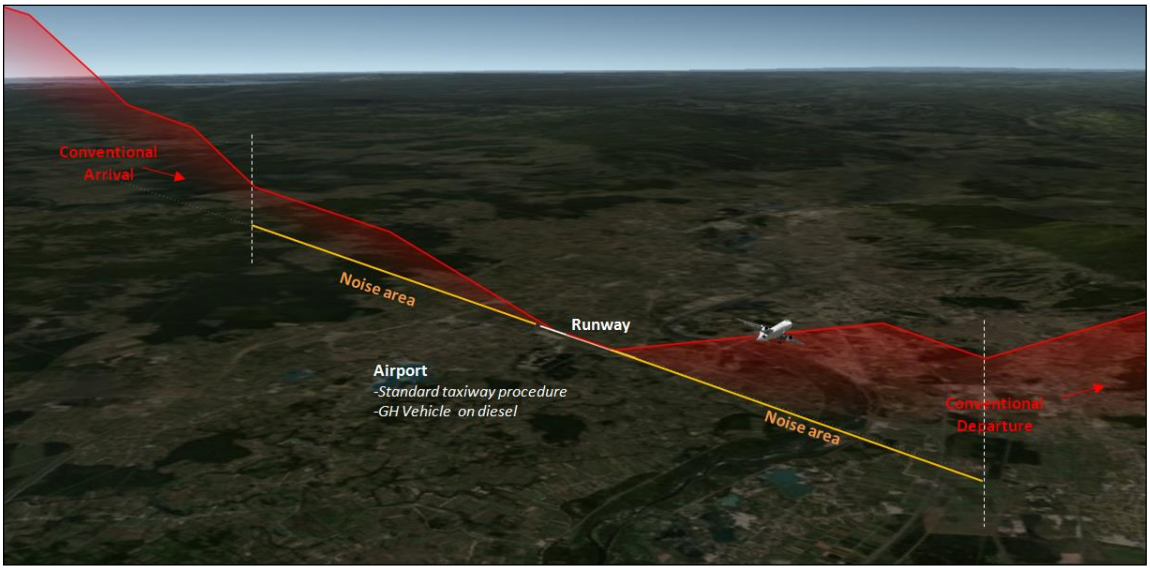

Figure 1 - Usual operational procedures at Zagreb Airport
Source: Prepared and edited by the authors

If noise exceeds the values defined by the Law, Zagreb Airport will activate the Environmental Action Plan, which consists of several operational procedures showed on Figure 2. It must be clear that an airport can reduce noise in its parameter, as well as reduce the noise related to Ground Handling Equipment. For all other noise reductions a strong collaboration with ATC and airlines must be established. Currently, there are speculations about the implementation of some noise abatement procedures which will be part of the project implementation known as Airport Collaborative Decision Management (A-CDM). Several years ago, Zagreb Airport, together with CroControl and Croatia Airlines, started to discuss about the implementation of CDM but its implementation is still in the negotiation and discussion status. As it was previously mentioned, the airport can have a role in noise measuring and helping the ATC and Airline to reduce the noise, but alone it cannot reduce the noise to a level which the population in the surroundings find acceptable. For a better visualization, Figure 2 shows all that can be implemented at Zagreb Airport from the above list of noise reduction options so that the airport can have the "Noise free airport" status.

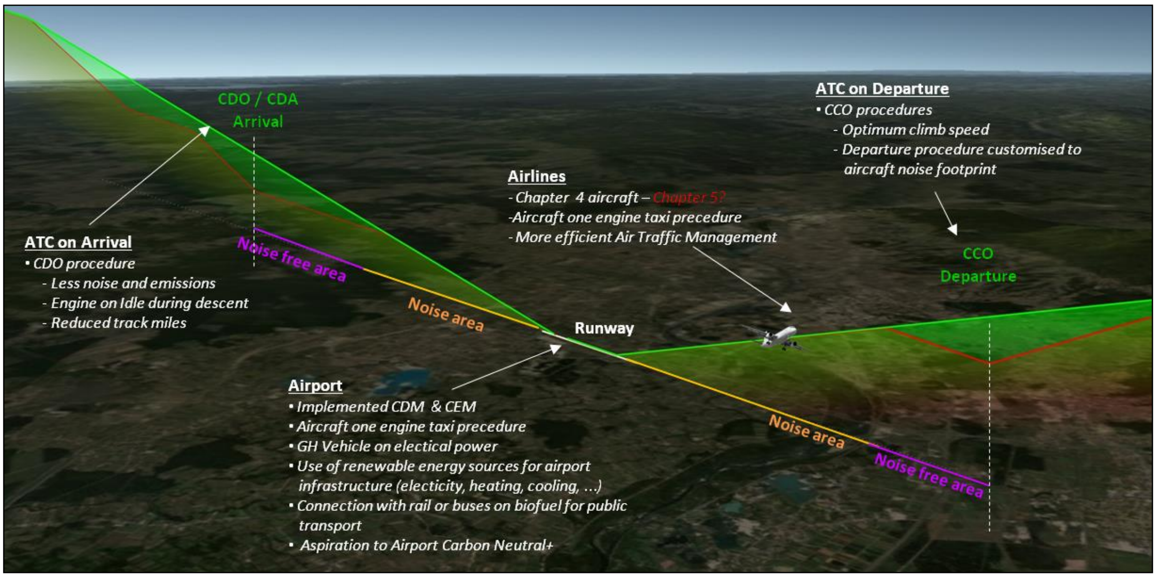

Figure 2 - Proposal for using combination of all procedures to reach "less noise airport" at Zagreb Airport
Source: Prepared and edited by the authors

6. DISCUSSION AND CONCLUSION

With the development of airports and expansion of the urban areas, which result in serious problems related to noise and air pollution, new approaches must be applied in way to harmonize the development and the modernization of the air traffic and the "potential enemies" that occur as the consequence of the technological development of airports.

The solution for the aircraft and airport noise will have to be found in some alternative options such as: replacement of the existing air-fleet which belongs to category 2, buying new generation of aircraft, construction of approach and take-off runways that are not in the paths of inhabited areas, or to implement operational measures which need to be defined to all stakeholders (Airline, ATC, Airport).

Lots of airports around the world have limited financial sources to invest in large infrastructures, such as a new runway which will be directed outside the population area, or to finance the citizens living around the airport to have their houses isolated from the noise. Due to that fact, this paper presents many of the "easily" implemented solutions that most of airports can use.

Although the reduction of noise largely depends on airport management, it is always necessary to remind that safety is the first priority in aviation. There are certain limits when noise can be prevented, but the safety standards do not allow it. In such situations, the noise reduction is neglected and the entire focus is on the flying safety.

Referring to all the above mentioned, it is clear that the noise reduction is not on the level at which population and engineers would like it to be. Nowadays, new technology and the possibility to implement less noise operating procedures enable the airport and the people living in the surrounding area can co-exist in the transport, economic and environmental system.

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ANALYSIS OF CUSTOMS VIOLATIONS IN THE REPUBLIC OF CROATIA

ABSTRACT

Customs means duty or fee for importing or exporting of goods from foreign countries and represents a way of protecting domestic production and goods from foreign competition.

The Customs Act lays down the rights and obligations of persons and customs services in the context of movement of goods and passengers between Croatia and foreign countries. Minor violations are the only acts regarding customs and criminal responsibility described in the Customs Act. It is important that every penalty for minor violations, including custom violations, is adequate to the committed act, so that any natural person or legal entity can take responsibility for the act committed.

This paper describes the basic terms related to international forwarding and presents the analysis of customs violations and their associated penalties in the EU and Republic of Croatia.

KEY WORDS

customs; Customs Act; customs violations; penalty

1. INTRODUCTION

Custom has always had significant part in national income, and after Republic of Croatia ingressed to European Union, some changes happened - customs control and border controls are terminated but still customs officers level of work is not reduced. This fact comes from requirements of European Union and all dedicated to the cause of reduction in number of customs violations. Violations keep occur, but due to big breakthrough in technology and stricter laws, goods are much easier to follow and it is much easier to control the carriers.

Customs violation is every illegal import or export of goods into customs area over customs border in irregular time, every disabling of access to the goods from the side of customs officers or disabling access to the vehicle which is transferring the goods. Every customs violation needs to be justly fined under conditions set by Law of implementation of custom regulations in the European Union (NN 110/15) and all other regulations set by the Republic of Croatia and European Union. Customs officers can decrease or increase every violation of the Violation law, while taking into consideration given circumstances.

For every violation, therefore also for every customs violation there is pre-defined penalty and fine taken from the regulations and laws. Every fine for certain violation is charged to responsible person, but also to the person who received the goods which is imported or exported under violation.

2. BASIC TERMS ABOUT CUSTOMS PROCEDURE

Law of implementation of custom regulations of the European Union (NN 54/13) defines the basics concepts about the customs procedure. Below are defined the basic terms which are important for understanding the article, and those are customs clearance of goods, customs control, customs checks, goods submition, goods release, customs-violation procedure and Intrastat.

Customs clearance of goods [1] is every action which is determined with customs regulations of permitted customs usage of goods.

Customs control [1] includes general acts which are used by Customs administration to ensure implementation of customs and other regulations which are aplicated on goods under customs control. Subject of customs control [1] is every good which has prescribed customs control, which is subject of prohibition and restriction of import or export into area determined with Customs regulations of European Union. Under customs control are also all means of transport, containers, tanks and packaging for which there is reasonable suspicion that inside of them can be found goods which is under customs control under the customs regulations of European Union.

Customs check [2] means certain actions like checking and searching of goods, checking and searching the means of transport, checking and searching persons in passenger transport and their luggage, checking of existence, credibility and truthfulness of documents in customs procedure, checking of business records, additional investigations which are under control of Customs administrations and its officers.

Goods release [2] is registration of goods to the customs house that goods are located in their facility or in any other place which is determined and approved by the customs house. *Goods release* means an action by which customs house allows disposition of goods in term of approved procedure.

Customs-violation [3] procedure is violation procedure which Customs administration is conducting for violations prescribed by the Custom law (NN 30/14), Law of implementation of customs regulations of the European Union (NN 54/13), Law on excise duties (NN 81/13) and laws of special taxes.

Intrastat form [4] is a statistical report by which goods exchange between member states is monitored. After entering the European Union, Republic of Croatia started to perform Intrastat form compilation. All business which has VAT number and the value of their annual good exchange exceeds determined level needs to compile Intrastat form. Data inserted into Intrastat give information of merchandise flow between state members of the European Union, and combined with data from Extrastat[1] are important source for compilation of balance sheet and for national expences.

3. CUSTOM AND VIOLATIONS REGULATION OF REPUBLIC OF CROATIA

With admission into European Union, Republic of Croatia became a part of unified custom area of European Union. Accordingly, following customs regulations of European Union are directly applied on the territory of Republic of Croatia [5]:

- Custom legal code of the Community (CZZ) – statute Council (EEZ) nr. 2913/92 of 12th October 1992, by which CZZ2 is enacted, with all additions and changes.

[1] Extrastat – Goods exchange with third countries, which are not members of the European Union

- Statute implementation of Custom legal code of the Community (UPCZZ – Statute of Commission (EEZ) nr. 2454/93of 2nd July 1993 about regulations for implementation Statute Council by which CZZ3 is enacted, with all additions and changes.
- Law of implementation of custom regulations of the European Union;
- Various implementation regulations (regulation books) by which customs institutions are regulated detailed and procedures whose inaction is under jurisdiction of individual member state (such as Rule book about conditions and ways of submition in insurance, Rule book of implementation the system for custom quotes, Rule book of conditions for determination of official jobs, etc.)

Besides that, basic rules and conditions for deliverance of paying the custom fees are regulated by Statute of the deliverance in the European Union – Statute Council of the European Union nr. 1186/2009 of 16th November 2009 about the system for Customs deliverance in the European Union.

Except mentioned regulations prescribed by the European Union, in Republic of Croatia customs management is regulated by the Customs law (NN 54/13) by which following customs authorizations are regulated:

- collecting, evaluation, recording, processing and use of data and notifications,
- overview and checking of documents truthfulness and credibility
- checking of person identity,
- checking of attributes and status of goods,
- adduction,
- giving warnings and orders,
- temporary restrictions regarding free movement,
- checking of persons,
- checking of goods,
- monitoring, stopping, checking and inspection of means of transport,
- entrance, checking and searching of business premises, spaces and objects,
- temporary expropriation of goods and documents,
- use of means of coercion.

Law of implementation of custom regulations of the European Union defines the violations which represent only actions of customs-criminal responsibility flow which fees are prescribed. Besides the Law of implementation of custom regulations of the European Union, custom violations are regulated with Misdemeanor law (NN 110/15) in Republic of Croatia. Sanction measure of most common custom violations is money fee which is prescribed in Misdemeanor law. Violations and violation-legal sanctions are prescribed for actions which threaten public order, social discipline and social values guaranteed according to the Constitution of Republic of Croatia. More detailed violations are described below in the article.

4. IDENTIFICATION OF CUSTOM VIOLATIONS IN REPUBLIC OF CROATIA

According to [6] violations are those behaviors which threatens public order, social discipline and social values guaranteed according to the Constitution of Republic of Croatia., international rights and laws which protection is not possible without violation-legal sanctions, and its protection is not accomplished criminal-legal coercion.

Custom violation is every violation of custom regulations. Law of implementation of custom regulations of the European Union (NN 54/13) defines following violations:

- illegal import or export of goods into custom area when crossing border is closed,
- preventing access to commercial property which is determined as a official place of work,
- illegal import or export of cultural and natural goods,
- import or export of motor vehicles,
- violations according to the customs code,
- violations regarding to the supporting documents,
- violations regarding documents,
- violations regarding the goods,
- violations regarding regulation on the exemption from customs duties.

Custom administration has a great role in suppression of "gray economy" which influences on the economy and economical activities on national and international plan. By conducting control activities, special attention is focused on the implementation of enhanced control measures and detection of illegal activities in the field of transport of excise goods, unregistered activities, illegal trade, the implementation of intellectual property rights, dedicated use of energy and control and collection of the tourist tax and the subsequent customs control.

As stated earlier, the customs administration attains certain revenue to the state, and according to data from [7] in 2014 the revenue was 20,925,654,994.00 HRK which constitutes 18.35% of the total revenues of the state budget in 2014 as shown in Figure 1.

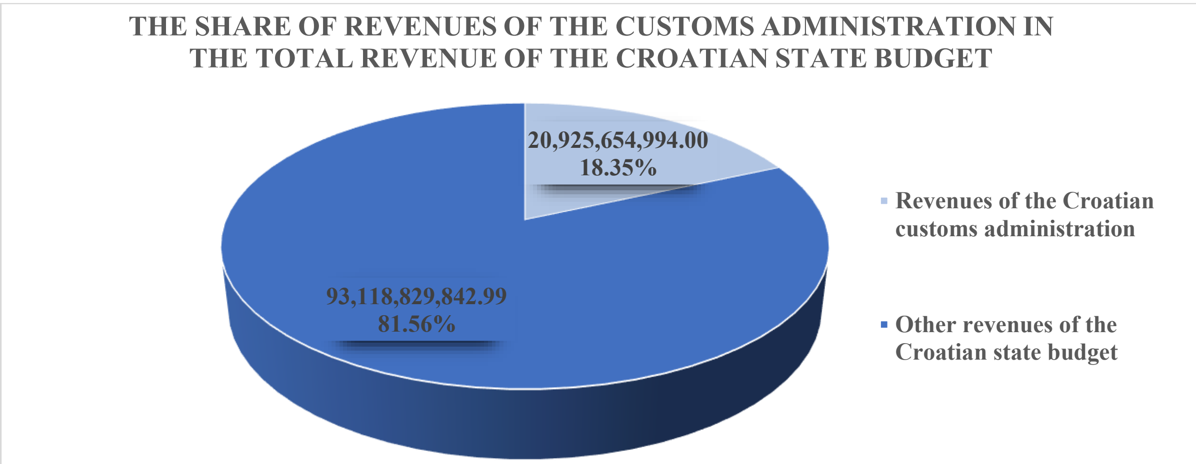

Figure 1 - Percentage of revenues of the Croatian customs administration in total revenues of the state budget in 2014
Source: Made and adjusted by author, according to [7]

According to data from [8], of 20,925,654,994.00 HRK, 26,045,190.18 HRK refers to funds received from payment of penalties for customs violations, which represents 0.12% of the total revenues of the Customs Administration. According to data from [9], total of 95,194 registered customs violations in all member states in 2014. The biggest number of customs violations was recorded in Germany, where it is recorded a total of 42,876 customs violations, approximately 45.04% of all customs violations in the European Union. Many violations were recorded in the United Kingdom (11,863, 12.46%), then Belgium (9,013, 9.47%), Ireland (8,121, 8.53%), Slovenia (4,050, 4.25%), Spain (3,410, 3.58%), and others, as shown in table 1. Approximately 0.94% or 895 customs violations have been recorded in Croatia, therefore Croatia is on the 14th place in European Union by the biggest number of customs violations.

Table 1 - Overview of cases detained per member state EU, 2014

OVERVIEW OF CASES DETAINED PER MEMBER STATE EU, 2014							
#	**Member States**	**Number of cases**	**%**	**#**	**Member States**	**Number of cases**	**%**
1	Germany	42,876	45.04%	15	Czech Republic	820	0.86%
2	United Kingdom	11,863	12.46%	16	Lithuania	506	0.53%
3	Belgium	9,013	9.47%	17	Bulgaria	502	0.53%
4	Ireland	8,121	8.53%	18	Netherlands	465	0.49%
5	Slovenia	4,050	4.25%	19	Romania	401	0.42%
6	Spain	3,410	3.58%	20	Sweden	347	0.36%
7	Italy	3,036	3.19%	21	Latvia	290	0.30%
8	Slovakia	1,584	1.66%	22	Hungary	226	0.24%
9	Denmark	1,475	1.55%	23	Luxemburg	203	0.21%
10	France	1,302	1.37%	24	Estonia	188	0.20%
11	Austria	1,289	1.35%	25	Malta	131	0.14%
12	Portugal	1,068	1.12%	26	Greece	112	0.12%
13	Poland	900	0.95%	27	Cyprus	87	0.09%
14	Croatia	895	0.94%	28	Finland	34	0.04%
Total customs violations in the EU					**95,194**		

Source: Adapted from [9]

Regarding the type and quantities of confiscated goods in Republic of Croatia, according to the data of Customs administration, most common type of goods which are the reason of customs violations are cigarettes, other tobacco products, drugs, opiates and alcoholic beverages. According to [7], in 2014 by conducting regular and increased supervision measures in Republic of Croatia was confiscated in total 12,873,542 pieces of various types and brands of cigarettes, 26,325.60 kg of tobacco, cash in the amount of 235,557.00 EUR and a total of 17,790.83 liters of alcohol and alcoholic beverages and 43,821.70 liters of wine. It has been confiscated a total of 288,145.67 grams of drugs and 15,168 pieces of medicines. When implementing the provisions of the CITES Convention and the provisions of the Law of international movement and trade in wildlife it was found 20 attempts to smuggle of endangered species of wild plants and animals. In addition, there were also 60 attempts to smuggle weapons. These violations are shown in Table 2.

Table 2 - Confiscated types and quantity of goods, 2014

CONFISCATED TYPES AND QUANTITY OF GOODS, 2014	
Types of goods	**Quantity**
Cigarette (pcs)	12,873,542
Tobacco products (kg)	26,325.60
Heroin (g)	43,500.00
Cocaine (g)	1,273.00
Marihuana (g)	241,850.00
Amphetamine, synthetic drugs (g)	306.72
Antibiotics / testosterone / steroid (g)	1,215.95
Medications containing narcotics (pcs)	15,168
Other (pcs)	3,642
Attempted smuggling of endangered species of wild plants and animals	20
Illegal transfer of cash across the state border (EUR)	235,557.00
Number of attempts to smuggle weapons	60
Alcohol and alcoholic beverages (l)	17,790.83
Wine (l)	43,821.70

Source: Adapted from [7]

Comparing the quantities, according to data from [7] and [9], which were found when committed violations between Croatian and the European Union can be noticed that Republic of Croatia makes a big share in the total amount of products found. The largest percentages are tobacco products which include electric cigarette, cigar, cigarette paper and etc. The percentage of tobacco products which were confiscated in the Republic of Croatia make 15.19% of the total confiscated products throughout the European Union, while confiscated quantity of cigarettes makes 5.21%. Alcohol, alcoholic beverages and wine also occupy a large share in the total amount of products found. Given the amount of alcoholic beverages to be imported / exported to / from Republic of Croatia, 9.65% and 2.95% in the total amount of the detected products make up a large percentage.

Table 3 - Comparison of the amount of confiscated quantity product between Croatia and EU, 2014

COMPARISON OF THE AMOUNT OF CONFISCATED QUANTITY PRODUCT BETWEEN CROATIA AND EU, 2014			
Types of goods	**Croatia**	**EU**	**%**
Cigarette (pcs)	12,873,542	246,926,160.00	5.21%
Other tobacco products (kg)	26,325.60	173,282.00	15.19%
Alcohol and alcoholic beverages (l)	17,790.83	602,409.00	2.95%
Wine (l)	43,821.70	453,971.00	9.65%

Source: Adapted from [7] and [9]

According to the means of transport [9], in 2014 most violations were recorded in postal traffic 81.32%, while attempting to smuggle illegal items and substances through parcels. The least of customs violations were recorded in railway transport, 0.01% of them.

When it comes to the quantity of products that were confiscated, according to [9] it can be concluded that in sea traffic confiscated quantities are the largest, or a total of 69.96%. In the postal traffic, which was recorded the highest number of total violations, now is located near the bottom with 6.46%. Rail transport is at the very bottom of the list with 0.85%.

According to [9], sea traffic is again at the top when it comes to the total value of the product over which customs violation in 2014 was made meaning 51.43%. While air (17.40%), postal traffic (16.38%) and road (14.53) traffic have approximately the same percentage, rail transport is again at the bottom of the list with 0.26%.

Table 4 - Violations by means of transport – Cases, Articles, Retail value, 2014

VIOLATIONS BY MEANS OF TRANSPORT – CASES, ARTICLES, RETAIL VALUE, 2014						
Mean of transport	**Cases**	**%**	**Articles**	**%**	**Retail value**	**%**
Air	13,166	13.83%	4,602,394	12.94%	107,346,976	17.40%
Post	77,416	81.32%	2,298,352	6.46%	101,056,697	16.38%
Rail	11	0.01%	303,000	0.85%	1,616,411	0.26%
Road	1,812	1.90%	3,480,222	9.78%	89,665,985	14.53%
Sea	2,789	2.93%	24,885,014	69.96%	317,360,268	51.43%

Source: Adapted from [9]

5. SANCTION OF CUSTOM VIOLATIONS IN REPUBLIC OF CROATIA

Sanction of custom violations is regulated by the Custom law, Law of implementation custom regulations of the European Union, Law of excise duties and the Law of special taxes. Custom-criminal procedure is solved by the Custom administration for all violations prescribed in mentioned laws.

In table 5 are shown the amounts of fees sanctions for certain types of violations which are mention earlier.

Table 5 - The prescribed punishment for customs violations

THE PRESCRIBED PUNISHMENT FOR CUSTOMS VIOLATIONS			
Types of charge	**Prescribed punishment (in HRK)**		
	Legal entities	**Persons in charge in the legal entity or natural person**	**Physical person, artisan or a person pursuing another independent business**
Illegal import or export of goods in the customs territory at the time of the border crossing does not work	10,000 – 1,000,000	3,000 – 100,000	5,000 - 900,000
Disabled access to business areas that are designated as a officially place	3,000 – 1,000,000	1,000 - 100,000	3,000 - 900,000
Illegal import or export of cultural and natural asset	10,000 - 1,000,000	3,000 - 100,000	5,000 - 900,000
Customs violation import and export of motor vehicles	10,000 - 1,000,000	3,000 - 100,000	5,000 - 900,000
Customs act violations	10,000 - 1,000,000	3,000 - 100,000	5,000 - 900,000
Violations related to supporting documentation	10,000 - 1,000,000	3,000 - 100,000	3,000 - 900,000
Violations related to required documents	2,000 – 500,000	1,000 – 50,000	1,000 - 100,000
Violations related to goods	2,000 – 500,000	500 – 50,000	1,000 – 100,000
Violations related to the Regulation on exemptions from customs duty	3,000 - 1,000,000	1,000 - 100,000	3,000 – 900,000

Source: Adapted from [1]

By the Law of implementation of custom violations in the European Union is regulated a sanction measure of resumption for [1]:

- every goods which is imported/exported or is tried to import/export in or from customs area in the time when the crossing border is closed,
- every protected animal, mushroom or plant which is imported/exported or is tried to import/export in or from customs area without according permissions,
- every cultural or natural goods which is imported/exported or is tried to import/export in or from customs area without prior notification,
- motor vehicle on which the identification numbers of the chassis are counterfeited or on which are placed the license plates not assigned to that vehicle or if for the vehicle the documents are counterfeited or are not belonging to that vehicle,
- goods which is tried to be hidden while import/export over crossing border,
- goods for which customs declaration was not submitted but should have been a subject of one of the custom procedures,
- goods which is found in natural persons possession, or it was sold, bought or received by the natural persons which is under review.

Mentioned goods will be resumpted even if it is not owned by the perpetrator of the violation, and also every mean of transport which is used for transport will be resumpted.

In the period from 1st January until 31st December 2014 in the custom area of Republic of Croatia there are conducted 11,178 checks. According to the data from [7], from total 11,178 custom checks, according to the found irregularities there has been 35 criminal reports to the State attorney, 2,907 criminal reports to the competent misdemeanor authority and 10,930 issued misdemeanor warrant from the side of Custom administration.

In 2014, the total number of presented indictments and misdemeanor was 13,837, and for that there was charged the penalties and other costs in the total amount of 30,334,112.54 HRK and it was billed penalties and other costs in the amount of 19,654,613.79 HRK. According to [7] in Figure 2 shows the total number of charged penalties and the total number of billed penalties. In 2014 the percentage of billed penalties was 39% of total penalties, while the percentage of calculated penalties was the 61%.

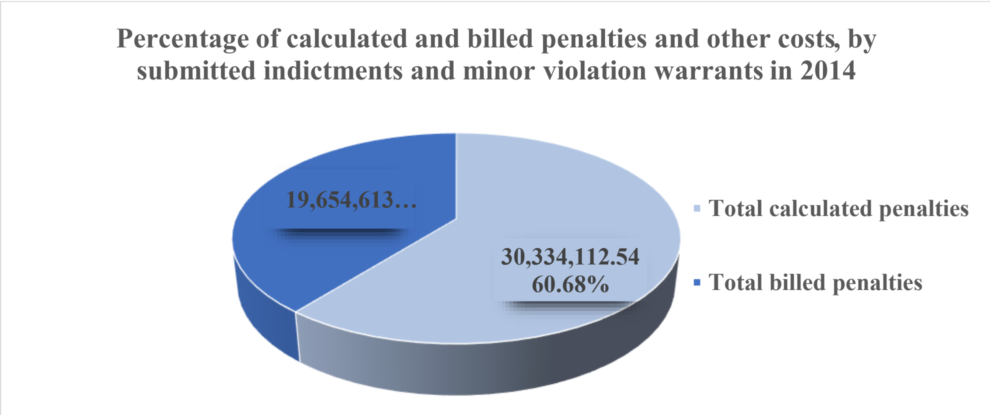

Figure 2 - Percentage of calculated and billed penalties and other costs in 2014
Source: Adapted from [7]

Table 6 shows the total number of accused legal entity for violation of the provisions of the Law on implementation of customs regulations of the European Union (NN 54/13) and the list of decisions that were made for those persons. According to [10] against 1,222 legal entities misdemeanor warrant was conducted, of which a total of 963 legal persons found guilty, and on them sanction were conducted. For 257 persons the procedure was suspended and not found guilty, for a single legal entity judgment was dismissed, and one was rejected.

Table 6 - Accused legal entities for violation of the provisions of the customs act by type of decision, 2014

ACCUSED LEGAL ENTITIES FOR VIOLATION OF THE PROVISIONS OF THE CUSTOMS ACT BY TYPE OF DECISION, 2014		
Found guilty		963
Not found guilty	Rebuff	1
	Terminated proceeding	257
	Judgment rejecting charges	1
	Judgment of acquittal	0
	All	259
Total		1,222

Source: Adapted from [10]

According to [10] on the classification of the violations, sanctions imposed and former imposed sanctions in 2014 fined 937 legal persons, while the number of responsible persons who have been fined with an amercement was 940. Warning was not given either to a legal entity or responsible person, and the total number of persons who are found guilty, but without punishment were 26 legal entities and 26 responsible persons as shown in table 7.

Table 7 – Legal entities and persons in charge, by previously pronounced sanctions, 2014

LEGAL ENTITIES AND PERSONS IN CHARGE, BY PREVIOUSLY PRONOUNCED SANCTIONS, 2014		
Person	**Sanctions**	**Total**
Legal entities	Fine	937
	Admonition	0
	Found responsible but no penal sentence	26
Persons in charge	Fine	940
	Admonition	0
	Found responsible but no penal sentence	26

Source: Adapted from [4]

Besides the above data relating to the implementation of sanction measures for violations of the provisions of the Law on implementation of customs regulations of the European Union (NN 54/13), according to [10] states the confiscation of objects penalized 1,682 person.

6. CONCLUSION

After ingression into European Union on 1st July 2013 custom area of Republic of Croatia became a part of unique customs area of the European Union. Custom controls no longer exist but border controls remain and police officers still perform border control according to regulations under jurisdiction of Ministry of internal affairs. On the day of ingression, responsibilities of custom officers decreased on crossing borders, but the level of work increased for custom administration officers. Controls performed on the streets are directed towards detection of violations from the domain of customs administration, especially on smuggling of goods, illegal traffic or usage of excise products, performing unregistered activities in road traffic, possession of goods which traffic is forbidden or restricted and also the goods by which intellectual property is endangered.

The aim of this article was to demonstrate the importance of the activities of the Customs administration in the Republic of Croatia and to analyze and display the way of sanctioning customs violations. Through the article, there were reviews on the total number of customs violations that were recorded in all member states. Total of 95,194 customs violations registered in all member states in 2014 and 895 customs violations have been recorded in Croatia. This number placed Croatia on the 14th place in European Union by the number of customs violations. The conduction of more stringent and frequent controls imposed by the EU could lead to a reduction or an increase of the number of recorded customs violations in the coming years, which could be seen in the coming period.

As for the sanctioning in 2014 for a total number of presented indictments and misdemeanor (13,837), it was billed 39% penalty, while charged for 61%. Therefore, funds received from payment penalty for customs violations constitute 0.12% of the revenues of the Customs Administration, which is a very small percentage if one considers that the very Customs Administration achieved a certain income to the country, and makes 18.35% of the total revenues of the state budget according to statistics from 2014.

Statistical data collection via Intrastat forms greatly eases the entire process of collecting data related to customs operations of all member states of the European Union. While analyzing customs violations it is possible to see the total number of violations in each of the member state, which is important in order that each member state can react promptly, and to see where it will eventually fail, and how to better suppress each attempt of re-entering of illegal goods.

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EUROPEAN TRANSPORT STRATEGIES AFFECTING REPUBLIC OF CROATIA

ABSTRACT

The Trans-European Transport Network Policy has been developing since the mid 80-ies to provide the infrastructure needed for a smooth functioning of the internal market, to ensure economic, social and territorial cohesion and to improve accessibility across the entire EU territory. The strategic planning of the transport sector is to be the basis of the transport sector development, defined as a tool at the service of major economic and social policy objectives. As a result, the strategic planning will consider transport to be the essential support providing Croatian inhabitants with quality services for their mobility needs and at the same time to be an effective instrument to promote economic development and social and territorial cohesion, so guaranteeing the best use in society's service.

KEY WORDS

Trans-European transport network, Network, Transport, Region, Corridors, Coordination

1. INTRODUCTION

The transport sector delivers 10% of European union wealth measured on the basis of gross domestic product (GDP), amounting to around one trillion euro's a year. It provides more than ten million jobs.

Strategy development is based on the White Paper on transport, which was adopted in September 2001 and represents the most important strategic document for the long term development of the common transport policy. The document contained an action plan to improve the quality and efficiency of European transport. To sixty based measures aimed at restructuring the existing transport policy to make it sustainable and to avoid major economic losses due to congestion, pollution and accidents. The ultimate strategic goal of achieving an equilibrium between different forms of transport by 2010 and to an active policy that should revitalize rail transport, and to promote trade by sea and inland waterways.

White Paper from the 2011 includes the following main objectives until 2050 [1]:

- No more conventionally-fueled cars in cities;
- 40% use of sustainable low carbon fuels in aviation; at least 40% cut in shipping emissions;
- A 50% shift of medium distance intercity passenger and freight journeys from road to rail and waterborne transport;
- All of which will contribute to a 60% cut in transport emissions by the middle of the century.

The European Cohesion Policy, which is based on the principle of solidarity, aims at support for sustainable economic development within the territory of the entire European Union - through activities aimed at reducing development disparities between countries and their regions and strengthening regional competitiveness [2]. This policy is expressed also in the new European policy of macro-regional cooperation, which was initiated back in 2007 with the Baltic Sea Strategy. Its objective is to promote territorial cooperation and interaction between regions that have different levels of economic development, and thus to achieve a synergy between diverse EU policies into a functional whole, which is suitable for a particular macro-region. Such macro-region strategies are also a tool to promote Territorial cohesion that is a new principle under the Lisbon Treaty. Croatia can see two major advantages in supporting the policy of macro-regional cooperation and its implementation through the European Union Strategy for the Danube Region (hereinafter: EUSDR). First, this is an original political process within the EU, which coincides with the demand for active participation in different forms of regional cooperation as a political precondition in the pre-accession process. Second, our country is not immune to the unbalanced socio-economic development of its regions and thus there are concrete benefits to be drawn from inter-regional and cross-border links, as these are ideal places to present and carry out the projects aimed at diminishing regional disparities in development. Comparative advantages of particular regions will be recognized through the EU Cohesion Policy, which will then be fostered through fund allocation programmes and through other means, with the ultimate goal of achieving the balanced development throughout the EU.

2. CROATION STRATEGIES OF INTEGRATION INTO THE EUROPEAN TRANSPORT NETWORKS

The extremely favorable geo-traffic position of Croatia is an important factor for its fast integration into the European transport system. Economic development and investment abilities of the country correlate with the traffic network development and the possibilities of the Croatian traffic system integration into the trans-European transport networks. The strategic planning of Croatian transport development should be in the function of the overall economic development, dynamically adjusted to the objective investment possibilities of the public sector, whereby the conceptual approach should be in the context of the wider region growth. The globalization and market liberalization processes have a considerable effect on the formation of the world flow of goods, thus having a direct influence on the transport system, generating economic and especially transport growth.

After attaining the status of the accession country in June 2004, Croatia benefited from various pre-accession instruments provided by the European Union relevant to the transport sector, namely on ISPA (Instrument for Structural Policies for Pre-Accession) and IPA (Instrument for Pre-accession Assistance) getting big impact in the Croatian transport sector [3]. In order to ensure an uninterrupted structural adjustment process in the transport sector and the utilization of the finance under the IPA Component III – *Regional Development*, Croatia drafted a Transport Operational Programme (TOP) for the period 2007-2013. The TOP covers the key issues and information such as the transport policy background, status of transposition of EU transport acquis into national legislation, transport sector assessment and strategies and measures to meet transport sector development needs, in line with accession and post accession requirements.

There is another corridor with special importance for the country which is a part of TEN-T core network, namely the Adriatic Ionian Road Transport Corridor which connects 8 countries (Italy, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Serbia, Albania and Greece) between Trieste and Kalamata. Along the Adriatic coast it connects the main sea ports

(Trieste, Koper, Rijeka, Zadar, Šibenik, Split, Ploče, Dubrovnik, Bar, Durresi, Igoumenitsa, Patras, Kalamata), and a number of Pan European corridors (V, Vb, Vc, and VIII). The possibility of building new roads at present corridor will be defined by the Prefeasibility study.

Croatia's accession to the European Union on 1 July 2013 has significantly changed its status and importance within the new European community and redefined its political relations with other countries in the neighborhood. As an EU member Croatia is obliged to harmonize its development strategy documents and to implement specific guidelines concerning further road infrastructure development.

Regarding its integration in international traffic, it should be emphasized that Croatia is already today, with its highly developed motorway network (90% constructed), close to high European standards regarding international road connections [4].

3. EUROPEAN TRANSPORT NETWORKS PASSING THROUGH CROATIA

A well-running transport infrastructure is essential to maintaining the European Union's competitiveness and wealth. Its 28 Member States currently have five million km of paved roads, more than 215.000 km of rail lines and 41.000 km of navigable inland waterways. Owing to its geostrategic position Croatia has certain advantages that have been, in part, recognized in the process of defining international transport corridors.

3.1 TEN-T Strategy of connecting Europe

The TEN-T policy supports the completion of 30 Priority Projects, representing high European added value, as well as projects of common interest and traffic management systems that will play a key role in facilitating the mobility of goods and passengers within the EU. The TEN-T Programme had a budget of €8.013 billion for the period 2007-2013 spending framework [5].

As of January 2014, the European Union has a new transport infrastructure policy that connects the continent between East and West, North and South. This policy aims to close the gaps between Member States' transport networks, remove bottlenecks that still hamper the smooth functioning of the internal market and overcome technical barriers such as incompatible standards for railway traffic. It promotes and strengthens seamless transport chains for passenger and freight, while keeping up with the latest technological trends.

In the most radical overhaul of EU infrastructure policy since its inception in the 1980s, the Commission has published new maps showing the nine major corridors which will act as a backbone for transportation in Europe's single market and revolutionize East–West connections.

The €26 billion (current prices) allocated to transport under the Connecting Europe Facility (CEF) of the MFF (multi-annual financial framework) will effectively act as "seed capital" to stimulate further investment by Member States to complete difficult cross-border connections and links which might not otherwise get built. It is estimated that the cost of implementing the first financing phase for the core network for 2014-2020 will cost €250 billion network is expected to be completed by 2030.

Taken as a whole, the new EU infrastructure policy will transform the existing patchwork of European roads, railways, airports and canals into a unified trans-European transport network (TEN-T).

The new policy establishes, for the first time, a core transport network built on nine major corridors: 2 North–South corridors, 3 East–West corridors; and 4 diagonal corridors. The core network will transform East–West connections, remove bottlenecks, upgrade infrastructure and streamline cross-border transport operations for passengers and businesses throughout the EU. It will improve connections between different modes of transport and contribute to the EU's climate change objectives. The core network is to be completed by 2030 [6].

The new core transport network will be supported by a comprehensive network of routes, feeding into the core network at regional and national level. The comprehensive network, will ensure full coverage of the EU and accessibility of all regions. The aim is to ensure that progressively, and by 2050, the great majority of Europe's citizens and businesses will be no more than 30 minutes' travel time from this comprehensive network. Taken as a whole, the new transport network will deliver safer and less congested travel, and smoother and quicker journeys.

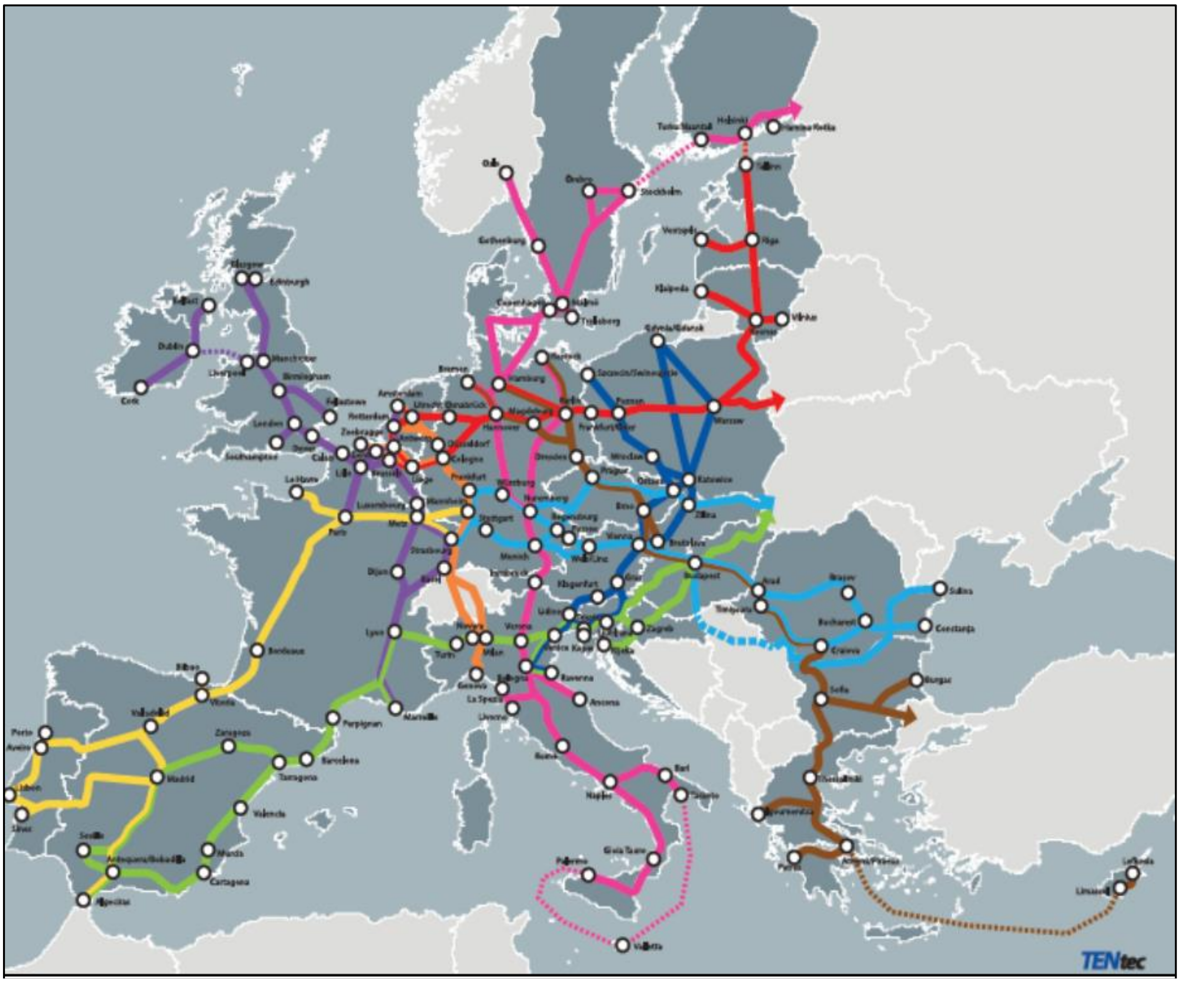

Figure 1 - Schematic map of the Core Network Corridors of the TEN-T Regulation
Source: http://ec.europa.eu/transport/themes/infrastructure

The core network will connect [6]:

- 94 main European ports with rail and road links
- 38 key airports with rail connections into major cities
- 15.000 km of railway line upgraded to high speed
- 35 cross-border projects to reduce bottlenecks

This will be the economic lifeblood of the single market, allowing a real free flow of goods and people around the EU.

Croatia has 2 Core Network Corridors crossing its country [7]:

1. The Mediterranean Corridor links the Iberian ports of Algeciras, Cartagena, Valencia, Tarragona and Barcelona through Southern France, with link to Marseille, and Lyon to Northern Italy, Slovenia and a branch via Croatia to Hungary and the Ukrainian border. It covers rail and road, airports, ports, RRT's and, in Northern Italy, also the Po river inland waterway. The key projects are UIC standard gauge railway lines in Spain, the Lyon –Turin railway tunnel and the Karst crossing Trieste/Koper – Ljubljana.
2. The Rhine-Danube Corridor, connects Strasbourg and Mannheim via two parallel axes in southern Germany, one along Main and Danube, the other one via Stuttgart and Munich, and with a branch to Prague and Zilina to the Slovak-Ukrainian border, through Austria, Slovakia and Hungary to the Romanian ports of Constanta and Galati. It covers rail, road, airports, ports, RRT's and the inland waterway system of Main, Main-Danube Canal, the entire Danube downstream of Kelheim and the Sava river. The key projects are removing the bottlenecks along the inland waterways and the railway sections Stuttgart – Ulm and München – Freilassing.

Figure 2 - Pan-European transport corridors through Croatia
Source: http://www.kassianos.eu

Owing to its geostrategic position Croatia has certain advantages that have been, in part, recognized in the process of defining international transport corridors. Consequently, Pan - European transport corridors Vb, Vc, X and Xa cross the Croatian territory and now form a part of the TEN-T network as follows: Vb (Rijeka - Zagreb - Budapest) TEN-T Mediterranean corridor, Vc (Ploče - Sarajevo - Osijek - Budapest) TEN-T comprehensive network, X (Salzburg - Ljubljana - Zagreb - Beograd - Niš - Skopje - Veles - Thessaloniki) TEN-T core network and Xa (Graz - Maribor - Zagreb) TEN-T comprehensive network.

The Croatian railway network stretches over 2.604 kilometers, which represents a fair ratio between kilometers and the country population, 1.556 persons per kilometer, thus ranking the Republic of Croatia among developed European countries such as, for example, Switzerland. It is, however, a fact that 90 per cent of the railway network consist of single-track rails, only 36 per cent of the railway tracks are electrified, while the speed limits, obsolete traffic control and signaling systems are also a problem [8].

All of the above is a result of the significant damage suffered by the railway sector during the war and the fact that it has not been developed nor modernized for a long time. For this very reason, the existing infrastructure requires reconstruction and modernization in order to create effective, safe and environmentally friendly modes of transport, thus creating a competitive railway corridor on both the extra-regional and interregional levels.

Within the territory of the Republic of Croatia, international Corridors are named as follows, according to the Decision on the Classification of Railroads of the Government of the Republic of Croatia (OG no. 03/14):

- RH1. TEN-T core and comprehensive network (Pan European Corridor X), Salzburg – Thessaloniki,
- RH2. TEN-T Mediterranean corridor (Pan European corridor Vb), Budapest – Rijeka,
- RH3. TEN-T comprehensive network (Pan European corridor Vc), Budapest – Ploče.

The aforementioned corridors correspond to the Core Network both for passenger and freight traffic. Besides, there are other international lines belonging to the Comprehensive Network.

Of these 2.604 km, only 5,4% is capable to reach speeds between 141 and 160 km/h, 17% has a maximum speed above 100 km/h, and 37,5% has maximum speeds below 60 km/h. The low speeds, together with the long distance between stations and the outdated traffic control and signaling systems have a direct impact on the transportation capacity of the lines. Low speeds, with the problem of the distance between stops and stations along with the outdated traffic control and signaling systems, have a direct impact on traffic capacity and competitiveness of the railways as a transport subsystem.

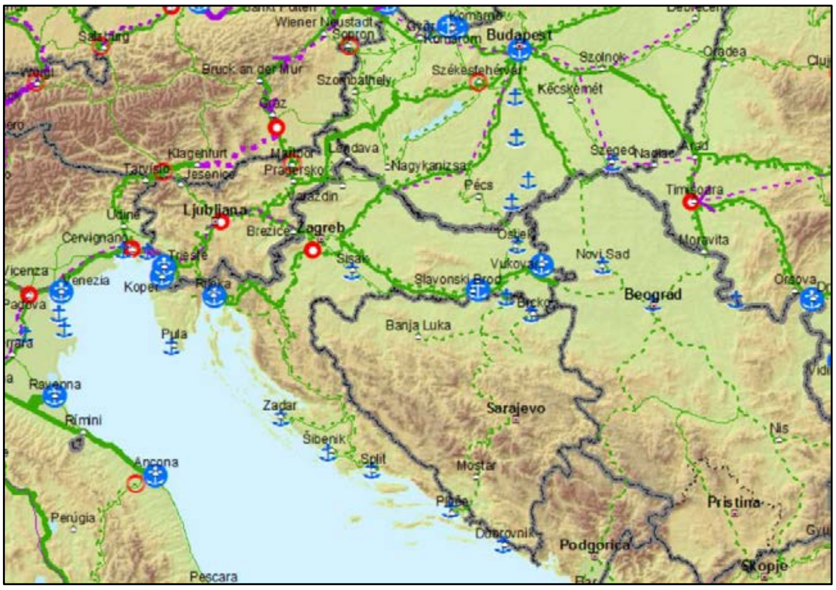

Figure 3 - Comprehensive and Core Network of Railways in Croatia
Source: ec.europa.eu

Additional possibilities of modernizing the railway system opened up in Croatia through the pre-accession programmes of the European Union (ISPA and IPA) and also, after accession, through the Structural and Investment Funds, even more so, as 55 per cent of the railway network in the Republic of Croatia consists of railway lines of international significance.

3.2 EU Strategy for the Adriatic and Ionian Region (EUSAIR)

In order to address a number of pressing socio-economic and environmental challenges facing the Region, the European Council of 13-14 December 2012 requested the European Commission to present a new macro regional strategy for the Adriatic and Ionian Region before the end of 2014. Building on previous strategies for the Baltic Sea Region (EUSBSR) and the Danube Region (EUSDR), the Commission is now adopting a Communication and Action Plan for the EU Strategy focusing on the Adriatic and Ionian Region (EUSAIR). This new Strategy also incorporates the Maritime Strategy for the Adriatic and Ionian Seas, adopted by the Commission on 30 November 2012 [9].

The EUSAIR will promote economic growth and prosperity in the Region by improving its attractiveness, competitiveness and connectivity. It also aims at protecting the sea, coastal and inland environment and ecosystems. Moreover, the Strategy is expected to better integrate into the EU both candidate and potential candidate countries across the Region.

The Region is a functional area primarily defined by the Adriatic and Ionian Seas basin. Covering also an important terrestrial surface area, it treats the marine, coastal and terrestrial areas as interconnected systems. With intensified movements of goods, services and peoples owing to Croatia's accession to the EU and with the prospect of EU accession for other countries in the Region, port hinterlands play a prominent role. Attention to land-sea linkages also highlights impacts of unsustainable land-based activities on coastal areas and marine ecosystems.

Home to more than 70 million people, the Region plays a key role in strengthening geographical continuity in Europe. The Strategy builds on the Adriatic-Ionian Initiative, which concern eight countries. The Adriatic-Ionian Region covers 4 EU countries (Croatia, Greece, Italy and Slovenia) and 4 non-EU countries (Albania, Bosnia - Herzegovina, Montenegro and Serbia) [10].

Figure 4 - Adriatic - Ionian Region
Source: http://www.adriatic-ionian.eu/about/the-adriatic-ionian-region

In a 2013 report, the Commission stressed that new macro-regional strategies should focus on a limited number of well-defined objectives and that these objectives should be implemented through a clear Action Plan. In short, the aim is to go from "words to actions" by identifying concrete priorities for the macro-region making the best use of existing institutions, legislation and funds for a quick turnaround. The EUSAIR is built on four thematic pillars [10]:

- Blue growth (coordinators are Greece and Montenegro)
- Connecting the region (coordinators are Italy and Serbia)
- Environmental quality (coordinators are Slovenia and Bosnia - Herzegovina)
- Sustainable tourism (coordinators are Croatia and Albania)

The transport sector in the Republic of Croatia is especially interested and active in ensuring coordination and actions implemented in the context of EUSAIR within the pillar "Connecting the Region (transport and energy)" which should focus on three strategic topics: improving maritime transport, developing intermodal links to the hinterland and, with regards to energy, improving interconnections.

Figure 5 - Possible Adriatic - Ionian Region route
Source: Adriatic – Ionian transport corridor on the territory of the Republic of Croatia

3.3 European Strategy for the Danube Region (EUSDR)

A strategy to boost the development of the Danube Region was proposed by the European Commission on 8 December 2010 (Commission Communication - EU Strategy for the Danube Region). Member States endorsed the EU Strategy for the Danube Region at the General Affairs Council on 13 April 2011 (Council Conclusions).

The Strategy was jointly developed by the Commission, together with the Danube Region countries and stakeholders, in order to address common challenges together. The Strategy seeks to create synergies and coordination between existing policies and initiatives taking place across the Danube Region. The Danube Strategy has put in place a cooperation structure to address common challenges. Four strategic policy objectives have been identified:

- Connecting the Danube Region,
- Protecting the environment of the Danube Region,
- Building prosperity in the Danube Region and
- Strengthening the Danube Region.

Structured through these four pillars, the Danube Strategy provides a framework for policymakers to coordinate national and regional policies both across borders and at different levels. The transport sector of the Republic of Croatia is especially interested and active in ensuring coordination and complementarities between ESI Funds and actions implemented in the context of EUSDR within the pillar Connecting the Danube region and Priority Areas 1A "To improve mobility and intermodality of inland waterways" which is coordinated by Austria and Romania, and 1B “To improve mobility and intermodality of rail, road, air” which is coordinated by Slovenia and Serbia.

The overall length of the current inland waterways in Croatia is 1016.8 km, of which 601.2 km has been integrated into the European network of inland waterways of international importance**.** The Danube part of the Republic of Croatia`s inland waterways system forms a part of the Rhine-Danube Corridor. Ports Vukovar and Slavonski Brod are classified as core ports in the EU TEN-T network, while Osijek and Sisak are classified as comprehensive ports.

Within the complete inland waterways sector in the Republic of Croatia there are two separated sub-systems with their specific characteristics: Danube`s basin sub-system which encompasses the Danube’s waterway as well as Drava’s waterway, and the Sava basin sub-system which encompasses the waterways of the Sava, Kupa, and Una. The Croatian inland waterways ports Vukovar, Osijek, Slavonski Brod and Sisak and their port areas have been characterized by an undeveloped infrastructure and unconnected logistical port network.

Figure 6 - Schematic map of the Danube Region EU Strategy
Source: http://www.danube-region.eu/about/the-danube-region

The overarching sector strategic documents related to the inland waterways and ports are the Strategy for Development of Inland Waterways in Republic of Croatia (2008-2018), adopted on 16 May 2008, as well as the Mid-term Plan of Development of Inland Waterways and Ports in the Republic of Croatia (2009-2016) adopted in 2009.

4. EU TRANSPORT STRATEGIES IMPACTS IN CROATIA

It is acknowledged that the TEN-T definition is in more or less in line with the national interest serving the declared targets of the EU Transport Policy for regional development, accessibility improvement, territorial and economic cohesion, employment. However, the impacts of major TEN-T projects on these components are not so obvious or tangible (apart from travel times' reduction) and publicly known, since the quantified results of any ex post evaluations are often not disseminated.

Investments in Croatia are also focused on Pan-European Corridor X. Included in activities to develop and modernize railway lines, to improve the safety and efficiency of railway operations and to prepare projects which will be financed at a later date. The projects in the scope of this programme that were carried out or are currently underway include the signaling and interlocking system at Zagreb Main Station in the value of 11.4 million euros and the rehabilitation of the Okučani - Novska line section in the value of 35.85 million euros. Not only this but design and other project documentation was prepared for a whole series of projects on the modernization and upgrading of Croatia's railway network in the estimated value of 66.5 million euros.

The impacts of the already implemented TEN-T projects in Croatia were mainly seen in its Transport operation program 2007-2013. Priorities in the field of transport and the measures which are implemented with EU financial aid, were defined in this Transport Operational Programme which was primarily directed to solving the problems in Croatia's transport sector, particularly the insufficient investments in the railway network which suffered heavy damage during the war in Croatia in the 1990's, the poor state of ports on inland waterways, the lack of investments in the modernization of airports and the poor commercial competitiveness of sea ports.

Table 1 - Potential investment projects within TEN-T policy 2014-2020 in Croatia

Section of the corridor	**Mode of transport**	**Potential investments**
Mediterranean corridor		
Rijeka – Zagreb – Budapest	Rail	Studies and works (including construction of new track and second track between Rijeka and Hungarian border)
Rijeka	Port	Infrastructure upgrading and development, development of multimodal platforms and interconnections
Ljubljana – Zagreb	Rail	Studies and works
Rhine-Danube		
Slavonski Brod	Port	Studies and works
Danube (Kehlheim-Constanta/Midia/Sulina)	Inland Waterway	Studies and works on several sections and bottlenecks; Inland waterway ports: multimodal interconnections
Sava	Inland Waterway	Studies and works on several sections and bottlenecks (including cross-border bridge)
Other		
Zagreb - Serbian border	Rail	Studies and works (Bottleneck)
Dubrovnik – Montenegro border	Road	Works

Source: European Commission, TEN-T, 2014.

As it can be seen from the table above TEN-T implementation will have impact on the rail sections on the stretches of Mediterranean corridor, inland waterways, ports and on cross-border bottlenecks that hinder development of faster and more efficient transport from Croatia to non-EU countries in the South Eastern European Region.

In Croatia, some critical TEN-T Core road links are at Zagreb node. Same situation has been forecasted for 2020, where also the connection between Zagreb and Karlovac up to A1/A6 junction and some sections in south Dalmatian coast are expected to have high v/c ratios. For 2030 the critical links would be the same and their extensions (A1/A6 junction to Delnice), while traffic will intensify on Novska - Slavonski Brod section of motorway Zagreb - Serbian borders.

5. CONCLUSION

Transport is vital to the European economy, without good connections Europe will not grow or prosper. The new European infrastructure policy will put in place a powerful European transport network across 28 Member States, connected to neighboring countries and the rest of the world, to promote growth and competitiveness. It will connect East with West and replace today's transport patchwork with a network which is genuinely European.

For Croatia expected impacts of TEN-T are mostly focused on enhancement of the transport network, especially on the core corridors and cross border sections. There are several projects in connection with the preparation and implementation of Bosnia and Herzegovina to the possible accession EU. In the area of Croatia, traffic problems at the borders with non-member countries (Bosnia and Herzegovina, Serbia and Montenegro), can only be solvable after expectable accessions of these countries to the European Union.

Geo-traffic, geostrategic and ecological sustainability of certain transport modes cannot be achieved without strategically investing in the entire transport infrastructure, especially the railway, port, river, road and air transport infrastructure, as well as in the terminals and transport and logistics centers, which could enable easy development of intermodal transportation. In the Republic of Croatia, there is an adequate road infrastructure, but it would need some modifications (the route to Dubrovnik and the section from Zagreb to Sisak) in order to secure integrated road infrastructure.

Intermodality entails cooperation and excludes severe competition among different modes of transport. Croatia offers many possibilities for the development of intermodal transportation which, for that reason, should become the transport services brand oriented towards the EU, rest of Europe and the world, as well as a generator of development of the EU and Croatia economies, which implies the creation of new values. Finally, the most important is that EU is interested in the execution of these projects and willing to finance them by means of concessions from the Structural and Cohesion Funds.

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