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- Provide international dissemination of knowledge and contributions to the science and practice in the field of traffic and transportation
- Promote and exchange information and knowledge in the transportation research arena and its application
- Explore the new trends in development and invention related to the efficiency, reliability, safety and economically and ecologically sustainable transportation.

TTTP provides conditions and positive environment for the new idea promotion, exchange research results and achievements accomplished by the scientific community from academia and transportation industry.

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EDITOR'S WORD

Dear readers,

It is my pleasure to present to you the eleventh, printed and electronic magazine "Traffic and transport theory and practice – TTTP" which successfully resists the challenges set in areas of contemporary processes of traffic and transport engineering.

Papers in this issue cover performance quality of carriageway construction and reconstruction in terms of increasing durability of the wearing course, preventing the creation of spider cracking and increase of quality values of friction, i.e. adhesion between the wheel and the carriageway. There is a significant focus on the environment in this issue, from use of electric vehicles to fuel decarbonisation. There are papers that discuss behaviour of electric vehicles in cities and their contribution to the better quality of life. We also gave space to PhD and MSc candidates in their research of logistic processes and location distribution of logistic centres. Of notice is also an approach to parking policy analysis on a case study in the City of Gradiška. In the end there is an overview on prevention of potential illegal actions and eliminating risk in air traffic from the aspect of "cyber" crime, where we presented contemporary methods of safety risks management by using artificial intelligence.

The magazine has ensured an open access to previous issues on its own website (https://apeiron-uni.eu) which provides wider population of researchers to publish and protect the copyright of their papers.

Editor-in-Chief
Prof. Danislav Drašković, PhD Eng.

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ORIGINAL SCIENTIFIC PAPER

Influence of aramid and polyolefin on the technical-operational characteristics of asphalt constructions

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Abstract: This paper used research results from renowned foreign and domestic institutes in terms of influence of synthetic fibres from armide and polyoefin family on physical and mechanical characteristics of asphalt mixture, firstly in terms of chemical bonding, longevity of use and solidity. The researches show that this is a new technology which provides for formation of 3D reinforcing net in the asphalt, and which has significant effect on increased resistance to permanent deformations, fractures and increased resistance with possible decreased thickness of asphalt layer and extended longevity, which provides for important economic benefit. Comparing this asphalt component with conventional we see increased resistance to "road ruts", sensitivity to water and permanent deformation.

Keywords: aramide, polyolefin, reinforcing net, deformations.

INTRODUCTION

Fibers have been used to improve the performance of asphalt mixtures against permanent deformation and fatigue cracking. By controlling thermal, reflective and fatigue cracking, as well as rutting, synthetic fibers provides the benefit of immediate cost savings through reduced asphalt thickness or extended asphalt life, or both. These fibers contain aramid and polyolefin fibers and other materials, known for their strength, durability, and binding properties. The objective of this study was to evaluate the performance of the conventional unmodified (control) and polypropylene/aramid fibers reinforced asphalt mixtures using laboratory tests. The main goal was to determine the properties of fiber reinforced asphalt mixtures in stiffness, permanent deformation, and cracking characteristics compared to unmodified mixtures. Wheel track rutting, resilient modulus, dynamic creep and indirect tensile fatigue tests were used to evaluate these properties. The fibers were added to the mixture in the laboratory and in batch asphalt plant. Both laboratory and plant mixed asphalt mixtures were compacted in the laboratory in to different test specimens and were tested to determine performance.

LABORATORY ASPHALT MIXTURES

The fibers used in this study were a blend of synthetic fibers named Forta-fi that are designed for use in hot mix asphalt applications. The fibers are designed to reinforce the HMA in three dimensions and provided by *FORTA Corporation*. Table 1 shows the physical properties of fibers. Fibers were added at a content of 1.0 pound per ton of asphalt mixture at the laboratory and at two contents of 1.0 and 2.0 pounds per ton at the batch asphalt plant. A laboratory mixer with a minimum working capacity of 10 kg was used to prepare asphalt mixtures and to distribute the fibers uniformly in the mixture. The fibers were also added to the mixture in the asphalt plant, while still in the bag, before the addition of asphalt binder [1].

Table 1. Fibers physical properties Materials[5]

Materials	Polyolefin	Aramid
Form	Twisted fibrillated& Monofilament	Monofilament
Specific gravity	0.91	1.44
Tensile strength (psi)	70000	400000
Length (mm)	19	19
Color	Tan, Black	Yellow
Acid/alkali resistance	Inert	Inert
Melt temperature (°C)	100	427

The 60/70 penetration grade asphalt cement from *Pasargad Oil Company* was used in this study which is widely used in Iran. The physical properties are provided in Table 2.

Table 2. Asphalt cement 60/70 physical properties[5]

Property	Test method	Result
Penetration at 25°C, 100 g, 5 s, 0.1 mm	ASTM D5	66
Softening point, °C	ASTM D36	49
Ductility at 25°C, 5 cm/min, cm	ASTM D113	> 100
Solubility in trichloroethylene, (wt)%	ASTM D2042	99.5
Flash Point, °C	ASTM D92	304
Kinematic viscosity at 135°C, centistokes	ASTM D2170	446
Loss on heating, (wt)%	ASTM D1754	0.01
Penetration at 25°C after thin-film oven test, 0.1 mm	ASTM D5	50
Ductility at 25°C after thin film oven test, cm	ASTM D113	> 50

Four aggregate size fractions (two coarse, one fine) and mineral filler sampled from hot bins of asphalt plant and utilized in this study, were crushed stone aggregates from Tehran in Iran and provided by *AljPars company*. The aggregate fractions were sieve analyzed following ASTM D136 standard test method and blended in the proportions that the resulting mixture met the grading of the mix design. The mix designation D5 from ASTM D3515 standard specifications for dense graded hot mixed asphalt mixtures was selected as asphalt mixture gradation. The mix gradation and specific gravity of aggregates are presented in tables 3 and 4 [5].

Table 3. Mix gradation[5]

Sieve	Specification limits	Percent passing
19 mm	100	100
12.5 mm	90-100	95
4.75 mm (No.4)	44-74	63
2.36 mm (No.8)	28-58	38
0.3 mm (No.50)	5-21	12
0.075 mm (No.200)	2-10	6

Table 4. Specific gravity and absorption of aggregates[5]

Aggregate size fraction	Specific gravity	
	bulk	apparent
aggregate remain on sieve No.8	2.435	2.628
aggregate pass sieve No.8 and remain sieve No.200	2.412	2.688
aggregate pass sieve No.200	2.630	
Total aggregate (mix)	2.437	

Asphalt mix design was performed through the Marshall method as specified in ASTM D1559. The optimum asphalt content was chosen in accordance with Asphalt Institute's Manual Series No.2. Optimum asphalt content, volumetric parameters and mechanical properties of asphalt mixture are shown in Table 5.

Table 5. Laboratory mixed asphalt mixture properties at optimum asphalt content[5]

Mixture property	Value	Mix design criteria
Optimum asphalt content	5.5	---
Unit weight of compacted specimen (Gmb), kg/m^3	2205	---
Air voids (Va), %	4.1	3-5
Voids filled with asphalt (VFA), %	79	65-75
Voids in mineral aggregates (VMA), %	14.6	> 14
Stability, kgf	1350	> 800
Flow, 0.25mm	13.2	8-14

Plant mixed asphalt mixtures

The mix designation D5 of ASTM D3515 specification with nominal maximum aggregate size of 1/2 in. from *Macadam Shargh Company* was used. The 60/70 penetration grade asphalt cement from *Pasargad Oil Company* was used in the mixture as asphalt binder. The bulk specific gravity of aggregates and theoretical maximum specific gravity of the mixture were 2.508 and 2.375, respectively. The design asphalt cement content was 4.6 % for the control mixture and it was kept the same for the fiber-reinforced asphalt mixtures. The same compaction procedure was also used for preparing both control and fiber modified specimens. The mix gradation (job mix formula) and the specification limits are presented in tables 6.

Table 6. Plant mixed aggregate gradation[5]

Sieve	Specification limits	Percent passing
19 mm	100	100
12.5 mm	90-100	96
4.75 mm (No.4)	44-74	64
2.36 mm (No.8)	28-58	30
0.3 mm (No.50)	5-21	9
0.075 mm (No.200)	2-10	5

Laboratory tests

Wheel track rutting test

The rutting test was performed on unmodified and fiber reinforced asphalt mixtures in accordance with AASHTO T324 standard test method employing the Hamburg Wheel Tracking. In this test, a rubber Wheel, 50 mm wide, is rolled across a compacted hot mix asphalt slab and the load which is applied to the wheel is 705 ± 5 N. The test path is 230 ± 10 mm long and the

average speed of wheel is approximately 0.305 m/s (50 ± 5 wheel passes per minute). Laboratory mixed and plant mixed asphalt mixtures compacted by the roller compactor. The slab specimens for unmodified and fiber reinforced asphalt mixtures were fabricated with the height of 50 mm using roller compactor. These specimens were compacted to an air void content of 6±0.5% and tested under dry condition at 50°C.

Dynamic creep test

The uniaxial repeated load (dynamic creep) test was carried out on cylindrical specimens of unmodified and fiber reinforced asphalt mixtures using UTM apparatusin accordance with BS: DD226 draft test method. UTM apparatus and the test loading frame. Specimens 4 inch in diameter were prepared for laboratory mixed asphalt mixtures using Marshall compaction apparatus according to ASTM D1559 standard method and 6 in. diameter specimens were prepared for plant mixed asphalt mixtures using modified Marshall apparatus according to ASTM D5581 standard method. In this test, a repeated dynamic load is applied for several thousand repetitions, and the cumulative permanent deformation including the beginning of the tertiary stage (FN) as a function of the number of loading cycles over the test period is recorded. The dynamic creep test is a test that applies a repeated pulsed uniaxial stress on an asphalt specimen and measures the resulting deformations in the same direction using linear variable differential transducers. Three stages of creep behavior can be identified. In the primary stage, the rate of deformation increases rapidly. In the secondary stage, the deformation rate becomes constant. In the last stage, the deformation increases rapidly and failure is reached. The tests were conducted at 50°C using a 100 kPa square pulse load of 1.0 s and a rest time of 1.0 s before the application of the next pulse. [2].

Resilient modulus test

The five pulse indirect tensile resilient modulus test of unmodified and fiber reinforced asphalt mixtures was performed at 25°C and 0.1 Hz loading frequency on 4 in. cylindrical specimens according to ASTM D4123 standard test method. In this test, a pulsed diametral loading force is applied to the specimen and the resulting total recoverable diametral strain is measured from axes 90 degrees from the applied force. Strain in the same axes is not measured, thus an assumed value of poisson's ratio is used as a constant. The test sequence consists of the application of 100 conditioning pulses followed by 5 pulses where data acquisition takes place. The conditioning pulses ensure that the loading platens are seated onto the specimen for consistent results. The test frame and accessories. Both laboratory-mixed and plant-mixed asphalt mixtures were tested for a load pulse period of 1000 ms, pulse width of 100 ms, Haversine waveform and 0.35 poisson's ratio[3].

Indirect tensile fatigue test

There are three main methods used to evaluate and predict the fatigue characteristics of asphalt mixes. They are initial strain-fatigue life, dissipated energy-fatigue life and fracture mechanics. Indirect tension fatigue test uses the fracture mechanics. The horizontal deformation during the indirect tension fatigue test is recorded as a function of load cycle. Fatigue life (Nf) of a specimen is number of cycles to failure for asphalt concrete mixtures. Fatigue cracking is a pavement distress that typically occurs at intermediate temperatures and so 20 °C is chosen as test temperature to characterize the fatigue lives of asphalt concrete mixtures. In this test a compressive load acts parallel to and along the vertical diametric plane. This loading configuration develops a reasonably uniform tensile stress in the specimen perpendicular to the direction of the applied load and along the vertical diametric plane. The procedure for indirect tensile fatigue test is described in details in the European Standard EN12697-24. Two types of controlled loading can be applied: control stress and control strain. In the control stress test, the stress remains constant but the strain increases with the number of repetitions. In the control stress test, the strain kept constant and the load or stress is decreased with the number of repetitions. The use of constant stress has the further advantage that failure occurs more quickly and can be more easily defined. Controlled stress indirect tensile fatigue test was done at 20°C which used to determine number of cycles to fracture for asphalt mixtures. Number of load cycles to the specimen failure is defined as fatigue life (Nf) for asphalt mixtures. The loading pattern used in the test is a haversine load and the 4 in. cylindrical specimens were subjected to a stress of 300 kPa. The loading time and the subsequent rest period were 0.25 s and 1.25 s, respectively. The indirect tensile fatigue test frame and loading apparatus.

RESULTS AND DISCUSSION

Wheel track rutting test

The rutting test was performed at 50°C in accordance with AASHTO T324 standard test method employing the Hamburg Wheel Tracking device. The rut depth was recorded after each loading cycle and plotted for laboratory mixed and plant mixed asphalt mixtures as a function of the number of loading cycles in Figure 1 and Figure 2, respectively. The maximum rut depths of these mixtures after 10000 loading cycles are presented in table 7. The results show that the permanent deformation (rutting) resistance of fiber reinforced asphalt mixtures is superior to that of unmodified asphalt mixture, so that the rut depth of 1 and 2 lb/t fiber reinforced plant mixed asphalt mixtures are 4.5 and 14 times lower than that of base control asphalt mixture. The rut depth of 1 lb/t fiber reinforced laboratory mixed asphalt mixture is also 1.3 times lower than that of base asphalt mixture.

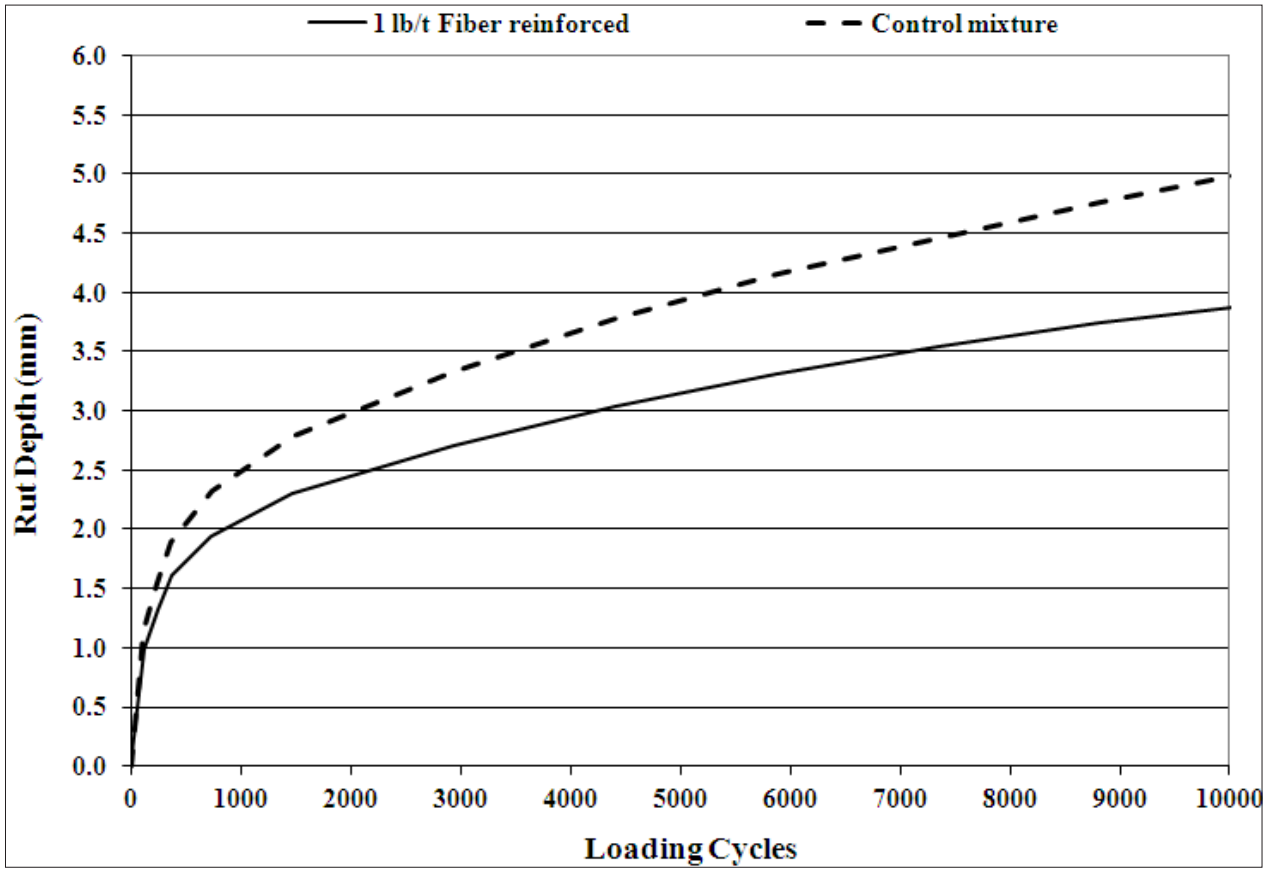

Fig. 1. Rut depth versus number of load cycles for laboratory mixed asphalt mixtures[5]

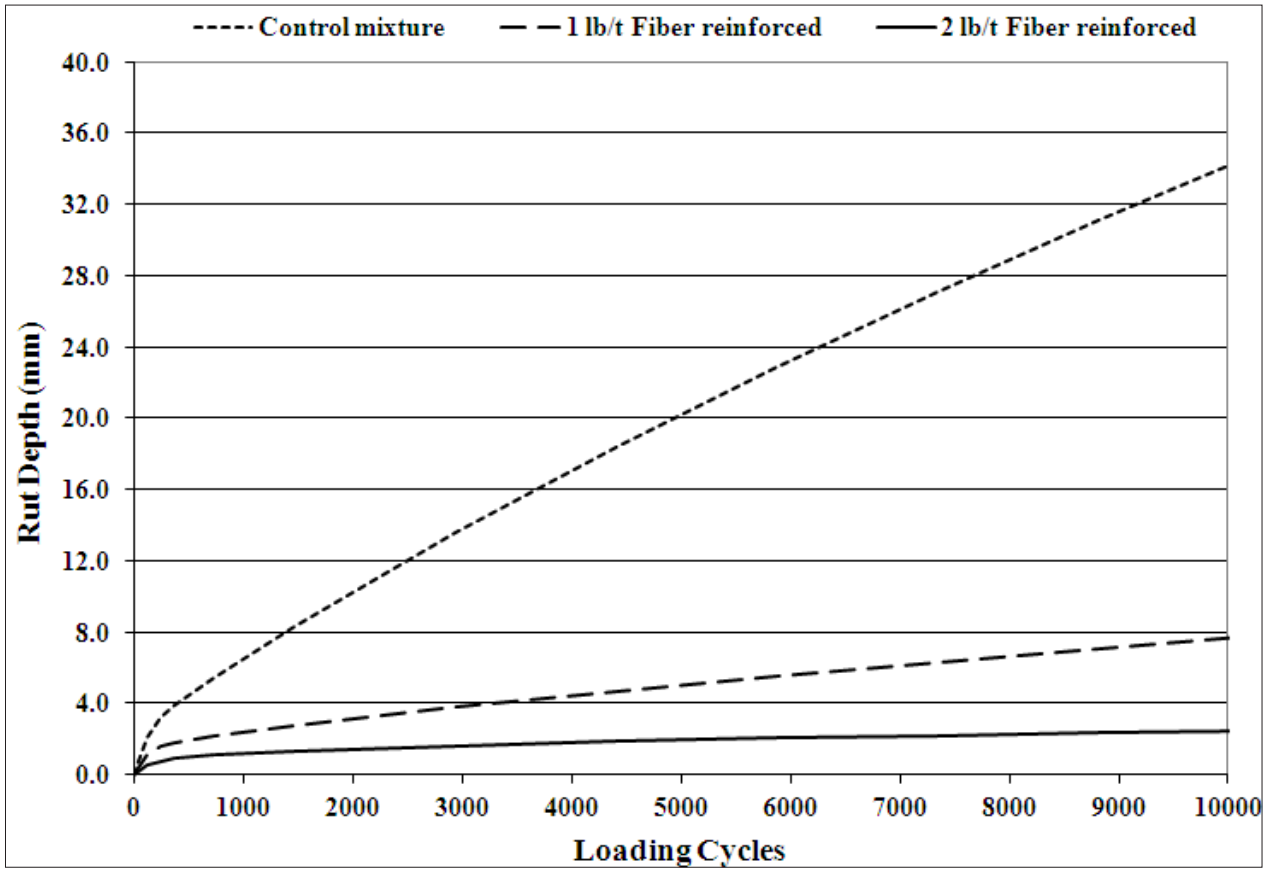

Fig. 2. Rut depth versus number of load cycles for plant mixed asphalt mixtures[5]

Comparing the results of laboratory mixed and plant mixed asphalt mixtures reveals that addition of synthetic fibers in batch asphalt plant is more effective than laboratory mixing of fibers with asphalt mixture, and plant mixing can uniformly and completely distribute the fibers in the mixture that leads to three-dimensionally reinforcing asphalt mixture. The results of plant mixed asphalt mixtures indicate that increasing the fibers content from 1lb/t by 1 pound per ton of asphalt mixture decreases the rut depth of asphalt mixture by a factor of 3 and effectively enhances the permanent deformation resistance of asphalt mixture. Furthermore, the lower resistance of plant mixed asphalt mixtures compared to laboratory mixtures can be related to the mix gradation. Inspecting the mix gradations show that the asphalt mixture produced in the asphalt plant has less fines and poor gradation respect to the permanent deformation resistance compared to laboratory mixed asphalt mixture[2].

Table 7. Wheel track rutting test results[5]

Mixing procedure	Mix type	Rut depth (mm)
laboratory mixed	control	4.98
	fiber reinforced	3.87
plant mixed	control	34.20
	1 lb/t fiber reinforced	7.64
	2 lb/t fiber reinforced	2.44

Dynamic creep test

The dynamic creep test was carried out on unmodified and fiber reinforced asphalt mixtures according to BS: DD226 test method. The flow number and the corresponding cumulative permanent strain as a function of the number of loading cycles over the test period was recorded for laboratory mixed and plant mixed asphalt mixtures. The average results for these mixtures are presented in table 8. The results show that reinforcing the asphalt mixtures by synthetic fibers improved permanent deformation resistance of asphalt mixtures, so that the flow times (FN) of 1 and 2 lb/t fiber reinforced plant mixed asphalt mixtures are 2.3 and 40 times lower than that of control mix. The flow number of 1 lb/t fiber reinforced laboratory mixed asphalt mixture is also 1.5 times lower than that of laboratory mixed control mixture. Inspecting the results of creep test reveals that flow-time has good correlation with rut depth in wheel track rutting test and the results are rational in that the flow time decreased as the rut depth increased. Poor performing mixtures had the lowest flow time (shortest time to failure) and good performing mixtures had the largest flow time (longest time to failure). Surveying dynamic creep test results shows that the rutting parameter, FN, is compatible with rutting performance of asphalt mixtures in Hamburg Wheel Track Rutting Tester. Dynamic creep test results also indicate that fiber reinforcing of asphalt mixtures in asphalt plant is more effective than laboratory reinforcing of asphalt mixtures and plant mixing can completely distribute the fibers in the mixture. It can be seen from the results that increasing the fibers content from 1lb/t by 1 pound per ton of asphalt mixture increased the flow time by a factor of 18 and the deformation resistance of asphalt mixture increased incredibly. Furthermore, the lower resistance of plant mixed asphalt mixtures compared to laboratory mixtures is evident and related to poor mix gradation of plant mixed asphalt mixture[4].

Table 8. Dynamic creep test results[5]

Mixing procedure	Mix type	Flow Number (cycles)	Permanent strain at failure (%)
laboratory mixed	control	1067	1.74
	fiber reinforced	1633	1.90
plant mixed	control	250	1.13
	1 lb/t fiber reinforced	560	1.11
	2 lb/t fiber reinforced	10150	1.57

Resilient modulus test

The resilient modulus of unmodified and fiber reinforced asphalt mixtures at 25°C was determined according to ASTM D4123 test method. The average results for laboratory mixed and plant mixed asphalt mixtures are presented in table 9. Modulus of resilience or stiffness modulus is directly related to the load spreading ability of a material and is the relationship between stress and strain and shows how much a material will deform under load. It can be observed from the results that fiber reinforcing of plant mixed asphalt mixtures increased the resilient modulus by a factor of 1.3 and 2.3 for 1 lb/t and 2 lb/t fiber contents, respectively. The Mr of 1 lb/t fiber reinforced laboratory mixed asphalt mixture is also 1.3 times higher than that of control mix[3].

The resilient modulus values can be utilized to analyze the response of the pavement structure due to the application of traffic loads. The resilient modulus is also the most important variable to mechanistic design approaches for pavement structures and an important parameter to predict the pavement performance and to analysis the pavement response to traffic loading. The stiffer pavements have greater resistance to permanent deformation and it is important not to ignore that high stiffness at low temperature tend to crack earlier than more flexible mixtures.

The fiber reinforced asphalt mixtures consistently exhibited higher resilient modulus values than control mixtures and 1 lb/t increase in fiber content produced a considerable increase in the elastic properties of the con-

trol mixtures. These findings indicate that using synthetic fibers produces asphalt mixtures with greater stiffness and thus higher load bearing capacity and decreases asphalt pavement design thickness[2].

Table 9. Resilient modulus test results[5]

Mixing procedure	Mix type	Mr (MPa)
laboratory mixed	control	1813
	Fiber reinforced	2324
plant mixed	control	2646
	1 lb/t fiber reinforced	3330
	2 lb/t fiber reinforced	6136

Indirect tensile fatigue test

Controlled stress indirect tensile fatigue test was done at 20°C according to EN12697-24 standard test method. Number of load cycles to the specimen failure (Nf) was recorded for plant mixed asphalt mixtures. The average results are presented in table 10. Because of the poor performance of laboratory mixed fiber reinforced asphalt mixtures compared to plant mix reinforced mixtures, fatigue test on laboratory mixed asphalt mixtures was cancelled. The relations between vertical deformations versus number of load cycles to failure are presented in figures 7 to 9 for plant mixed asphalt mixtures. The results show that fatigue behavior of fiber reinforced mixtures significantly improved compared to control mixture. Based on indirect tensile fatigue test results, fatigue life of 1 and 2 lb/t fiber reinforced plant asphalt mixtures are 2.0 and 34 times higher than that of control mix. Besides, the increasing of fibers content by 1 lb/t of asphalt mixture leads to a considerable improvement of fatigue behavior. The fatigue test results can be related to the three- dimensionally reinforcement of asphalt mixture by synthetic fibers. Test results reveal that plant mixing of fibers into the asphalt mixture completely distributes the fibers throughout the mixture and develops strength and durability.

Table 10. Indirect tensile fatigue test results for plant mixed asphalt mixtures[5]

Mix type	Nf
control	2555
1 lb/t fiber reinforced	5125
2 lb/t fiber reinforced	9

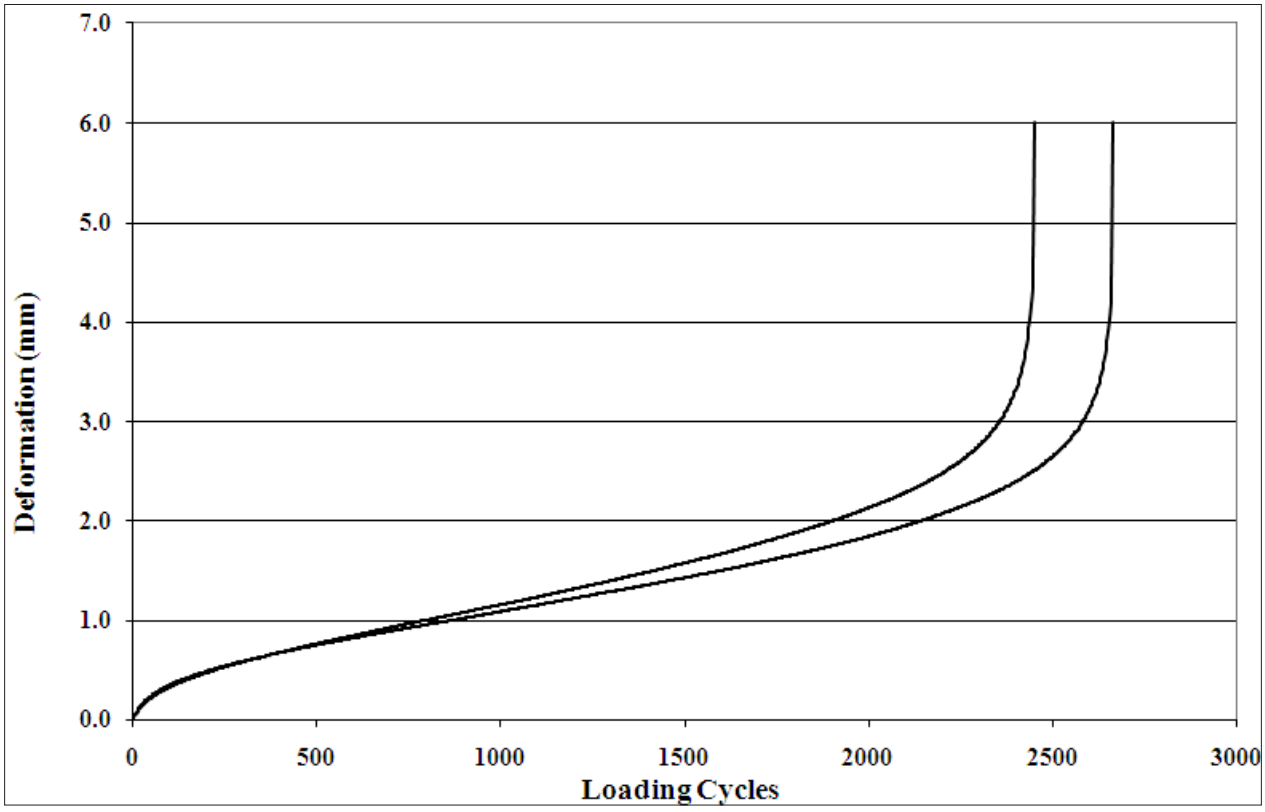

Fig. 3. vertical deformation versus number of load cycles for control mixtures [5]

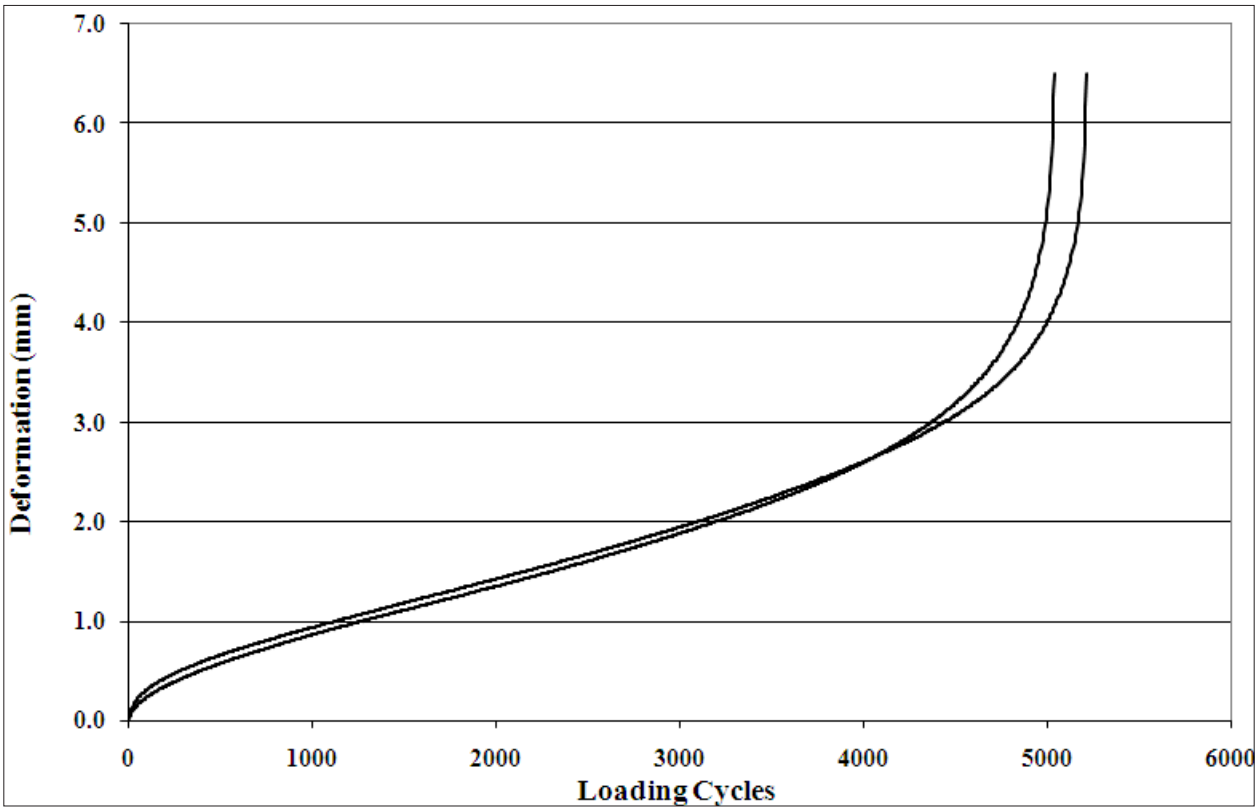

Fig. 4. vertical deformation versus number of load cycles for control mixtures [5]

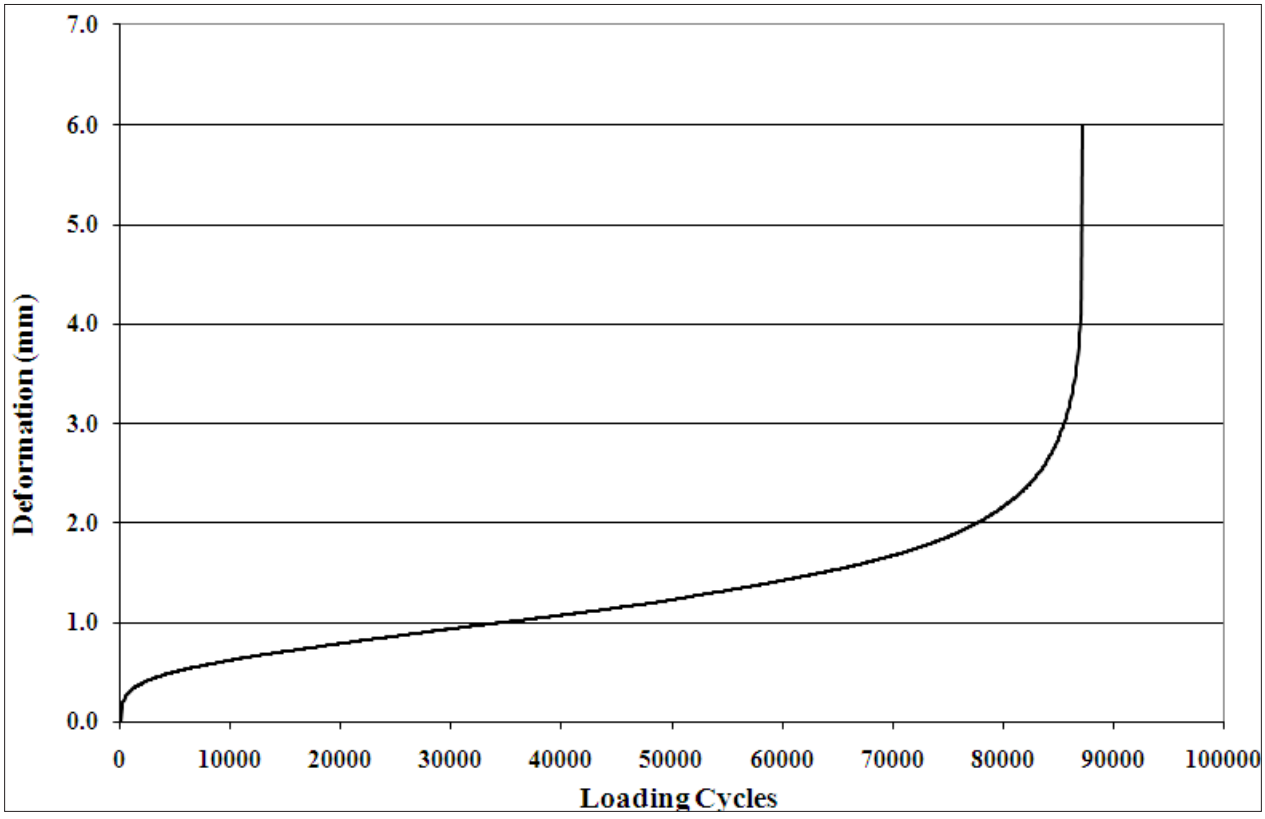

Fig. 5. vertical deformation versus number of load cycles for 1 lb/t fiber reinforced mixtures

CONCLUSION

- Rutting resistance of fiber reinforced asphalt mixtures is superior to that of unmodified asphalt mixture. The rut depth of 1 and 2 lb/t fiber reinforced plant mixed asphalt mixtures were 4.5 and 14 times lower than that of base control asphalt mixture [5].
- The rut depth of 1 lb/t fiber reinforced laboratory mixed asphalt mixture was 1.3 times lower than that of base asphalt mixture.
- Fibers reinforcing of asphalt mixtures improved creep behavior of asphalt mixtures, so that the flow times (FN) of 1 and 2 lb/t fiber reinforced plant mixed asphalt mixtures were 2.3 and 40 times lower than that of control mix.
- The flow number of 1 lb/t fiber reinforced laboratory mixed asphalt mixture was 1.5 times lower than that of control mix.
- Increasing the fibers content from 1lb/t to 2 lb/t decreased the rut depth in the wheel track test by a factor of 3 and increased the flow time in the creep test by a factor of 18 and the permanent deformation resistance of asphalt mixture increased incredibly.
- Fiber reinforcing of asphalt mixtures increased the resilient modulus by a factor of 1.3 and 2.3 for 1 lb/t and 2 lb/t fiber contents, respectively. The stiffer pavements have greater resistance to permanent deformation. Using synthetic fibers produces asphalt mixtures with greater stiffness and thus decreases asphalt pavement design thickness.
- Fatigue behavior of fiber reinforced mixtures significantly improved compared to control mixture. Fatigue life of 1 and 2 lb/t fiber reinforced asphalt mixtures in the indirect tensile repeated load test were 2.0 and 34 times higher than that of control mix.
- Addition of fibers in asphalt plant is more effective than laboratory mixing. Plant mixing of fibers into the asphalt mixture completely distributes the fibers throughout the mixture and develops strength and durability.

On the whole, fiber reinforcing asphalt mixtures by a minimum dosage rate of 1 lb/t of asphalt mixture considerably enhances permanent deformation, elastic and fatigue cracking behavior of asphalt mixtures. Furthermore, the best results are achieved by 2 lb/t fiber-reinforced plant-mixed asphalt mixture in the laboratory [5].

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[5] Kamil E. Kaloush ''Evaluation of Fiber-Reinforced Asphalt Mixtures Using Advanced MaterialCharacterization TestsBy'', ''Associate ProfessorArizona State UniversityDepartment of Civil and Environmental EngineeringPO Box 875306, Tempe,*) Evaluation of Fiber-Reinforced Asphalt Mixtures Using Advanced Material Characterization Tests*. Available from.

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ORIGINAL SCIENTIFIC PAPER

Selection of the location of a goods transportation center using the moora method

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Abstract: The location of goods transport centers in the Republic of Srpska can be observed in several ways, two of which are of decisive importance, namely, the position and strength of the flows that converge in certain nodes and the mutual relationship between the located and projected capacities in the observed nodes. The special importance of individual goods transport centers is the variety of logistics services provided. Especially in places where multiple branches of traffic meet and engage multiple entities in meeting transport demand. The factors used in selecting the basic criteria for choosing the location of freight transport centers in the Republic of Srpska are the position they occupy on railway and road routes, i.e. corridors. According to the basic definition, the role and task of goods transport centers is the collection of cargo and other shipments by road vehicles, if necessary, storage, formation of transport handling units and shipment by rail and other modes of transport for a specific goods transport center, where the goods are delivered to the recipient. Taking into account all the above, seven basic criteria were selected for the subject analysis: social, legislative, ecological, organizational, technical, technological and economic. During the research, a survey was used, on the basis of which the mentioned criteria were evaluated. By applying multi-criteria analysis, the weight of individual criteria and the value of alternatives according to criteria were determined. By applying the MOORA mathematical method, the city of Doboj was chosen as the optimal location for the construction of a goods transport center.

Keywords: goods transport center, logistics, multi-criteria analysis, mathematical method MOORA.

INTRODUCTION

Contemporary trends in the development of the economy and society, strategic and technological trends in developed countries of Europe and the world have led to a new concept of optimizing the movement of material goods, i.e. optimizing the transport process, developing new technologies and providing transport services in a modern logistical, rational and economical way. The development of large economic centers within the framework of large agglomerations in the world conditions a high level of development of goods transport centers (RTC), which represent the imperative of the modern transport process.

The formation of a commodity transport center enables a rational division of work on the transport market, concentration of commodity work, selection of the most favorable carrier of transport in macro distribution and concentration of activities with unique servicing of urban wholes of industrial zones, then in macro distribution with a unique information system in all links of the logistics chain.The place and role of the goods transport center is not only to connect certain subjects (demand-

ers, providers and connectors of transport services) into a single transport chain, but the multiplication task is to make it continuous, but ultimately continuous. In addition, goods transport centers, as links in the logistics chain, represent a link in connecting all participants in the transport process, thus creating a unique transport system with the possibility of fitting into a single transport market.

Bosnia and Herzegovina, as a European country, cannot be included in world trends, nor in cooperation and organization of traffic without the construction of goods transport centers in larger agglomerations. Bearing this in mind, and going to meet the modern solutions applied in Europe, the basic idea was to develop a methodology based on multi-criteria decision-making aimed at solving the tasks of choosing the optimal location of the goods transport center. Such tasks represent a complex interdisciplinary process with a high degree of expert activity.

Starting from the analysis of logistics flows and processes in the region, attention is focused on the main tasks that are solved when choosing the optimal location of the goods transport center. It is based on the assumption and knowledge that in the logistics chain of supply, economic organizations, city infrastructure facilities and citizens, goods transport centers have a very important role. The success of the economy and city infrastructure depends on their ability to dispose of goods and provide quality logistics services. The assumption is that the existence of a goods transport center with an optimal location, assortment and quantities of goods with a focus on elements and transport and storage systems makes a key contribution to the improvement of the economy and business.

When solving such problems, the decision-making process requires the use of a large number of rules, the consideration of a large number of alternatives and criteria, in addition to the fact that the attributes that describe certain conditions can be of a qualitative or quantitative nature. Namely, in the modern decision-making process, the trend is to include a large number of expert teams and interested parties who are existentially interested and located in the studied area and who can feel direct or indirect impacts through the process of solving the problem itself. At the same time, we should not forget the fact that every facility integrated into a logistics system affects the efficiency, effectiveness and costs of its operation.

CRITERIA USED FOR THE SELECTION OF THE RTC LOCATION

The large number and heterogeneity of location factors clearly indicate that location problems are of an interdisciplinary nature and often require the application of complex procedures when choosing the best location for rtc construction. There are numerous methodologies, as well as models that are directed towards this kind of problem. The criterion is a component that is present in almost all procedures related to the selection of the location or area of the rtc, that is, the terminal, regardless of the various models and methodologies used. As already mentioned, the process of choosing the area or location of the rtc, that is, the terminal, can be performed in two phases, from the aspect of two levels of observation, which refers to the macrolocation and microlocation procedure.

The mentioned macro and micro levels of observation require the definition of a set of certain criteria that can partially or completely differ and match. Based on the very structure of the problem and criteria, the selection and application of the optimization methodology and model is approached, as well as the evaluation of the solution regarding the location of the RTC. The procedure for selecting criteria for the realization of the definition of the area of the RTC, i.e. the terminal, can be different, starting from expert evaluation, to the hierarchical generation of criteria aimed at interest groups, certain participants - decision makers, along with their interests and goals.

Therefore, we can generate and classify criteria in relation to different points of view of the system and also of the decision maker. The choice of criteria may contain the subjective application of the individual decision-maker. For the selection of the area, that is, the location of the RTC, the criteria can be grouped in three ways (Kebić et al., 2004):

- According to the level of observation, to the criteria related to the determination of the macrolocation and microlocation of the goods terminal, that is, RTC;
- According to interest groups that are able to make certain decisions and to create influence on the concept of terminal development. This first of all refers to users of terminals and services, then owners and investors, operators, also to society from the aspect of socio-management institutions, population and others;
- According to the type of criteria and its corresponding position in one of the areas from the aspects of technology, economy, technique, organization, legal regulations, ecology and interest of the state.

The area for the construction of a goods transport center, that is, a goods terminal, must be coordinated according to the specific needs of the users of the center and the socio-economic system located in the narrower area, as well as in the wider area. The expectations of RTC users are reduced to the quality of logistics services and affordable prices, i.e. the provision of lower service prices. It would be desirable for the center - terminal to be located in the area as close as possible to its users, and

if it is of an open type to provide accessibility for all types of goods, i.e. cargo, also to integrate as many types of transport as possible and to provide the option of connecting within the international transport network networks and others (Zečević, 2006).

The terminal as a system in the economic environment must be viewed as a profit center with all elements that directly and indirectly affect the results of the Cost-Benefit analysis. This means that the terminal must be in a location with a strong economic and logistical environment that will attract goods, transport flows and all other supporting activities that support these flows (service systems, catering, shops, post offices, banks, insurance companies, customs services, etc.) .). The level of infrastructure construction, the presence of subsystems that enable synergistic effects, the possibility of expansion, legal regulations and the possibility of efficiently activating the location without ownership and other legal restrictions are very important criteria that are taken into account by investors, terminal owners. Quality connections with other logistics centers and the possibility of inclusion in national and international logistics networks are also important decision criteria. Of extreme importance for the terminal is its position in relation to the main transport axes, corridors or roads within urban areas.

Society and the state want the terminal to promote the development of all activities, to be in the function of the development of the entire system, to protect and preserve natural resources. It is desirable and necessary for the terminal to fit into the environment, to be in accordance with spatial and urban plans at the observed location, to fit into development plans at all levels, from city or regional to national or international planning levels.

The criteria listed and shown in Figure 1 do not constitute a complete set of possible criteria that are applied in solving location problems. At the next level, the mentioned criteria can be broken down into sub-criteria, and depending on the system being observed, modeled. Thus, for example, transport costs, as part of logistics costs, can be broken down into costs of local collection transport, local distribution transport in the gravity zone of the terminal, costs of remote transport between terminals in the logistics network, costs of transporting containers, exchangeable transport vessels, etc. Degree of breakdown criteria depends on the specific setting of the location problem. In addition to the fact that not all criteria have been mentioned, not all of those mentioned have to be applied to specific location problems. When choosing criteria, their power in terms of selective action on alternative solutions for the location of goods terminals is important.

The generation and classification of criteria according to technological, economic, ecological, legal-regulatory, organizational and technical character gives the possibility of selection and observation of the shortcomings of locational alternatives from the aspect of significant areas for the development of the terminal. This approach gives the possibility of a general overview of the advantages and disadvantages of potential locations. The selection of criteria from all groups is a guarantee of its successful construction, development and sustainability. Each location methodology or model that is based on one or two groups of the mentioned criteria represents a partial procedure for choosing the location of a goods transport center, that is, a goods terminal.

When comparing the choice of cities for RTC locations in the region or in the country, in addition to these criteria, the state's interest in financing RTC should also be taken into account. The choice of the location of the RTC largely depends on the decision and the state's ability to finance the construction of the RTC.

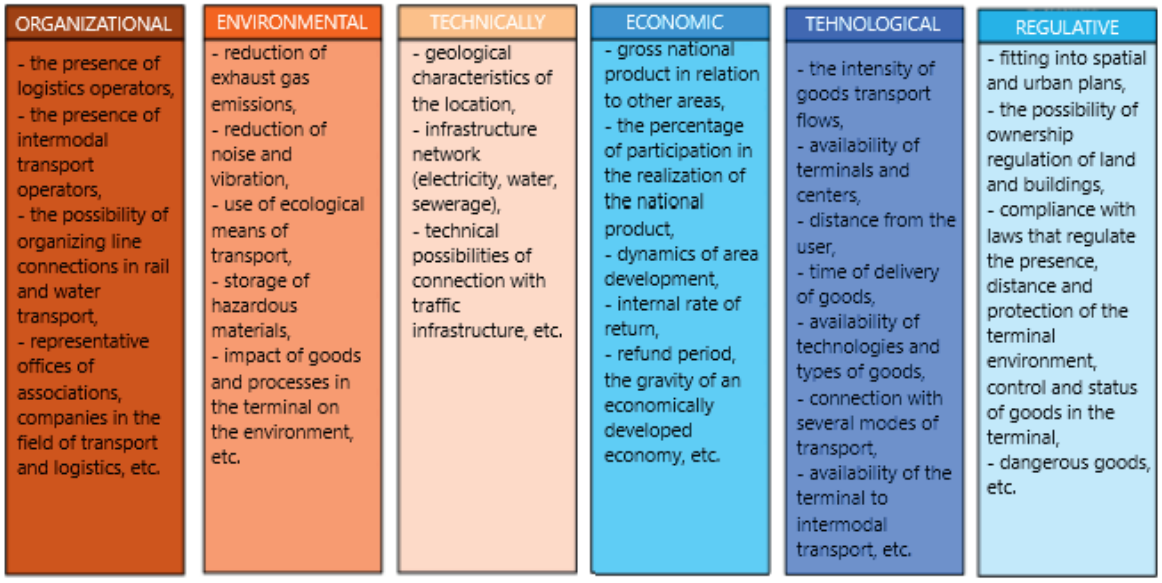

Figure 1. *RTC location selection criteria according to area affiliation (Zečević, 2006)*

In these examples, quantitative and qualitative data are not detailed and allow us to observe differences and adequacy in analyzing regions. It should be emphasized that the comparative analysis of the RTC process must be complete and include all levels and criteria, because there are connections between the macro level and the detailed level of RTC operations. Omitting one of the comparative steps can give a false picture and lead to incomplete or wrong conclusions.

OVERVIEW OF POSSIBLE ALTERNATIVES FOR THE CONSTRUCTION OF RTC AND THE APPLICATION OF MOORE'S MATHEMATICAL METHOD FOR THEIR RANKING

The location of goods transport centers in the Republic of Srpska can be observed in several ways, two of which are of decisive importance, namely, the position and strength of the flows that flow in certain nodes and the mutual relationship between the located and projected capacities in the observed nodes. The special importance of individual goods transport centers is the variety of logistics services provided. And especially in places where multiple branches of traffic meet and engage multiple entities in meeting transport demand.

The Republic of Srpska is located on the Balkan Peninsula (geographical region of Southeastern Europe). The area of The Republic of Srpska is approximately 25,000 square kilometers, which is only slightly more than the area of Vojvodina, while the length of its border is a whopping 2170 kilometers, which is only slightly less than the much larger Serbia. The problem of The Republic of Srpska is the traffic infrastructure, which is not conducive to its development. No major road or railway corridor passes through The Republic of Srpska. A special category of problems when it comes to the traffic situation of The Republic of Srpska is air traffic. The main problem of air traffic is the fact that the only international airport in the Republic of Srpska is located near Banja Luka, which is at a great distance from, for example, Herzegovina.

The position of The Republic of Srpska also has certain advantages, i.e. access to an international river such as the Sava, proximity to the Adriatic Sea and the important Dubrovnik international airport, proximity to the interna-

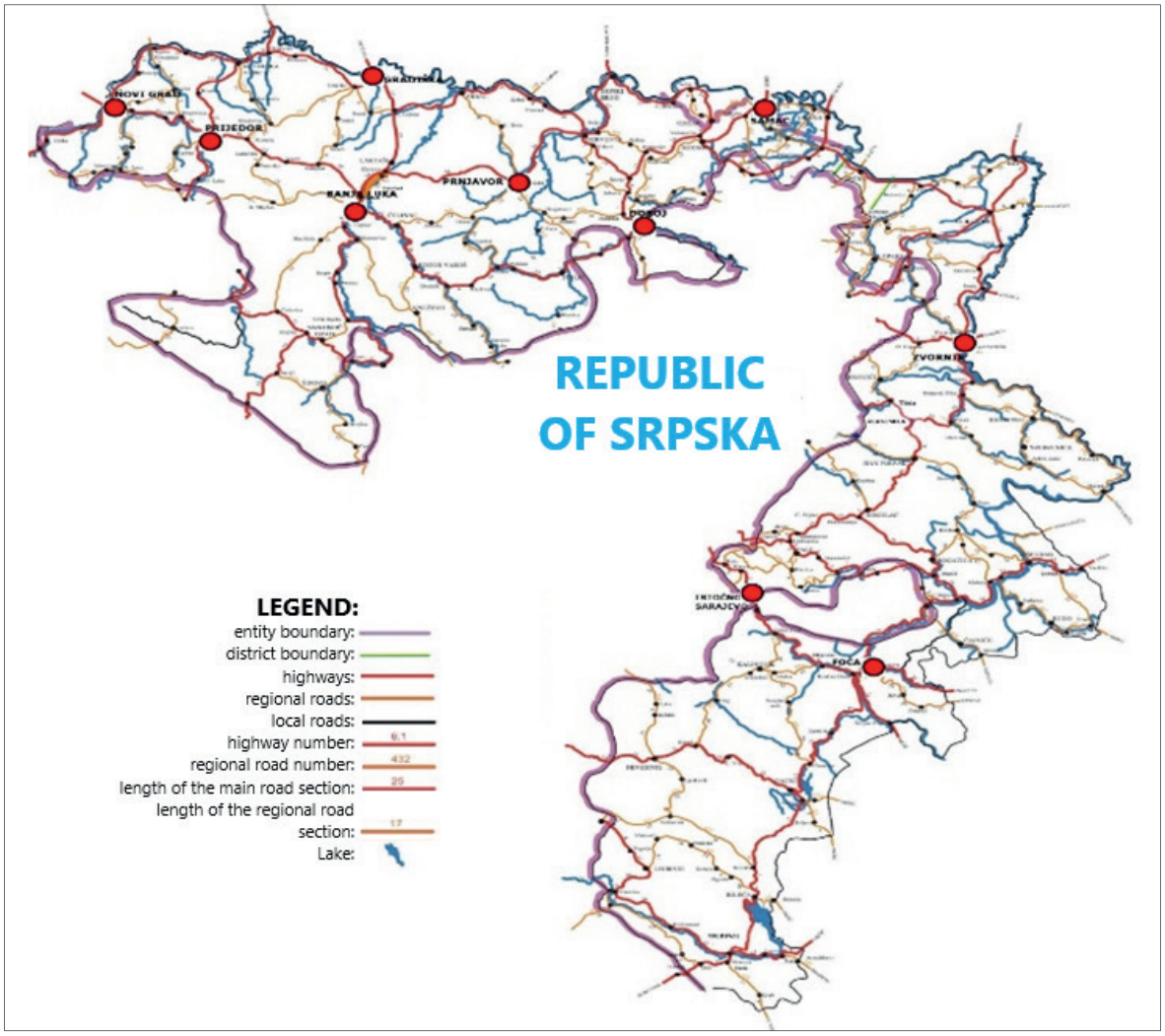

Figure 2. Proposal for RTC locations in The Republic of Srpska (Authors)

tional road corridor that connects the west with the south and east of Europe (Belgrade-Zagreb highway), connection with corridor Vc which connects central and eastern Europe with the southern Adriatic and the future Adriatic-Ionian road route, as well as the position of the eastern part of The Republic of Srpska, which abuts the Drina, a river with enormous potential in various spheres - from energy to tourism. However, as it usually happens in our case, these potentials are almost completely unused.

Presentation of potential alternatives for the construction of the RTC

The basic criteria used in the selection of areas for RTC locations in The Republic of Srpska are the position they occupy on railway and road routes, i.e. corridors. Based on this criterion, the areas-cities were taken into consideration: Gradiška, Novi Grad, Prijedor, Banja Luka, Prnjavor, Doboj, Zvornik, Šamac, East Sarajevo and Foča. The location of these cities is shown in Figure 2. These cities correspond to the requirements where RTCs could be built. The basic criteria used in the selection of areas for RTC locations in The Republic of Srpska are the position they occupy on railway and road routes, i.e. corridors. Based on this criterion, the areas-cities were taken into consideration: Gradiška, Novi Grad, Prijedor, Banja Luka, Prnjavor, Doboj, Zvornik, Šamac, East Sarajevo and Foča. The location of these cities is shown in Figure 2. These cities correspond to the requirements where RTCs could be built.

The process of solving the location problem using multi-criteria analysis

In the process of solving the problem of multi-criteria analysis, goals are defined, criteria are chosen to measure the achievement of goals, alternatives are specified, the performance of alternatives according to different criteria is transformed so that they have the same metric, weighting coefficients are assigned to the criteria in order to determine their relative importance, choices are made is the appropriate method of multi-criteria analysis for ranking the alternatives and finally the best alternative is determined. In our case, the criteria for choosing the RTC location were defined, namely: Organizational (K1), Environmental (K2), Technical (K3), Economic (K4), Legal-regulatory (K5), Technological (K6) and State interest in financing of the RTC (K7), and the areas - locations, i.e. the alternatives are defined as follows: Gradiška (A1), Novi Grad (A2), Prijedor (A3), Banja Luka (A4), Prnjavor (A5), Doboj (A6), Šamac (A7), Zvornik (A8), East Sarajevo (A9) and Foča (A10).

The problem solving process is preceded by recognition, i.e. identification of the decision-making problem itself. The identification of the decision-making problem refers to the collection and classification of data, then data processing and finally the interpretation of the collected and processed data, which is a prerequisite for the correct identification of the problem. The first step in the identification phase is the collection of relevant data and information by the decision maker from a number of sources. The main goal is to extract the most significant and relevant data and information that are of crucial importance for a given decision-making problem. The essence of this phase is to collect and process data so as to enable the formation of a decision-making model.

Application of the MOORA method

The entire procedure of preparation and collection of input data required for the application of the MOORA method to the ranking of the selection of areas for the location of the RTC is shown in Figure 3.

We will present the mechanism and method of its application to the selection of the RTC location. As the MOORA method consists of two approaches: the ratio system approach (eng. Ratio System Approach-RS) and the reference point approach (eng. Reference Point Approach-RP), the procedure for applying this method to the obtained data consists of the following stages (Gatarić, 2017):

- initial, normalized and weight-normalized decision matrix (common steps for both approaches),

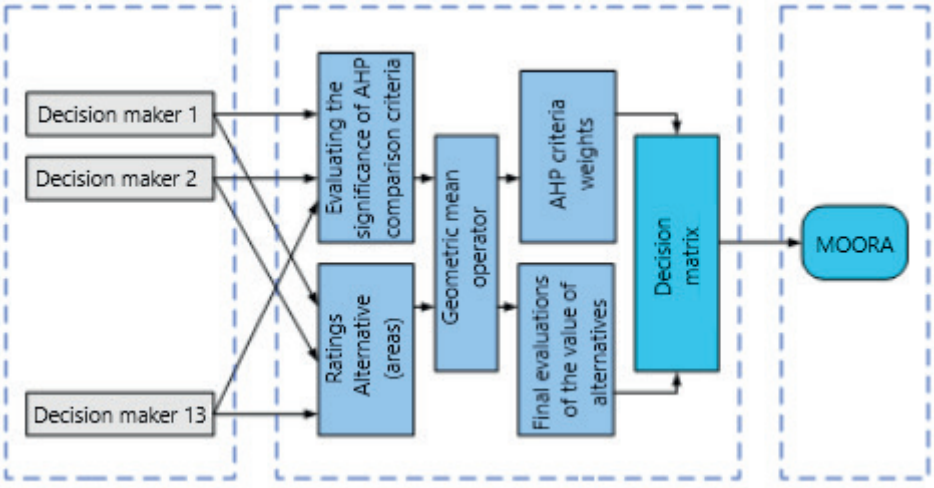

Figure 3. The flow of preparation and collection of input data required for the application of the MOORA method (Gatarić, 2017)

- approach to the relationship system and
- reference point approach.

Initial, normalized and weight-normalized decision matrix

The input values, i.e. the initial data for almost all methods, are the weights of the criteria and the values of the alternatives in relation to each criterion, which are the elements of the decision matrix. The initial decision-making matrix is presented in the following table.

Step 1. In this step, the values of the alternatives are transformed into dimensionless quantities, i.e. quantities that do not depend on the system of units. The MOORA method is based on vector normalization, which is the most complex. Therefore, the normalized decision matrix $R = [r_{ij}]_{10x7}$ contains normalized elements from the previous table and is shown in the following table 2.

Step 2. Formation of the weight-normalized decision matrix $V = [v_{ij}]_{10x7}$. The elements of the weight-normalized matrix Vj represent the product of the elements of the normalized matrix with the corresponding criteria weights, that is, the weight-normalized performance of the i-th alternative in relation to the j-th criterion (table 3).

Table 1. Initial decision-making matrix of evaluation of alternatives in relation to the selected criteria

Selection criteria	K1	K2	K3	K4	K5	K6	K7
Areas							
weights Wj	0.0822	0.1081	0.0858	0.1788	0.0473	0.1451	0.0953
Load direction	max	max	max	max	max	max	max
A1	8.2622	6.7338	7.3276	8.0588	6.6714	8.7940	8.4081
A2	8.2882	7.9764	7.7558	8.1118	5.1132	7.6025	6.8033
A3	8.5548	7.4382	6.5172	8.2149	7.3187	7.4474	7.6336
A4	9.1641	9.1209	9.1209	8.5321	7.1451	8.5375	7.3782
A5	7.8329	7.7197	8.3182	8.2594	5.5590	8.5871	7.2351
A6	8.9657	8.2443	8.7940	8.5457	7.5901	8.7147	8.6936
A7	8.4024	7.5433	7.9611	8.0182	6.7526	7.1025	5.4934
A8	8.0891	7.1292	7.5151	8.3113	8.2164	6.3943	5.4541
A9	7.9891	7.5480	7.6002	7.7485	7.2282	8.2933	5.8575
A10	6.9951	6.8586	7.7431	6.7425	6.8737	8.1955	6.2015
Suma	684.6528	586.7866	623.6106	651.1411	476.3813	640.4464	490.3095
Sqrt	26.1659	24.2237	24.9722	25.5175	21.8262	25.3070	22.1429

Table 2. Normalized decision matrix

	K1	K2	K3	K4	K5	K6	K7
Wj	0.0822	0.1081	0.0858	0.1788	0.0473	0.1451	0.0953
Load	max	max	max	max	max	max	max
A1	0.3158	0.2780	0.2934	0.3158	0.3057	0.3475	0.3797
A2	0.3168	0.3293	0.3106	0.3179	0.2343	0.3004	0.3072
A3	0.3269	0.3071	0.2610	0.3219	0.3353	0.2943	0.3447
A4	0.3502	0.3765	0.3652	0.3344	0.3274	0.3374	0.3332
A5	0.2994	0.3187	0.3331	0.3237	0.2547	0.3393	0.3267
A6	0.3426	0.3403	0.3522	0.3349	0.3478	0.3444	0.3926
A7	0.3211	0.3114	0.3188	0.3142	0.3094	0.2807	0.2481
A8	0.3091	0.2943	0.3009	0.3257	0.3764	0.2527	0.2463
A9	0.3053	0.3116	0.3043	0.3037	0.3312	0.3277	0.2645
A10	0.2673	0.2831	0.3101	0.2642	0.3149	0.3238	0.2801

Table 3. Weight-normalized decision matrix

Column1	K1	K2	K3	K4	K5	K6	K7
Wj	0.0822	0.1081	0.0858	0.1788	0.0473	0.1451	0.0953
Load	max	max	max	max	max	max	max
A1	0.0260	0.0300	0.0252	0.0565	0.0145	0.0504	0.0362
A2	0.0260	0.0356	0.0267	0.0568	0.0111	0.0436	0.0293
A3	0.0269	0.0332	0.0224	0.0576	0.0159	0.0427	0.0329
A4	0.0288	0.0407	0.0313	0.0598	0.0155	0.0489	0.0318
A5	0.0246	0.0344	0.0286	0.0579	0.0120	0.0492	0.0312
A6	0.0282	0.0368	0.0302	0.0599	0.0164	0.0500	0.0374
A7	0.0264	0.0337	0.0274	0.0562	0.0146	0.0407	0.0237
A8	0.0254	0.0318	0.0258	0.0582	0.0178	0.0367	0.0235
A9	0.0251	0.0337	0.0261	0.0543	0.0157	0.0475	0.0252
A10	0.0220	0.0306	0.0266	0.0472	0.0149	0.0470	0.0267

Ratio System Approach

The weight/importance of each alternative is determined as the difference of the income sums $Pi, i = 1,\ldots 10$ and expenditure elements $Ri, i = 1,\ldots 10$ weighted normalized decision matrices $V = \left[v_{ij}\right]_{10x7}$.

Step 3. The sums of income and expenditure elements for all alternatives are determined by applying the formulas:

$$P_i = \sum_{j=1}^{n} v_{ij} | j \in J^{max},\ i = 1, \ldots, m \quad (1)$$

$$R_i = \sum_{j=1}^{n} v_{ij} | j \in J^{min},\ i = 1, \ldots, m \quad (2)$$

where: J^{max} represents a set of income, and J^{min} represents a set of expenditure criteria.

In our case, there are no expenditure criteria, ie. all of them are profitable, because a better rating is more suitable for each criterion - the aim is to maximize the rating (value) of the criteria, that is $R_i = 0$, so we have that the difference is the sum of income and expenditure elements:

Step 4. $S_i = P_i - R_i = \sum_{j=1}^{7} V_{ij}, j \in J^{max}, i = 1, \ldots 10$

Step 5. The ranking results of this MOORA method approach are as follows (tables 4 and 5):

Table 4. Ranking results using the ratio system approach of the MOORA method

K3	K4	K5	K6	K7				
0.0858	0.1788	0.0473	0.1451	0.0953				
max	max	max	max	max	P	R	P-R	Rang
0.0252	0.0565	0.0145	0.0504	0.0362	0.2387	0.000	0.2387	3
0.0267	0.0568	0.0111	0.0436	0.0293	0.2291	0.000	0.2291	6
0.0224	0.0576	0.0159	0.0427	0.0329	0.2314	0.000	0.2314	5
0.0313	0.0598	0.0155	0.0489	0.0318	0.2568	0.000	0.2568	2
0.0286	0.0579	0.0120	0.0492	0.0312	0.2379	0.000	0.2379	4
0.0302	0.0599	0.0164	0.0500	0.0374	0.2589	0.000	0.2589	1
0.0274	0.0562	0.0146	0.0407	0.0237	0.2226	0.000	0.2226	8
0.0258	0.0582	0.0178	0.0367	0.0235	0.2192	0.000	0.2192	9
0.0261	0.0543	0.0157	0.0475	0.0252	0.2276	0.000	0.2276	7
0.0266	0.0472	0.0149	0.0470	0.0267	0.2150	0.000	0.2150	10

Table 5. Rankings from best to worst alternatives using the MOORA relationship system approach

Rang	Alternative
1	A6
2	A4
3	A1
4	A5
5	A3
6	A2
7	A9
8	A7
9	A8
10	A10

Reference Point Approach - RP

The weight/importance of each alternative is determined as its maximum distance from the ideal solution, after which the alternative with the smallest distance is selected. It is Min-Maxmetrics: $A^*_{RP} = \left\{A_i \middle| \min_i \max_j d_i\right\}$. Calculating the distance of the alternative, ie. in relation to the ideal point, in relation to each criterion (table 6).

Table 6. Calculation v_j - j-th and reference point coordinates (ideal alternatives)

	K1	K2	K3	K4	K5	K6	K7
Wj	0.0822	0.1081	0.0858	0.1788	0.0473	0.1451	0.0953
Load	max	max	max	max	max	max	max
A1	0.0260	0.0300	0.0252	0.0565	0.0145	0.0504	0.0362
A2	0.0260	0.0356	0.0267	0.0568	0.0111	0.0436	0.0293
A3	0.0269	0.0332	0.0224	0.0576	0.0159	0.0427	0.0329
A4	0.0288	0.0407	0.0313	0.0598	0.0155	0.0489	0.0318
A5	0.0246	0.0344	0.0286	0.0579	0.0120	0.0492	0.0312
A6	0.0282	0.0368	0.0302	0.0599	0.0164	0.0500	0.0374
A7	0.0264	0.0337	0.0274	0.0562	0.0146	0.0407	0.0237
A8	0.0254	0.0318	0.0258	0.0582	0.0178	0.0367	0.0235
A9	0.0251	0.0337	0.0261	0.0543	0.0157	0.0475	0.0252
A10	0.0220	0.0306	0.0266	0.0472	0.0149	0.0470	0.0267
Vj	0.0288	0.0407	0.0313	0.0599	0.0178	0.0504	0.0374

Based on the above table and the calculated value v_j, we get the distance matrix $D = \left[d_{ij}\right]_{10x7}$, d_{ij} the absolute value of the distance of the i-th alternative in relation to the j-th coordinate of the reference point. Matrix D and its elements are shown in Table 7.

Table 7. Distance matrix D

Distance matrix D							
A1	0.0028	0.0107	0.0062	0.0034	0.0033	0.0000	0.0012
A2	0.0028	0.0051	0.0047	0.0030	0.0067	0.0068	0.0081
A3	0.0019	0.0075	0.0089	0.0023	0.0019	0.0077	0.0046
A4	0.0000	0.0000	0.0000	0.0001	0.0023	0.0015	0.0057
A5	0.0042	0.0063	0.0029	0.0020	0.0058	0.0012	0.0063
A6	0.0006	0.0039	0.0011	0.0000	0.0014	0.0005	0.0000
A7	0.0024	0.0070	0.0040	0.0037	0.0032	0.0097	0.0138
A8	0.0034	0.0089	0.0055	0.0016	0.0000	0.0138	0.0139
A9	0.0037	0.0070	0.0052	0.0056	0.0021	0.0029	0.0122
A10	0.0068	0.0101	0.0047	0.0126	0.0029	0.0034	0.0107

Step 6. Calculation of the maximum distance(d_i) alternative A_i from the ideal solution.

Step 7. Ranking alternatives by rule $A^* = \left\{A_i \middle| \min_i d_i\right\}$. Both steps are shown in the following tables.

Table 8. Calculation of the maximum distance

	di=max dij	Rang
A1	0.0107	6
A2	0.0096	4
A3	0.0104	5
A4	0.0126	2
A5	0.0107	3
A6	0.0127	1
A7	0.0138	9
A8	0.0139	10
A9	0.0122	7
A10	0.0107	8

Table 9. Final ranking of MOORA alternatives using the reference point approach

Rang	Alternative
1	A6
2	A4
3	A5
4	A2
5	A3
6	A1
7	A9
8	A10
9	A7
10	A8

It is clearly visible from the table that alternative 6, which represents Doboj as a potential location, is ranked best. Second in order is alternative four, i.e. Banja Luka.

CONCLUSION

Realization of goods flows within international, national, regional and urban areas cannot be imagined without some type of logistics centers as such. Therefore, goods transport centers constitute one of the most important networks of links within logistics and logistics chains. Requirements for quality logistics service such as: completeness, speed, accuracy, reliability, safety, flexibility, economy and others can be successfully met only by transport systems based on logistics principles, cooperation, coordination and technologies of combined and intermodal transport. Partial transport systems and service providers can never independently and successfully implement strict market requirements.

The selection of the location of the RTC is an extremely complex problem that cannot be solved without defining a large number of criteria that will take into account all the requirements and interests of interested parties and a large number of factors that reflect the characteristics of the area, in order to assess the weight of the criteria. In this sense, the choice of RTC location is a multi-criteria decision-making problem, and its solution requires the application of multi-criteria analysis methods. The approach allows for each criterion function to see the form of adopted generalized criteria and the position of experimental points, and when it comes to determining the relative importance of a set of attributes or criteria, the concept of balance that characterizes these methods is used. In this way, multi-criteria analysis methods support decision makers, as they can incorporate multiple sustainability goals. The paper defines a multi-criteria analysis method that provides a holistic approach to solving the problem of RTC location selection. In the process of choosing the location of the RTC, the determination of the set of criteria by which the selection will be made is of the greatest importance. Out of a large number of criteria, the criteria for choosing the location of the RTC were defined. Several measurable and non-measurable factors are included in the criteria for comparing alternative solutions. Given that the weights of the criteria and the values of the alternatives are unclear and imprecise, they were also applied to the expansion phase of conventional methods of multi-criteria analysis.

The reason for choosing the MOORA method is not its possible simplicity and easy application, but the fact that it has mechanisms that ensure the reliability of the calculated weights (significance) of the criteria. Since in the process of determining the weight (importance) the criteria for the evaluation of the RTC location were selected in advance, a large number of decision-makers were also included, who gave their assessment of the importance of the criteria by completing the survey, thus the process of group decision-making was introduced into the overall problem solving process. . It introduces significant difficulties in obtaining a unique solution, but therefore subjectivity in assessments is avoided. Namely, by completing the survey (based on the AHP questionnaire and assessment scale), opinions on the significance of the criteria and evaluations of the alternatives were accepted. The answers obtained are considered reliable and objective, which made it possible to accurately determine the weights (importance) of the criteria. Solutions were obtained by comparative analysis of the results of the ranking of alternatives in relation to the selected criteria, applying the MOORA method of multi-criteria analysis. The best solution for choosing the RTC location is the Doboj area.

The work opens up the possibility of further directions of research in a narrower scientific field, which can be the identification of new criteria. Their quantification and evaluation and research of other methods of quantification of criteria using different techniques that

successfully treat various types of uncertainty and imprecision. The work also leaves the possibility of micro-location research in the area of the selected city.

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PROFESSIONAL PAPER

The economic, ecological and safety impact of electric vehicles on traffic in the local community

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Abstract: The introduction of electric vehicles into city traffic enables a better use of economic resources, significantly reduces environmental pollution and increases traffic safety, because such vehicles encourage safer driving. In order to achieve the best results, it is necessary to ensure adequate infrastructure and all conditions that enable the greatest efficiency of individual influences and their complete synergy. The systematic and encouraged introduction of electric vehicles is the most important measure for improving city traffic.

Keywords: electric vehicles, pollution, traffic safety, urban traffic, resources.

INTRODUCTION

Electric vehicles are becoming an increasingly important segment of motorized traffic in urban areas, because they solve traffic, environmental and functional problems. Electric transport in urban areas refers to public transport, commercial transport, personal transport and micromobility of citizens. Each of the segments affects all essential features of urban traffic, and the most favorable effects are achieved through the synergy of all types of traffic. In the Western Balkans region, public transport in urban areas is not solved according to the standards of larger urban areas of the European Union with an electrified underground railway as the basis of urban transport. It places special emphasis on all other types of electrified traffic in order to improve the functionality, ecology and safety of city traffic. In this paper, the impacts of electric buses, electric delivery vehicles, electric personal vehicles and electrified micromobility of citizens are analysed in particular.

ELECTRIC VEHICLES IN URBAN TRAFFIC

The development of electric vehicles began at the end of the 19th century, and in the first decade of the 20th century, especially in urban areas, they were more promising than conventional ones. However, the accelerated development of internal combustion engines and the increasing production and availability of oil and oil derivatives pushed electric vehicles into the background. The problem was in the energy density of the fuel. Namely, 30 to 40 Wh of energy could be stored in a kilogram of lead batteries, while a kilogram of gasoline stored 300 times more energy. This limited the range and functionality of such vehicles, because the real range of 10 to 50 kilometers, depending on the type of vehicle and driving conditions, was inadequate for mass use.

Further development followed in the 1970s, when nickel-cadmium (NiCd) with a capacity of 40 to 60 Wh/kg and nickel-metal hydride (NiMH) - 75 to 100 Wh/kg began to be used, but this was still not enough for the development usable electric vehicles.

Further development followed in the 1970s, when nickel-cadmium (NiCd) with a capacity of 40 to 60 Wh/kg and nickel-metal hydride (NiMH) - 75 to 100 Wh/kg began to be used, but this was still not enough for the development usable electric vehicles. More intensive development began in the 2000s, when lithium-ion batteries with a capacity of 100 to 265 Wh/kg began to be introduced.

Electric vehicles in urban traffic were used with external power supply from the electrical network, rail (underground and overhead railways and trams) and road (trolleybuses), but in most urban areas in countries with less developed traffic, this type of traffic was neglected. For this reason, in this paper we analyse the impact of road electric vehicles with battery power on efficiency, ecology and safety in urban traffic, whose impact on urban traffic began to be felt in 2010, and more intensively since 2020, and their impact will grow in the coming years, especially when In 2035, the European Union bans the production and sale of passenger vehicles powered by internal combustion engines and restricts them to commercial vehicles.

Electrification of traffic refers to: personal electric vehicles, commercial electric vehicles, micromobility.

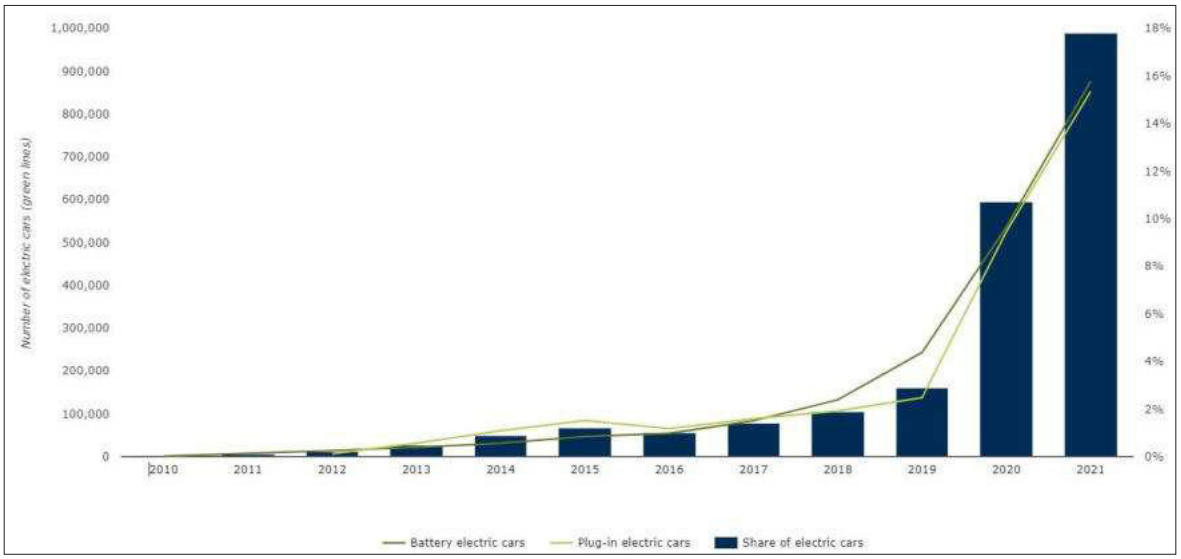

Figure 1. New registration of electric vehicles in Europe (https://www.eea.europa.eu/ims/new-registrations-of-electric-vehicles)

The winner of the 2011 European Car competition was the Nissan Leaf, which with a synchronous AC electric motor with a power of 80 kW and a lithium-ion battery with a capacity of 24 kWh had a range of 117 km, according to the American EPA (Environment Protection Agency) standard, or 175 km according to to the European standard NEDC (New European Driving Cycle). The first global success of a car with an electric drive was achieved by the Tesla Model S, which with two electric motors with a total system power of 340 kW and a torque of 967 Nm and a lithium-ion battery of 85 kWh achieved excellent performance, with a range according to the NEDC standard of 480 km. After that, with the introduction of smaller electric cars, Renault Zoe, Fiat 500e, Opel Corsa-e, Peugeot e-208, the introduction of electric vehicles to the European market began.

The share of electric vehicles on the European market reached 1% in 2014, 2.4% in 2019, and then the rapid growth began. During 2020, 1,061,000 electric vehicles were sold on the EU market with a market share of 10.7%, and in 2021, 1,729,000 electric vehicles were sold, with a market share of 17.8%, and in 2022, around 2 million electric vehicles are expected to be sold., with a market share of 20 percent.

"In 2021, the share of electric vehicles (BEVs and PHEVs) in national new car registrations increased in all countries (EU-27, Iceland, Norway) compared with 2020. The highest shares were found in Norway (86%), Iceland (64%), Sweden (46%) and Denmark (35%).

Germany, France and Norway accounted for about 63% of BEV registrations (in the EU-27 and non-EU EEA countries). In Norway, the country where the highest number of electric cars was registered in 2021, BEVs accounted for 65% of new car sales that year. In some other European countries, however, the percentage of BEV registrations remained around 1% of the total fleet (Cyprus, Poland, Czechia and Slovakia). PHEV percentage sales were highest in Iceland (36%), Sweden (25%) and Norway (22%).

The leading countries in electric mobility offered, over the years, financial incentives such as tax reductions

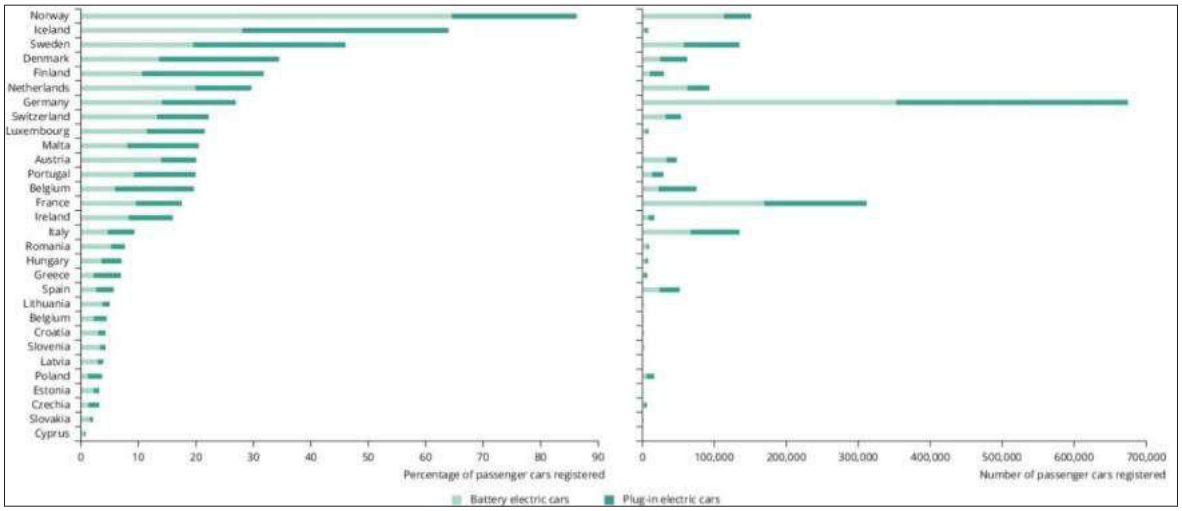

Figure 2. Electric vehicles EU 2020 (https://www.eea.europa.eu/ims/new-registrations-of-electric-vehicles)

and exemptions for electric vehicles, designed to stimulate an increased uptake of these vehicles. More countries are increasing the number of incentives for electric mobility" (https://www.eea.europa.eu/ims/new-registrations-of-electric-vehicles).

INFLUENCE OF ELECTRIC CARS ON URBAN TRAFFIC

Electric vehicles affect urban traffic according to three criteria: ecological, safety and functional, and significantly change the structure and characteristics of personal and business mobility in cities. Therefore, it is necessary to analyse each of the mentioned influences separately.

Environmental impact of electric cars on urban traffic

Replacing an internal combustion engine with an electric motor directly affects the ecology in urban areas, as the following harmful and toxic gaseous compounds are produced:

- Carbon monoxide (CO), Hydrocarbons (HC),
- Volatile organic compounds (VOC), Nitrogen oxides (NOx),
- Particulates (P).

Electric vehicles almost completely remove harmful gaseous emissions and thereby significantly contribute to the ecological characteristics of urban areas, which affect the health of citizens, visitors and tourists, and thus positively affect the economic and tourist characteristics of urban areas. Regardless of the fact that electric mobility, in the production of vehicles and in the production of electrical emissions, create indirect and global pollution, which is still less than the pollution created by fossil fuels, their ecological contribution to urban environments is direct and decisive, which, in addition to the reduction of harmful gaseous emissions also applies to noise reduction.

Safety impact of electric cars on urban traffic

Electric vehicles affect the safety of urban traffic in a number of ways, both negative and positive, which need to be considered and properly treated, so that their overall impact on the safety of urban traffic is synergistic and positive.

Negative impacts of electric cars on urban traffic safety

Electric vehicles have two negative impacts on safety in urban traffic:

- they do not create noise, which, in addition to the negative ones, has significant positive effects, primarily on the safety of pedestrians, cyclists and moped riders in urban traffic,
- significantly better accelerations of electric vehicles encourage drivers to violate regulations and occasional fast driving, which reduces traffic safety in urban areas, in the event of a collision or technical failure, there is a risk of the

Tier	Date (type approval)	Date (first registration)	CO	THC	VOC	NO_x	$HC+NO_x$	P	PN [#/km]
Diesel									
Euro 1[b]	July 1992	January 1993	2.72 (3.16)	–	–	–	0.97 (1.13)	0.14 (0.18)	–
Euro 2	January 1996	January 1997	1.0	–	–	–	0.7	0.08	–
Euro 3	January 2000	January 2001	0.66	–	–	0.50	0.56	0.05	–
Euro 4	January 2005	January 2006	0.50	–	–	0.25	0.30	0.025	–
Euro 5a	September 2009	January 2011	0.50	–	–	0.180	0.230	0.005	–
Euro 5b	September 2011	January 2013	0.50	–	–	0.180	0.230	0.0045	6×10^{11}
Euro 6b	September 2014	September 2015	0.50	–	–	0.080	0.170	0.0045	6×10^{11}
Euro 6c	–	September 2018	0.50	–	–	0.080	0.170	0.0045	6×10^{11}
Euro 6d-Temp	September 2017	September 2019	0.50	–	–	0.080	0.170	0.0045	6×10^{11}
Euro 6d	January 2020	January 2021	0.50	–	–	0.080	0.170	0.0045	6×10^{11}
Petrol									
Euro 1[b]	July 1992	January 1993	2.72 (3.16)	–	–	–	0.97 (1.13)	–	–
Euro 2	January 1996	January 1997	2.2	–	–	–	0.5	–	–
Euro 3	January 2000	January 2001	2.3	0.20	–	0.15	–	–	–
Euro 4	January 2005	January 2006	1.0	0.10	–	0.08	–	–	–
Euro 5a	September 2009	January 2011	1.0	0.10	0.068	0.060	–	0.005[c]	–
Euro 5b	September 2011	January 2013	1.0	0.10	0.068	0.060	–	0.0045[c]	–
Euro 6b	September 2014	September 2015	1.0	0.10	0.068	0.060	–	0.0045[c]	6×10^{11}[d]
Euro 6c	–	September 2018	1.0	0.10	0.068	0.060	–	0.0045[c]	6×10^{11}
Euro 6d-Temp	September 2017	September 2019	1.0	0.10	0.068	0.060	–	0.0045[c]	6×10^{11}
Euro 6d	January 2020	January 2021	1.0	0.10	0.068	0.060	–	0.0045[c]	6×10^{11}
Petrol and diesel									
Euro 7[21] (proposed)	2025[22]	2025[22]	0.1 to 0.3[23]			0.030[23]			

Figure 3. EU emission standards for passenger cars (https://www.eea.europa.eu/ims/new-registrations-of-electric-vehicles)

vehicle catching fire, which is more intense and difficult to control than fires in vehicles powered by internal combustion engines.

Positive impacts of electric cars on urban traffic safety

Positive impacts are:

- encourage calmer driving (the profile of people who buy them and the knowledge that any sudden acceleration shortens the range), they have a larger mass, which reduces inertial forces in the event of a collision, greater mass improves the grip of the tires on the asphalt,
- lower centre of gravity that increases static and dynamic stability,
- more intense engine braking significantly contributes to safety, because every reduction in pressure on the power pedal activates regenerative braking and reduces the car's speed, the combination of intensive electric braking and the working brake system ensures better overall braking capabilities of the car.

With the introduction of the artificial sound effect of electric vehicles, sufficient to achieve driving safety and the recommended limit of vehicle engine power for young drivers, the negative effects are minimized, and the large positive effects make a great contribution to the safety of urban traffic. The positive effects on safety in urban traffic are increased by electric micromobility, i.e. by increasing the share of electric two-wheelers in urban traffic.

Functional impacts of electric cars on urban traffic

The electric motor concept facilitates the production of smaller, nimble vehicles, which are ideal for urban vehicle conditions. It also facilitates the construction and performance of smaller delivery vehicles for urban environments, which contributes to functionality and environmental friendliness in urban traffic. The role of electric micromobility is particularly important, because it reduces the number of cars and delivery vehicles in urban areas and thus achieves a large, indirect positive effect on ecology and functionality in urban traffic.

In order to achieve all this, it is necessary to provide the appropriate infrastructure. Primarily, ensure the conditions so that citizens can charge these vehicles at their place of residence and build a network of standard and fast charging stations at the necessary locations in the centre and outskirts of urban areas.

CONCLUSION

The introduction of electric vehicles into city traffic enables a better use of economic resources, significantly reduces environmental pollution and increases traffic safety because such vehicles encourage safer driving. For this reason, it is important to ensure a gradual increase in the share of electric vehicles in urban transport through a systematic approach, improvement of infrastructure and incentive measures for the purchase of electric vehicles. The systematic and encouraged introduction of electric vehicles is the most important measure for improving city traffic, in terms of ecology, economy and safety. This will ensure better living and working conditions for citizens in urban areas and improve the conditions for the growth of the economy and tourism. This is why the promotion of electric mobility is the most important measure in urban areas with multiple and synergistic effects on all sectors of the economy.

LITERATURE

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PROFESSIONAL PAPER

Comparative analysis parking spaces in the city of Gradiška

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Abstract: We live in an era of global urbanization, which largely represents the expansion of existing cities and the creation of new ones, but at the same time the reduction of rural settlements. The number of people living in cities is increasing day by day. If the organization of the city is good, the work is done well, it has a predisposition to become a smart city. In order for a city to become smart, it needs to keep up with the times, follow trends, the development of technology, infrastructure, have intelligent transport systems and the like. Interruption of vehicle movement for a period of time longer than 3 minutes constitutes parking. A parking space is a limited part of the road intended for parking vehicles. It can be part of a garage, parking lot or street. A parking lot is a space intended exclusively for parking vehicles.

Keywords: parking space, urban environment, parking features...

INTRODUCTION

Parking lots can be private or public. A public parking lot is a part of the traffic area intended exclusively for parking cars. The time period of parking in the public parking lot can be limited or unlimited. It is characteristic of public parking lots that they are classified by parking zones. Private car parks are usually built by legal institutions for the needs of their employee members or clients.

In order for a parking lot to be considered good, certain criteria must be met:

- The parking lot is located in an accessible location in the immediate vicinity of all or most of the contents and attractions of the population;
- The parking lot has an aesthetically acceptable external and internal appearance;
- In the parking lot, there is a possibility to quickly and easily find a free parking space with the help of a guidance system;
- The parking lot is provided with lighting during the night, which ensures the confidence and safety of the parking lot users;
- The parking lot is regularly maintained and cleaned.

Cars used to represent luxury, while today they represent a necessity for daily life activities. [4] The increase in the degree of motorization of the population not infrequently creates a problem in terms of stationary traffic. There is an increasingly frequent need for a parking place, more. In urban areas, the problem is the same for everyone because there is a lack of parking spaces. It often happens that due to the lack of parking spaces, drivers resort to parking in residential areas. Parking in residential areas is a new problem itself. [2]

The subject of this paper is the investigation of parking characteristics in the parking lots in the streets of Dr. Mladen Stojanović, Vidovdanska (near the Cultural Center) and the parking lot of the "Kozara" building, which are located in the central area of Gradiška. The location itself (Dr. Mladen Stojanović Street) is very attractive and busy. Until recently, the planned parking lot was unorganized with numerous obstacles, unmarked parking spaces, and did not have an adequate method of payment. The parking space in Vidovdanska street is also very attractive due to the proximity of all important municipal institutions, banks, services and the like. The parking lot of the "Kozara" building is specific and is more in the domain of parking for building tenants. [3] [6] [7] This research was conducted in order to improve the functioning of the parking system, after arranging the plot.

Data that must be collected and presented by this research:

- surface accessibility,
- available number of parking spaces,

- parking mode;
- type and characteristics of parking,
- vehicle retention time,
- frequency of parking,
- purpose of parking,
- the most necessary item for users (walking time to the destination, price of a parking space);
- remarks and suggestions of users of parking services.

In order to improve parking services, a survey of parking users was conducted on July 12, 2023 - Wednesday. The counting of vehicles at the given location was carried out in the period from 07:00 a.m. to 1:00 p.m. At the very beginning of the research, a record of the vehicles found was made.

LOCATION AND CHARACTERISTICS OF PARKING

Pictures 1, 2 and 3 show the appearance of the parking lot located in Dr. Mladen Stojanović Street. The parking lot located in Dr. Mladen Stojanović Street includes 36 paid parking spaces, 2 spaces for people with disabilities and 5 reserved spaces. Due to the proximity of the residential complex, there are several annual preferential tenancy tickets in the collection. The number of monthly tickets charged varies depending on the time of year.

Picture 1. View of the parking lot (spaces for persons with disabilities)

Picture 2. View of the parking lot in Dr. Mladen Stojanović Street

Table 1. Characteristics of parking in Dr. Mladen Stojanović Street

Parking lot location	**Dr. Mladen Stojanović Street**		
Type of parking lot	Closed		
Parking lot organization	90º		
Number of parking spaces	Under payment 36	For persons with disabilities 2	Reserved parking spaces 5
Illegally parked vehicles	5		
Number of vehicles found	21		

Picture 3. Illegally parked vehicles in Dr. Mladena Stojanović Street

Table 2. Characteristics of parking in Vidovdanska Street (near the Cultural Center)

Parking lot location	**Vidovdanska Street (near the Cultural Center)**		
Type of parking lot	Closed		
Parking lot organization	90º		
Number of parking spaces	Under payment 35	For persons with disabilities 1	Reserved parking spaces 0
Illegally parked vehicles	15		
Number of vehicles found	27		

Picture 4. View of the parking lot in Vidovdanska Street (near the Cultural Center)

Picture 4 shows the parking lot in Vidovdanska Street (near the House of Culture). This parking space has 35 paid parking spaces, 1 space for people with disabilities and no reserved spaces. Due to the proximity of the residential complex, there are several annual preferential tenancy tickets in the collection. The number of monthly tickets charged varies depending on the time of year.

In the attached tables, you can see the basic characteristics of the parking lot that are the subject of this research. All three parking lots are in the central city area. The type of parking lot is closed for all three. The number of parking spaces is almost the same. However, the obvious difference is the number of vehicles that were found in parking lots before 7:00 a.m. when the survey began. The reason for this is the residential complexes located nearby.

Table 3. Characteristics of the parking lot near the Kozara building

Parking lot location	Parking lot of the Kozara building		
Type of parking lot	Closed		
Parking lot organization	90º		
Number of parking spaces	Under payment 36	For persons with disabilities 2	Reserved parking spaces 0
Illegally parked vehicles	1		
Number of vehicles found	3		

TIME OF VEHICLE DETENTION

The length of parking can be divided into:

- very short parking (15-30 minutes),
- short (from 30 - 120 minutes),
- medium length (from 2-6 hours),
- long (from 6 to 10 hours),
- very long (more than 10 hours);
- permanent (24 hours and more).

Short-term parking is predominantly present in urban areas and tourist areas, while long-term parking is characteristic of the perimeter of a narrow or wider ring of an area. [4]

Table 4. Duration of parking in fifteen-minute intervals at the parking lot in Dr. Mladena Stojanović Street

Retention time	Vehicle number	Numerical value expressed in %
up to 15 minutes	39	37.14%
15-30	21	20.00%
30-45	12	11.43%
45-60	10	9.52%
60-75	5	4.76%
75-90	5	4.76%
90-105	2	1.90%
105-120	2	1.90%
over 2 hours	9	8.57%
in total	105	100.00%

From the results attached, obtained by this research, it can be seen that there is an evident difference in the number of vehicles for the same time period. Based on the collected data, which was created by surveying the parking lot users, it was established that the parking lot users on Dr. Mladen Stojanović Street most often use it to go shopping (close to shops and greater convenience for people with disabilities).

Table 5. Duration of parking in fifteen-minute intervals at the Vidovdanska Street parking lot (near the Cultural Center)

Retention time	Vehicle number	Numerical value expressed in %
up to 15 minutes	29	48.33%
15-30	12	20.00%
30-45	7	11.66%
45-60	3	5.00%
60-75	2	3.33%
75-90	1	1.66%
90-105	1	1.66%
105-120	2	3.33%
over 2 hours	3	5.00%
in total	60	100.00%

Table 6. Duration of parking at fifteen-minute intervals in the parking lot of the Kozara building

Retention time	Vehicle number	Numerical value expressed in %
up to 15 minutes	7	13.20%
15-30	5	9.43%
30-45	5	9.43%
45-60	4	7.54%
60-75	3	5.66%
75-90	5	9.43%
90-105	2	3.77%
105-120	3	5.66%
over 2 hours	19	35.84%
in total	53	100.00%

SURVEY RESULTS

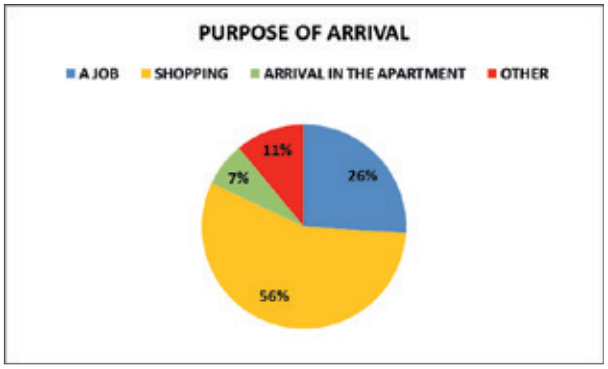
Parking is the process of settling and idling the vehicle, which is limited in time from departure to leaving, i.e. the departure of the vehicle from that space, while the user continues with the activities that were a consequence of the transportation. [5] The method of planning and dimensioning of areas intended for vehicle parking, in addition to the space and surroundings, can also affect

the safety of road traffic. [1] [9] Users of parking services park in certain parts of the city for a specific purpose, whether it is for work, school, recreation, shopping, returning to the apartment, and the like. [1] [8] There are many reasons.

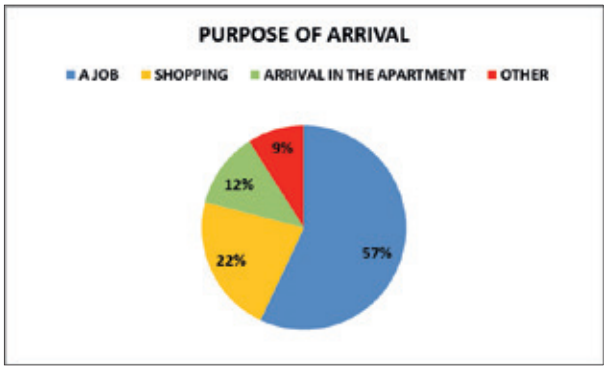
Analyzing the collected data, it was determined that the leading purpose is shopping with 56% and work with 26%. The processed collected data can be seen in the following pictures, for the parking space in Dr. Mladen Stojanović Street.

Analyzing the collected data, it was determined that the leading purpose is business with 57% and shopping with 22%. The processed collected data can be seen in the following pictures, for the parking space in Vidovdanska Street (near the Cultural Center).

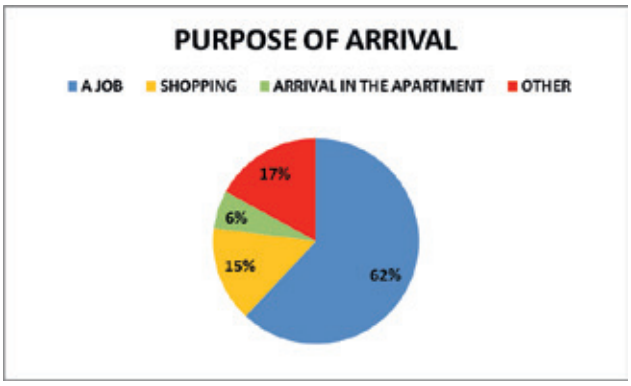
Analyzing the collected data, it was determined that the leading purpose is work with 62% and other with 17%. The processed collected data can be seen in the following pictures, for the parking area of the "Kozara" parking building.



Picture 5. The percentage value of the purpose of coming to the parking lot in Dr. Mladena Stojanović Street

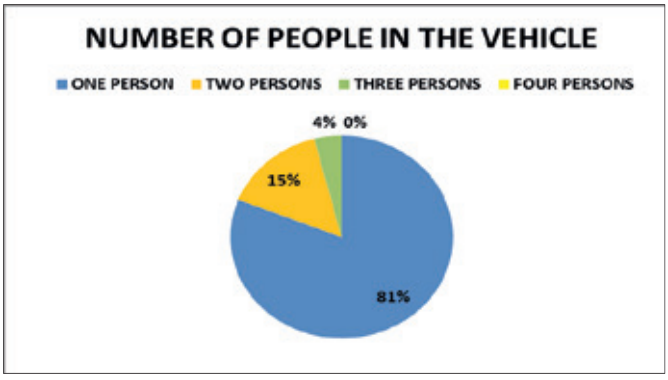


Picture 6. The percentage value of the purpose of coming to the parking lot in Vidovdanska Street (near the Cultural Center)

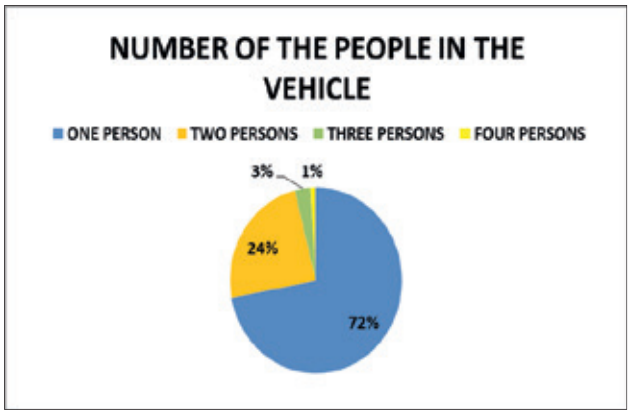


Picture 7. The percentage value of the purpose of coming to the parking area of the Kozara building

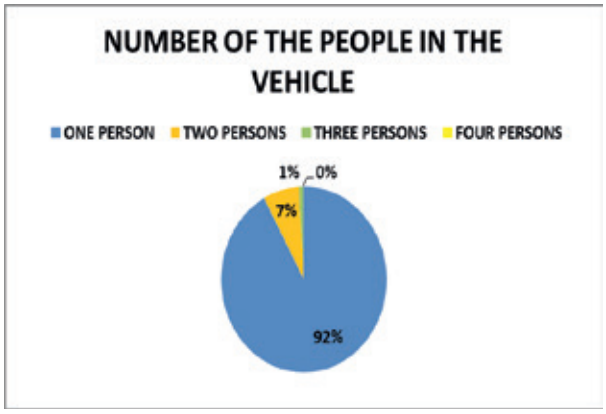
Although all three parking spaces are in the city center, the collected and processed data revealed interesting facts. The parking lot in Dr. Mladen Stojanović Street is mostly used for shopping purposes. Parking space in Vidovdanska street is used for business and private business needs, this is supported by the fact that city and municipal institutions are nearby while the parking area of the "Kozara" building, according to the data, is mostly used for business purposes. Pictures 8, 9 and 10 show the percentage value of the number of people in the car who parked. In Dr. Mladen Stojanović Street, 81% of users came alone in a car, 15% two people, 4% three people. In Vidovdanska Street, 72% came with one person, 24% with two people, 3% with three people, and 1% with four people. While for the parking lot of the "Kozara" building, 92% are for one person in a car, 7% for two people, and 1% for three people.



Picture 8. The number of people in the vehicle in the parking area in Dr. Mladena Stojanović Street



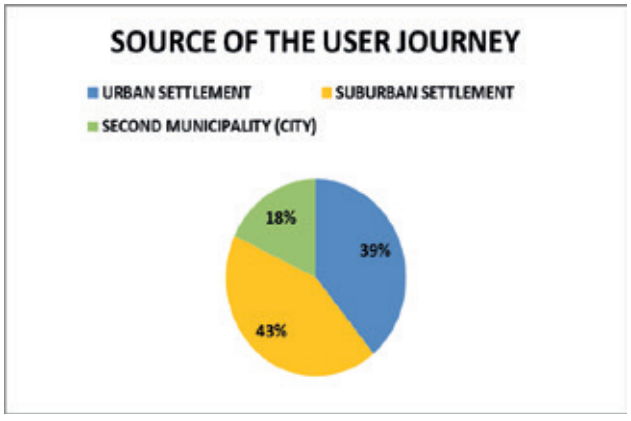
Picture 9. Number of people in the vehicle in the parking lot in Vidovdanska street



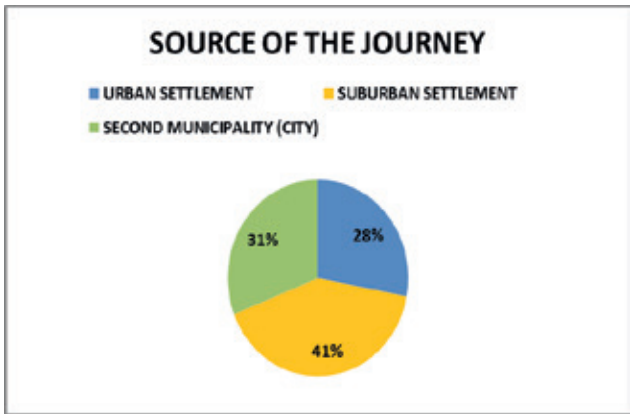
Picture 10. Number of people in the vehicle in the parking area of the Kozara building

According to the collected and processed data, it can be seen that for all three parking lots, the maximum number of arrivals per person in a car was determined. The arrival of one person in a car is a problem. Because of such cases, the use of public city transport or cycling is promoted.

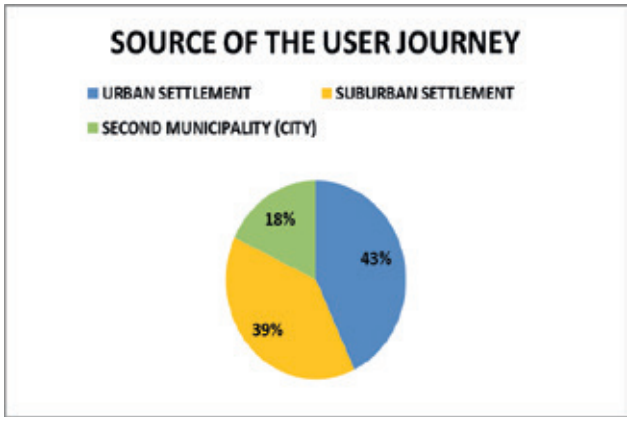
Pictures 11, 12 and 13 show the distribution of users according to the source of travel. The largest number of users comes from suburban settlements, then from urban settlements and from other municipalities. Certain deviations are possible during holidays, vacations and the like.



Picture 11. The source of user travel in the parking area in Dr. Mladena Stojanović Street



Picture 12. The source of user travel at the parking area in Vidovdanska Street



Picture 13. The source of user travel in the area of the Kozara building

From the above pictures it can be seen that the majority of users came from suburban areas. Changes may vary depending on population migration.

Transport service quality parameter

One of the questions mentioned in the survey was related to what the users perceive as the most important item in parking: that there are spaces, the price of the service, the distance from the destination. Most of them declared that the most important thing for them is to have a place.

With the fact that they would still give up parking if the price of the parking service per hour costs 2 KM.

In the survey, there was a question related to the alternative way of getting to the desired place, where the majority said they would come: by public transport (52%), by bicycle (29%), on foot (19%).

Remarks and suggestions

Within the requested data, during the survey, users were given the opportunity to express suggestions or objections to the existing way of service. The largest number of respondents complained about the lack of parking spaces. Also, the parking spaces for people with disabilities, which are really too few, stand out. In

Dr. Mladen Stojanović Street, they have two parking spaces for people with disabilities. However, according to the data obtained from the survey, it can be seen that this parking lot is mostly at the service of citizens who make purchases. Vidovdanska street has only one place for people with disabilities. Very unfavorable considering the proximity of city and municipal institutions that most citizens visit on a weekly basis.

CONCLUSION

On 12th July 2023, a survey was carried out of the parking payment system in Dr. Mladen Stojanović Street, Vidovdanska and the parking lot of the "Kozara" building in Gradiška. Time period of performance from 07:00 a.m-1:00 p.m. The requested data has been collected and processed. Analysis of the given data determined the following:

- The parking lots that are the subject of this research are located in the central city core;
- Although all three parking spaces are located in the central part of the city, there are interesting differences;
- Non-prescribed parking spots were also determined by recording on the fly. Certain illegally parked vehicles belong to tenants of a nearby residential complex (they have privileged annual tenant cards), while other vehicles were not parked in places that were not marked as parking spaces.
- Regarding the retention time itself, the results are different. In Dr. Mladen Stojanovića Street and Vidovdanska Street, vehicles mostly stopped for shorter time intervals (15-30 minutes). While in the parking area of the "Kozara" building, it is a longer time interval, over 2 hours;
- The survey found that about 43% of parking lot users come from suburban areas, 37% from urban areas, and 22% from other municipalities;
- The user's suggestions and remarks are expressed in the form of complaints about the insufficient number of parking spaces.

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PRELIMINARY REPORT

Decarbonization of the energy sector with reference to the transport sector

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Abstract: The transition of the energy sector is largely reflected in transport, which is an important a link in the economy. The decarbonization process, which is an integral part of this entire transition of the energy sector, began much earlier by finding new fuels in order to replace the already well-known and well-established fossil fuels. In order to protect the environment, many scientific research institutions and manufacturers of transport vehicles are looking for alternatives to fossil fuels. The development and transition to means of transport whose power is carried out by electric motors, i.e. where the driver of these means of transport is electricity, accumulated in batteries, is not the optimal solution, which in return caused a rapid development of various technologies and models in the last decade whose primary objectives encompass obtaining hydrogen and its use in all types of transport from road, rail, naval to the air force.

Keywords: energy sector transition, decarbonization of the energy sector, hydrogen as a propellant, application of hydrogen in the transport sector.

INTRODUCTION

The transition of the energy sector under the condition of constant reduction of CO_2 emissions is a major challenge and is related to all participants in the energy sector, from production, transportation and consumption, and applies to all economic entities and the population as a whole. In order to adopt legislation and ensure secure supply of energy and energy products under market principles, and in order to attract significant investments in the energy sector (primarily in renewable energy sources), the Energy Community was formed between the EU and the countries of Southeastern Europe, of which Bosnia and Herzegovina and therefore the Republic of Srpska is a member.

As one of the basic postulates of this Treaty is the obligation of the signatories of the Treaty, the implementation of EU legislation in domestic legislation, especially focusing on the process of liberalization of the market and the decarbonization of non-energy production.

On the basis of such commitments undertaken from the Treaty, all countries signatory to the Treaty are also obliged to undertake a series of activities in the segment of rational use of energy, i.e. to pay full attention to energy efficiency as well as the use of incentive measures in order to increase the production of energy from renewable energy sources.

When it comes to The Republic of Srpska and Bosnia and Herzegovina as a whole, quite ambitious short-term goals have been set for increasing energy efficiency and the use of renewable energy sources. The preparation and harmonization of strategic documents for the area of decarbonization, which includes the areas of energy and climate strategy and whose time validity is until 2030, is in progress.

Bearing in mind that Bosnia and Herzegovina is a very complex community, where the energy sector jurisdiction falls under independent jurisdiction of the entities and where very different levels and types of regulation of the energy sector are present, the adoption of these strategic documents at the level of BiH is slow and often delayed, in return making fulfilling of its obligations under the provisions of the Treaty significantly more difficult.

DECARBONIZATION

One of the key topics of the transition of the energy sector is the process of decarbonization, i.e. reduction and elimination of harmful emissions of gases, especially carbon dioxide (CO_2) emissions. This process has been ongoing for years, starting with the Kyoto Protocol, then the Paris Agreement of 2015, which determined the intention of the signatory countries to limit global warming to significantly below the 2°C above pre-industrial levels and to continue efforts to limit it to 1.5 °C – partly by achieving net carbon neutrality by 2050.

Reducing global greenhouse gas emissions (including CO_2) will limit the rise in global temperature. In practice, achieving net-zero emissions requires a shift from fossil fuels to alternative low-carbon energy sources.

With the European Green Deal, the European Union has set additional targets for member states to guarantee the decarbonisation of the EU. These targets are further strengthened by the Fit for 55 package, which ensures that the EU's objectives are in line with climate goals.

The European Union has imposed sanctions on energy imports from the Russian Federation, oil and gas in response to developments in Ukraine. The new situation has resulted in a profound change in energy markets, with major supply disruptions and energy insecurity due to volatility of prices, which has caused a general global economic crisis with high inflation rates.

Given the recognised large impact of fossil fuels on Member States, the European Union is introducing a new package of measures with its "REPowerEU" aimed at reducing dependence on fossil fuels, thereby encouraging additional decarbonization. In such a complex energy-political situation, alternative solutions are being sought through significant electrification of motor vehicles, using liquefied natural gas (LNG), compressed natural gas (CNG), liquefied petroleum gas (LPG), and lately more and more emphasis has been placed on green hydrogen, as one of the possible fuels that will encourage faster decarbonization of various sectors. Using these initiatives, ambitious reductions in greenhouse gas emissions are expected by 2030.

In addition, in early November 2022, a meeting of global leaders representing governments, the private sector and civil society was organized at the 27th session of the COP (Conference of the Parties/ United Nations Conference on Climate Change – UNFCCC). Since the last meeting, awareness has been growing about the important contribution to decarbonization that needs to come from the private sector, with discussions about increasing investment in new technological solutions that could help accelerate decarbonization. Although hydrogen is referred to as a decarbonization technology, it is often not clearly explained what exactly it means and what the positive applications of this technology are.

HYDROGEN AS AN ALTERNATIVE FUEL

It is a well-known fact that hydrogen is the most abundant element in nature and it is a dilemma in itself why we do not use the resource of which we posses the most. When we look at the production and use of hydrogen recently, it can be concluded that hydrogen is increasingly used, especially in conjunction with renewable energy, i.e. solar and wind energy. This approach enables the increasing integration of interminent energy sources into the daily energy supply and use in the network.

The use of hydrogen essentially represents the transition of the use of fossil fuels to hydrogen as the energy source of the future, which constitutes the essence of the transition and decarbonization process in the energy sector. Last year, most EU countries adopted hydrogen strategies defining the transition from fossil fuels to hydrogen.

Hydrogen is an essential element of the EU Green Deal, an EU strategy aimed at reducing dependence on fossil fuels that are mainly imported into EU countries. Hydrogen is very important both for mitigating climate change and for reducing environmental pollution.

It should be noted that hydrogen is not a source of energy, but a carrier of energy. As a way to store electricity, hydrogen can be used to balance the production of electricity from renewable sources of electricity and facilitate the long-term use of electricity that could not be integrated directly into the electricity grid especially in the case of high-renewable generation. Not all hydrogen is equally acceptable. It is important to distinguish the methods of its production, and different colors are used for marking, so there is: gray, blue and green hydrogen. Gray hydrogen is produced from fossil fuels, and green electricity from renewable sources. Blue hydrogen is one that, like gray, is produced from fossil fuels, but with the use of carbon extraction and storage procedures – Carbon Capture and Storage (CCS).

For the current transition, it has been planned to use exclusively green hydrogen, although today the most used is the gray hydrogen derived from natural gas. Green hydrogen, which today is mostly produced using electricity from renewable energy sources, i.e. from solar and wind farms provides the solution to the problem of 'volatility' of these sources, i.e. the production of electricity. The surpluses of production can then simply be used to produce hydrogen by electrolysis, and this hydrogen can be used for various purposes. The hydrogen produced can be transported to any place, where, by means of fuel cells or other means, the accumulated energy can converted into electricity and heat. The production of green hydrogen by electrolysis of water is the process of separating water into oxygen and hydrogen. The oxygen that is obtained, can be and is used in a significant part in various areas of life, industries and medicine.

The production of hydrogen by electrolysis of water is a clean technology whose main problem is an efficient electrolyzer. The reaction takes place using electricity and requires high purity of water for hydrogen to be produced. Therefore, before electrolysis is carried out, water is treated so that minerals and ions are removed.

Hydrogen produced from renewable sources (green hydrogen) as a substitute for fossil fuels and raw materials in sectors that are not easily decarbonised can contribute to reducing greenhouse gas emissions before 2030, economic development and achieving a climate-neutral economy by 2050. Hydrogen from renewable

sources is a unique opportunity for both research and innovation, and the creation of economic growth and jobs throughout the value chain.

Bearing in mind the fact that the production of green hydrogen requires resources that are already at the disposal of the Republic of Srpska and BiH, such as water and the commitment to the construction of solar power plants and wind farms, means that significant amounts of electricity from intermenent sources will be disposed of. It is therefore necessary to simultaneously encourage and develop the production, distribution and use of green hydrogen in BiH.

APPLICATION AND USE OF HYDROGEN

According to significant analyses and predictions, hydrogen could and should find wide application in certain industries in the coming period, especially in the process industry as a substitute for fossil fuels. The use of hydrogen is particularly interested in segments of the economy such as the petroleum industry, chemical industry, iron and steel industry, and industrial heat, and based on the characteristics and characteristics of hydrogen, especially green hydrogen, many utility companies are considering its application in the production of thermal energy for heating residential buildings and public institutions.

In addition to its use in industry and economy, hydrogen will play a significant role in the decarbonisation of transport and mobility, especially in the segments of road transport as well as sea and aviation transport. When it comes to road traffic, the fact is that freight trucks are significant potential consumers of hydrogen because when compared to electric vehicles, their range is significantly higher. If we take into account the fact that road transport vehicles produce six percent of total emissions, this percentage will be significantly reduced by substitution of petroleum products with hydrogen.

In the coming period by 2030, maritime transport should record significant growth, and the use of hydrogen as a renewable energy source in this sector would be very important, and mostly for cargo ships. In the power system, hydrogen has a high chance of being used as a medium for storing energy derived from renewable sources.

The use of hydrogen in aviation is increasingly causing interest of individual investors and research and scientific institutions, but it is important to emphasize the fact that the application of this technology requires and requires significant investments.

Recently, an increasing number of the most important companies from the aviation industry have been investing significant funds in research and the possibility of using green hydrogen as a propellant, putting decarbonization in the foreground. Swiss startup Destinus is developing a hypersonic passenger plane with hydrogen engines.

Fig. 1. New model of hypersonic aircraft of the company "Destinus"

The aircraft will have a capacity of about 25 passengers and is expected to be put into service by 2030. By developing a hypersonic ultra-long-range aircraft that would easily integrate into already existing air traffic with a set goal, creating far less noise. A statement by the company's representatives said that the flight from Sydney to Frankfurt, which takes about 20 hours, would be shortened to only 4 hours, which indicates that the speed of the aircraft should be up to Mach 5, which is more than 2 times the speed that the supersonic passenger plane "Concorde" could have developed.

The use of hydrogen for aircraft propulsion would be environmentally more sustainable as well as from the aspect of economy compared to today's solutions and the use of kerosene as a propellant, with significant technological improvements in energy use.

In addition to this development, other companies are planning and developing new types and models of aircraft that would use alternative fuels. By comparison, Boeing plans to test a jet engine that would use hydrogen as a propellant by the mid-2020s, and Boom Supersonic has plans for supersonic flights in the U.S. Hermes is also working with NASA and the U.S. Air Force to develop new aircraft engines that would use hydrogen as fuel. Venus Aerospace, a Houston startup, is also known to be developing a hypersonic spacecraft that would speed up to Mach 12.

Successful application of hydrogen in the aforementioned branches will depend on the production price of green hydrogen, which will be conditioned by the price of electricity obtained from renewable energy sources, then the price of the electrolysis process itself, which largely depends on the technological development and improvement of electrolysis technology, as well as on the prices of CO2 emission units. Significant investments in the development and improvement of these tenologies will contribute to the increased competitiveness of green hydrogen, By 2050, green hydrogen can be expected to account for 10% of total energy consumption.

DIRECTIONS OF FURTHER DEVELOPMENT

Based on the analysis done by Deloitte in 2022, more than 150 projects related to hydrogen production and its application in various fields have been announced in Europe. Of these projects, more than 50% are related to green hydrogen projects. Based on the commitment and

significant reduction of the possibilities for the use of fossil fuels in the EU, a significant increase in the number of these projects can be expected in the future. In order for green hydrogen to be widely used in all segments of economic activities, it is necessary to ensure its accessibility to potential users, and therefore it is necessary to provide significant funds for investments in infrastructure that will enable this. The European Union has planned to provide around 27 billion euros as part of the REPowerEU project, which will be available to member states.

In addition to the significant impact on decarbonisation, the production and use of hydrogen can have a major impact on the provision of new jobs in all segments from highly sophisticated jobs in the research and advanced technologies sector to jobs in manufacturing and transport as well as in various industries that need to develop new products for the needs of this sector. According to estimates, the European Union predicts that by 2030, for every billion euros invested, about 10,000 new jobs will be created related to green hydrogen. The picture below clearly shows the orientation of EU countries when it comes to investing and investing in hydrogen as the energy source of the future.

2. it is necessary through the adoption of positive legal regulations to facilitate and enable the financing of projects and harmonize legislation, all with the aim of shortening the administration of permits.

Define the technologies that will decarbonise individual sectors most appropriately and successfully, while supporting the adoption of hydrogen as the fuel of the future.

4. The decision of investors to harmonize and reconstruct the plants used in the industry today in accordance with the new trend, i.e. the acceptance and adoption of new hydrogen technologies, for the simple reason that certain plants can still function intensively.

5. Cooperation, between all interested entities from manufacturers, consumers, public institutions of government, financial and technological organizations can contribute to the development of the necessary projects of high value.

Based on the above facts and set goals, through strategic documents, with the condition of fulfilling the set goals, from these documents, it is realistic to expect that hydrogen will have a significant impact on economic development in all segments in the coming period, as well as in the process of transition and decarbonization of the energy sector and therefore in environmental protection.

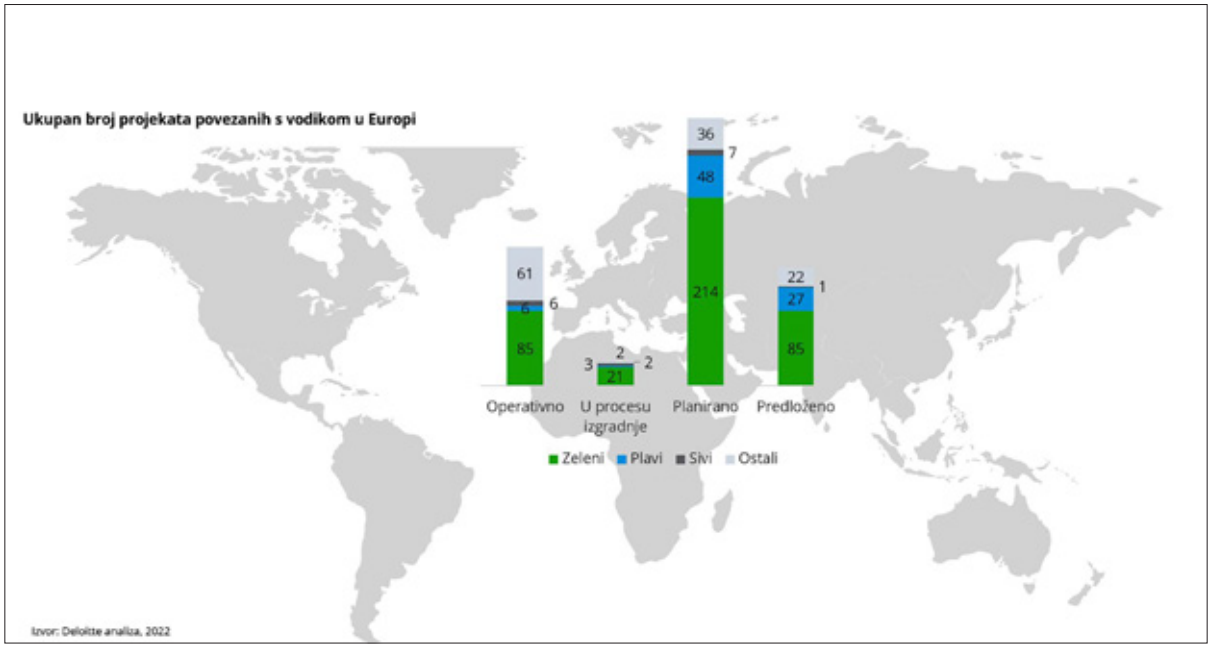

Fig. 2. Structure of development projects in the EU for hydrogen production

INSTEAD OF A CONCLUSION

The most important factors that will influence the greater use of hydrogen can be expressed in five key assumptions and facts, namely:

1. hydrogen demand, which is related to three factors namely:

- the possibility of creating profits for business entities and consumers a high level of control by the company, and
- low price growth for the consumer.

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REVIEW

Aviation cyber security

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Abstract: Information technology is increasingly prevalent in all branches of traffic. In aviation, a significant amount of data is processed by computerized systems and transmitted through communication networks. Within this digital environment, characterized by technology and a vast number of digital files, a security system is essential to ensure the proper functioning of the system. To achieve effective and efficient information security management, it is crucial to thoroughly examine the factors influencing information security and plan the necessary measures for implementation.
Keywords: information system, safety, cyber, aviation.

INTRODUCTION

"Cyber in aviation" refers to the application of cybersecurity or cyber technology in the aviation sector. This includes the protection of aircraft, flight systems, networks, and information from cyberattacks and threats. Aviation cybersecurity is crucial to ensure the safe and reliable operation of aircraft and aviation operations. Cyber space is an environment in which the cognitive world (sensory world) is created through intellectual action via information and communication systems. [1]

The use of different types of information ensures the functioning of segments and activities of many organizations. Business risk is permanently affected by information security. All information systems and networks must be provided for their operation [2]. When we talk about information security, we mean - preserving the confidentiality, integrity, and availability of information. Due to the risk of information security, significant attention must be paid to conducting business activities in the market [3].

These are just some of the basic steps that the aviation sector takes to protect against cyberattacks, but cybersecurity is a dynamic field that requires constant updating and adaptation to confront increasingly sophisticated threats. The protection of information security has been especially imposed by the development of computer technologies by networking computers that are becoming vulnerable in all branches of the economy and life, so we must approach the effective protection of the information we have.

Information properties:

- The information can only be accessed by confidential persons, organizations, or processes, and care must be taken to ensure that an unauthorized person cannot access it, which is – Confidentiality;
- Each piece of information must have completeness and the property of preservation and accuracy that it represents - Integrity of information;
- The information must be available to users who have the authority to access it - the availability of information.

The above properties of information will increase their security as well as business continuity and reduce the risk to the lowest possible acceptable level. Care must be taken in the processes of designing information systems through various technical solutions for both software and hardware. To achieve the required level of security, it's necessary to consider factors that affect the security of information, as well as the analysis and implementation of the necessary measures. [4]

Digital information technologies, as well as large amounts of data that are processed through computerized systems, must be protected. In other words, access to sensitive data can only be had by authorized persons, and unauthorized persons should be denied access, with any such attempt being recorded and analyzed. To protect the system, effective and efficient protection of the information we have at our disposal is essential, regard-

less of the place and form in which it is stored and used. It must be taken into account that the security of information is also represented by the information carrier, the protection of objects, its storage, use, and storage. Applying the appropriate policy of processes, procedures, organizational culture, and software and hardware components ensures information security. By implementing a large number of processes of different types and levels of complexity that are provided through the appropriate number of resources, we call this information security management [5].

As the use of information is an important segment in the activities of organizations, it is given great importance through ISO standards, especially the ISO 27000 series - Information Security Management Systems (ISMS). Information is an interpreted message, reducing uncertainty and increasing knowledge. When we talk about data, we mean raw facts about the real world that are represented by information carriers. When we want to obtain quality information, we need to process a certain type of data to make their selection to obtain the essence. We use this information in our work, and when we apply it several times, it grows into knowledge. The development of information technologies, computer technologies, and their networking in computer networks requires attention to information security. Through increased production, computer prices are falling and becoming more affordable for everyone. The trend is to use wireless technologies. Mobility is one of the characteristics and intentions. Data is being distributed more and more, more and more people are mastering computer technology, and access to standards is open to anything that presents a chance for information security to be compromised. For this reason, new standards like ISO/IEC 27001 dealing with the business risk approach are being introduced [4].

There are more and more attempts at cyber attacks on digital computer network systems from an unknown source. There are a number of attacks - cyber attacks that an attacker can launch. They look for system vulnerabilities where an attack can be effectively implemented. We characterize all this as an illegal action that should be disabled and prevented.

CYBER SECURITY IN AVIATION

Information technologies are increasingly represented. Security issues we need to address: access to sensitive data and unauthorized persons who should be denied access. When talking about such security problems in the digital world, the term cybersecurity is used. There is a great attempt at cybercrime in various branches of industry. Currently, according to EASA data, about 1000 attacks per month are directed at the aviation sector in aviation. Certain technical failures (problems in the operation of the radar system and automated systems in aviation) are often presented in the media as possible cyber attacks. No cyber attack has been confirmed, the air community has begun to address a potential problem.

Cyber threats were mentioned in a 2011 update in ICAO Annex 17, Security. ICAO mentioned cyber security as a high-level obstacle to the implementation of the Global Air Navigation Plan. With the transition to technologically advanced systems comes the need to address technologically advanced threats. How the system evolves from a connected point-to-point structure to a networked network where node elements are connected by digital connections using IP (Internet Protocol). An Internet-like network structure requires security comparable to critical Internet services. When the system is set up, every step of implementation must be taken into account. And it doesn't stop when the system is broadcast online: it must remain a focal point throughout its life cycle, every working day at every level. Taking this attitude into account, the user is an essential component for maintaining and improving security.

Powerful algorithms are the domain of engineers as well as secure implementation, robust hardware and software and solid networks, but choosing a good password and refusing to give any relevant data to someone who may be an attacker using social engineering techniques remains in the domain of end users. As a consequence, end users must understand the basics of security and appropriate protocols and behaviors to avoid weakening the system, which means that training on the topic must be provided.

Potential aviation-specific threats

So far, there has been talk of attacks on networks in general. Attention should be drawn to potential attackers. Who might be interested in removing any element of the civil aviation system? There are at least four types of hazards: Amateur hackers: this is the first group when it comes to computer attacks. The challenge of finding a way to break into a protected system may be the reason for a computer-savvy individual with high skills and motivation, but most are unwilling to cause harm or face the legal consequences of breaking into a critical system. However, they cannot be ignored. Criminals: One person behind a computer can attack thousands of potential targets often thousands of miles away, in another country with a different legal system. This explains why scams, such as phishing or ransomware, are on the rise. This group is potentially more dangerous than the previous one because they have economic motivation. On the other hand, criminals try to maximize the benefits by attacking targets with minimal cost and effort to take defensive measures, but no extraordinary resources are needed as they will switch to less protected and most profitable targets if they find appropriate resistance.

Terrorists: While ordinary cybercriminals tend to have financial motivations and no reason to create un-

necessary damage, the goal of terrorists is generally to cause as much damage as possible. High visibility of aviation events makes it an attractive target for such purposes. Individual aircraft were previously targeted, but computerized networks can allow an attack on multiple aircraft at once or cause widespread disruption of the ATM system. The will to maximize damage makes terrorists a dangerous threat and creates the need to use the most powerful forms of cyber defense for flight control, as well as for any other highly automated security-critical system.

Cyber war: when hostilities occur, the enemy's key infrastructure becomes the target: electricity, communication, food supply and of course flight control. As a result, target systems are automated and their malware infection is sometimes attributed to foreign agencies. It is accepted that malware is already ready to attack critical infrastructure and that such attacks can be launched as retaliation against other cyber attacks. It is almost impossible to protect the system against such opponents because they have huge resources at their disposal, as well as the necessary skills. [5]

What kind of attacks can aviation expect?

Ways of harming and disrupting the system are limited only by the human imagination. Any of the components of the CNS-ATM system would have its own vulnerabilities. Currently, the voice communication between the controller and the pilot seems to be compromised, and occasionally false messages are reported from someone pretending to be pilots using a simple radio transmitter. Cyberattacks on aircraft equipment represent a serious threat to passenger safety and the operational functionality of aircraft. Attackers may attempt to target various aircraft systems and components. Here are several potential scenarios and the impacts of cyberattacks on aircraft equipment:

1. Aircraft Systems: Attacks on aircraft systems, such as flight control, navigation, communication, and electrical systems, can lead to a loss of control over the aircraft or other critical flight issues;

2. Entertainment Systems: Cyberattacks on in-flight entertainment systems (IFE - In-Flight Entertainment) can enable attackers to access passenger devices or even cause discomfort to passengers;

3. Communication Systems: Attacks on aircraft communication systems can jeopardize the pilots' ability to communicate with air traffic control or other aircraft, leading to confusion and hazards in the air;

4. Navigation Systems: Manipulation of aircraft navigation systems can result in changes to the flight path or pilot disorientation;

5. Engines and Maintenance Systems: Cyberattacks on aircraft engines or maintenance systems can impact their reliability and safety.

A datalink controller-pilot (CPDLC) would require a higher technical skill level for an attacker to succeed in an attack. But because there is no "party line" effect, a successful attack will be harder to detect. A fake controller or a successful attack by a man in the environment that changes the appropriate approval can have a serious impact. Theoretically, it is possible to mention navigation systems, including conventional terrestrial systems, as well as satellite ones. But as the attacker should be close to the target, it seems that it will have a difficult effect on commercial aviation - unless the attacker is not on a plane or the attack takes place near the airport. Simply interfering with voice, data connection, or navigation, including satellite signals, is also a threat. Newer ATM concepts, some of which rely on (encrypted) networks, may be even more vulnerable.

Traffic at a remote controlled airport - Remote Control - can be interrupted by inserting false data in the communication between the sensors at the airport and

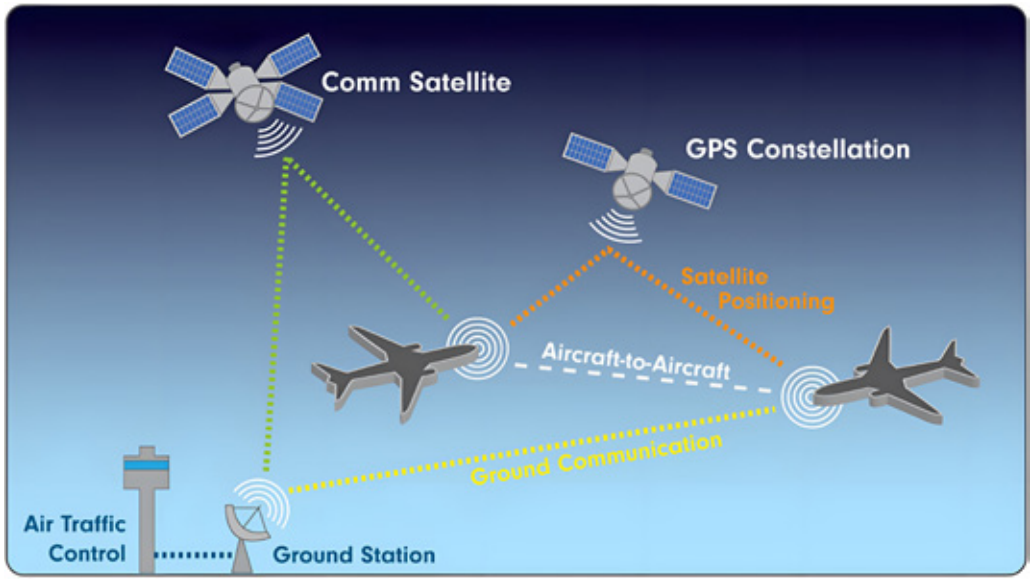

Figure 1. ADS-B system mode

the cameras and the remote tower. It is much easier to simply cut off communication via DDoS attacks that would make controllers blind, deaf and mute. The worst-case scenario is a DDoS attack on a single facility that controls several remote towers that would disrupt traffic at several single-action airports.

The use of - ADS-B

Automatic – the system works automatically, without pilot command,

Dependent – position obtained from GNSS*,

Surveillance – each station on the ground as well as the aircraft in the air which are equipped with a suitable receiver can perform surveillance.

The basis of the ADS idea is the fact that within the aircraft itself, there are data (aircraft identification, position, state vectors, short-term "intentions," description of maneuvers, aircraft type ...) that "only" should be delivered to interested users, whether they are on the ground (e.g., ATC *) or in the air (collision avoidance). ADS-B communication, not - encrypted - encrypted. To prevent the spread of "ghost planes" into the system, the ADS-B position was confirmed by calculating the Time Difference of Arrival (TDOA) signal to different ADS-B receivers. A concept such as SWIM (System Wide Information Management) may be a target for hackers. Best described as "ATM-only Internet" is a network in which all types of data are available exclusively to authorized users: meteorological data, flight trajectories, surveillance data, etc. This information is shared by all authorized users connected to the system, including individual aircraft. But the use of IP (Internet Protocol) means that the same types of attacks used on the Internet can be used against such a SWIM network, including DDoS, insertion of false data, theft of sensitive data, or ransomware. Extending the system to all types of users, from ATC to smaller parts of the general aviation structure and from airlines to meteorological services, means that there are many vulnerable entry points that could be used to compromise such a system [3]

FMS - Fligt Management System

It is a system of programmed optimal flight control that consists of the integration of various aircraft subsystems.

FMS enables the selection of automation levels for all phases of flight and provides information on appropriate indicators:

1. The main components of FMS are: FMC (Flight Management and Guidance Computer), calculates the 3D position of the aircraft, performance, and other parameters necessary for accurate and efficient flight according to a previously defined path, which are obtained based on manually entered or automatically entered data;

2. MCDU (Multipurpose Control and Display Unit), a multi-purpose control panel used for data entry and representing the connection between the pilot and the FMC;

3. FCU (Flight Control Unit), a device for controlling the horizontal and vertical flight profile of an aircraft;

4. Flight Management Source Selector, a device through which input sources are selected, used by FMC;

5. Display system, a system that displays data and information to the pilot.

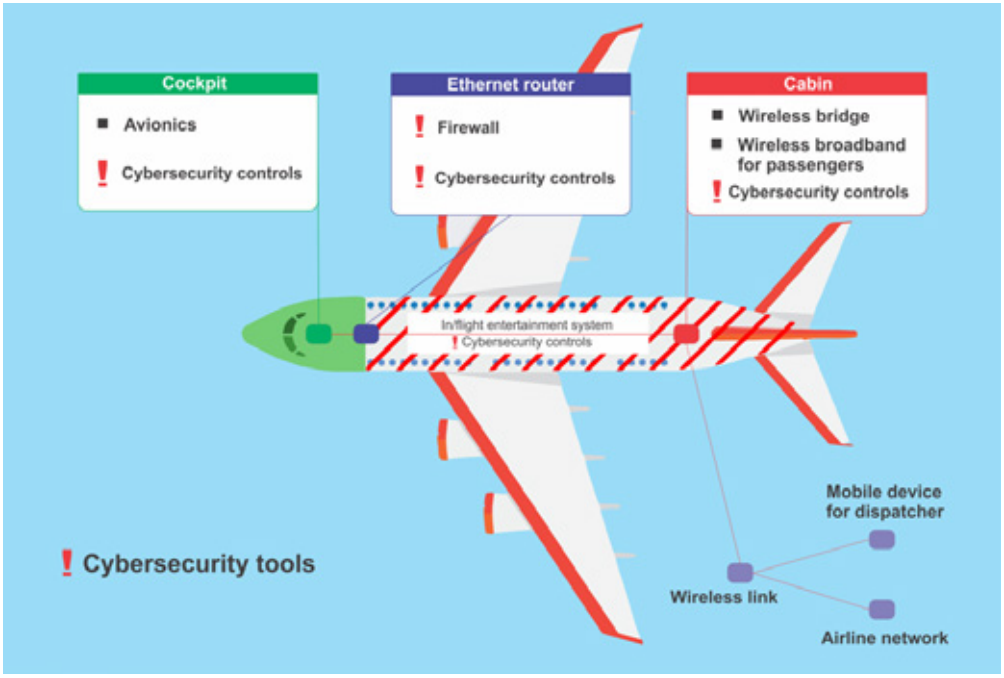

Figure 2. Illustration of active protection against cyber attacks in commercial passenger aircraft

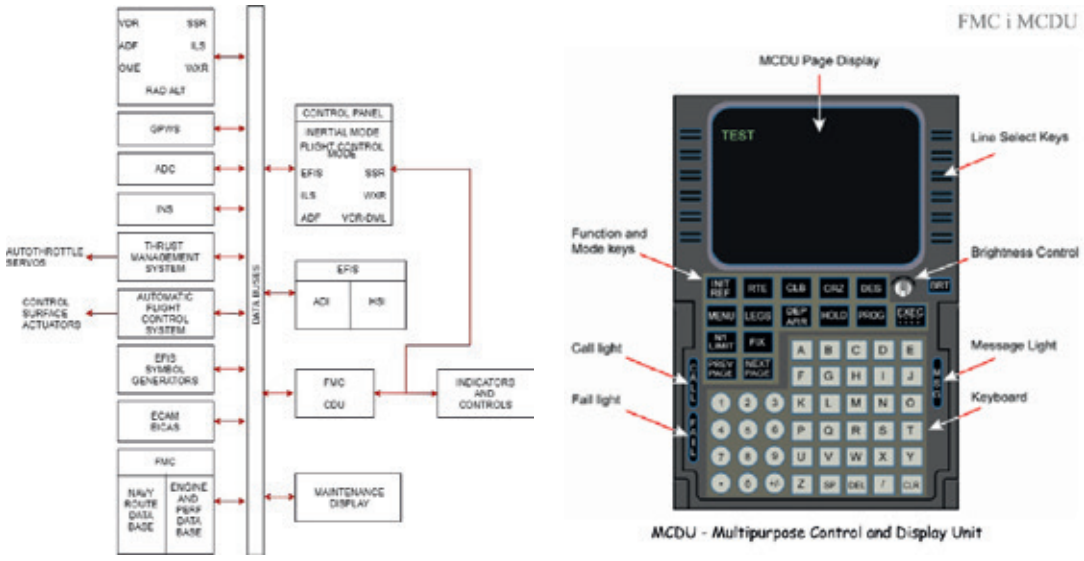

Figure 3. FMS scheme

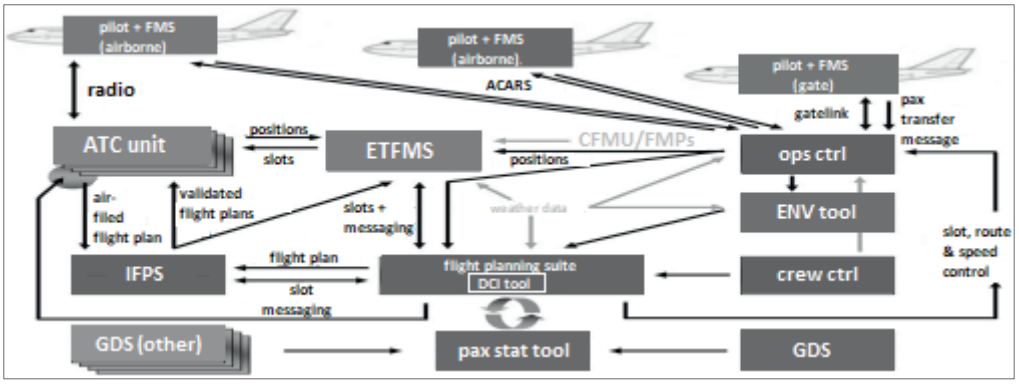

Figure 4. Data exchange mechanism

DATA EXCHANGE

The mechanism of data exchange includes meteorological data (weather data), aircraft positions, flight plans submitted from the air and confirmed flight plans (air-filed flight plan, validated flight plan), and the flow of information within this system. Coordination is provided by exchanging data on slots (a slot is a permit obtained by the airport to use its resources at a specific time) and flight plans with flight control (ATC unit) and its various services.

Communication between the aircraft and the company is provided by the system. For slots, speed, and route, data is transmitted via datalink and gatelink. Datalink as a means of digital data exchange should play a major role in practical application, as it can be used to change a flight plan or enter via FMS with the assistance of a pilot. In addition, it can be used as a means of dynamic flight monitoring, sending automatic downlink messages about the position and altitude of the aircraft and the remaining amount of fuel, in response to questionable uplink messages. Downlink messages are messages sent by an aircraft via the datalink to the ground (airline operations center), while uplink messages are messages sent from the ground to an aircraft [5].

CONCLUSION

Information, including process information support, information systems, and networks, is a critical business asset for any organization and is indispensable to its operations.

In a modern, highly complex, and interconnected business environment, information is increasingly exposed to a growing number of threats and vulnerabilities from various sources, including human activities, natural disasters, accidents, and more.

To protect against cyberattacks on aircraft equipment, aviation companies and aircraft manufacturers must implement a range of measures, including:

1. Strengthening Cybersecurity Systems: This involves implementing the latest security measures and technologies to preserve the security of aircraft systems.
2. Monitoring Network Activities: This includes regularly monitoring network activities to detect unusual or suspicious events.
3. Fundamental Information Protection: This involves classifying and encrypting sensitive data to prevent unauthorized access.

4. Staff Training: This is about educating pilots and technical personnel on cybersecurity and helping them recognize suspicious activities.
5. Regular System Updates: It is essential to keep avionics software and systems up-to-date to address vulnerabilities.

Cybersecurity in the aviation industry is paramount for ensuring passenger safety and the proper functioning of aircraft.

n many cases, information systems lack sufficient security measures during the design process. While certain technical means (software and hardware) for system protection are often applied, these measures are inadequate given the current conditions of system application. To achieve the required level of information system security, effective and efficient management is necessary, involving appropriate organizational and managerial solutions, procedures, and practices.

Although the Air Force has relatively few cybersecurity incidents, the increasing use of modern technology and network connectivity makes such events more likely. The International Civil Aviation Organization (ICAO) has recognized cybersecurity as a priority issue and called on states to commit to addressing it through a resolution. Various steps have been taken to enhance cybersecurity by organizations, including national regulators such as the FAA and EUROCONTROL. However, the aviation industry still has a long way to go to catch up with other industries in terms of adopting interconnected systems [5].

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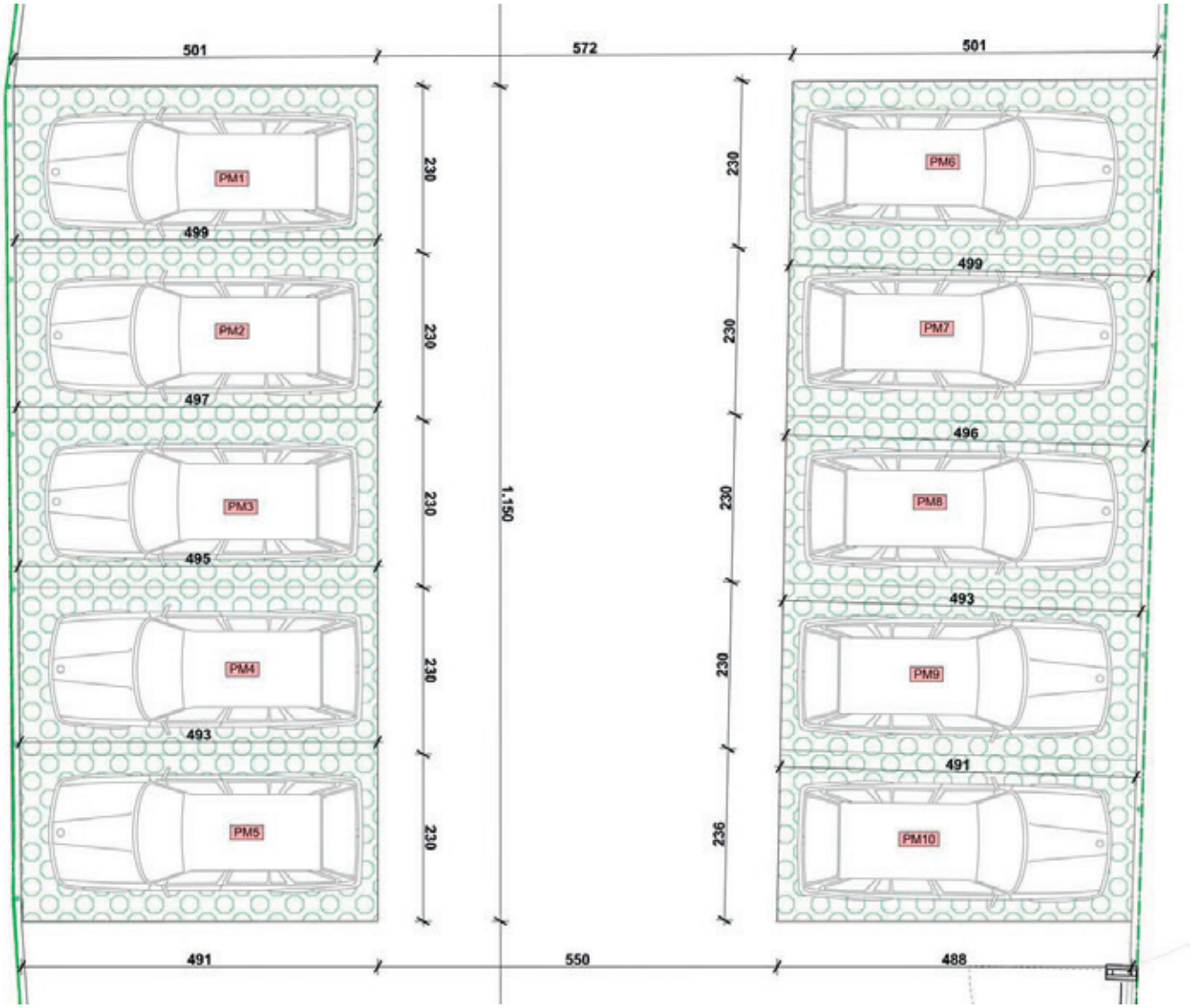

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