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RAILWAY TRAFFIC MANAGEMENT AS A FUNCTION OF THE NEW INFRASTRUCTURE MANAGER

ABSTRACT

This article offers a survey of the current decentralised form of railway traffic management within the public railway infrastructure in the The Republic of Slovenia, which is the result of out-of-date and worn-out safety installations of railway stations and railway lines. The article presents a new model of railway traffic management as the basis for efficient activity and harmonization of railway traffic management in the The Republic of Slovenia to the systems of railway traffic management within EU. This article presents the advantages of a centralised system of railway traffic management and demonstrates that the application of this system can solve the problem of decentralized traffic management as a function of the new infrastructure manager.

KEYWORDS

traffic management, centralization of railway traffic, traffic management centre, railway traffic management model

1. INTRODUCTION

Efficient development of every society (especially the development of its economy) depends on sufficient effectiveness, organization and level of development of its traffic system. The most important goal of sustainable development of the railway traffic system is the reduction of the negative impact on the environment and people. In order to take advantage of all the potentials of railway traffic system and to create good conditions for sustainable development of the economy, effectiveness, competitive position and the quality of the transport system have to be improved.

The railway transport system now has a unique chance to play an important role as a successful, environmentally friendly and energetically adequate factor in the national traffic system. Strong and healthy railway traffic system economics is a condition on which the possibility of offering competitive transport services depends.

Efficient railway traffic management implies that the organization and management of railway traffic have to be developed in a manner that ensures optimal performance of railway passenger and freight traffic and the largest possible exploitation of the existing railway infrastructure considering the criteria of maximum traffic safety. [1]

The need of optimization of railway traffic management and the use of modern IT solutions dictates the development of new railway traffic management systems.

In the past years all the activities connected with railway traffic (including railway traffic management) were joined in one Railway Company. Nowadays, the need for liberalization of the railway transport system has interfered with traditional manner of providing railway transport services. Considering the diverse functions of the transporter and of infrastructure manager, these two functions have to be redefined and boundaries between them have to be set (according to EU directives). The functions of the transporter and infrastructure manager have to be strictly separated.

2. ORGANIZATION OF RAILWAY TRANSPORT SYSTEM IN EU COUNTRIES

According to EU directives the railway traffic systems within EU countries have to ensure free access to railway infrastructure to all the transporters who meet the defined condition; the goal of the principle of free access to railway infrastructure is the introduction of internal railway competition within national railway network.

The most important condition for realization of the former goal is the separation of railway infrastructure from railway service providers. It has to be ac-

knowledged that accountancy separation is obligatory whereas institutional separation is not.

There are four basic forms of organizing railway traffic systems:

- railway traffic systems integrated in the holding organizations; railway traffic system is organized in a holding form, with a dependent company for infrastructure management and a dependent transport company,
- institutionally separated railway traffic systems; railway traffic system is organized in independent, institutionally separated companies, which are not connected in any way.
- unified railway traffic systems; railway traffic system is organized in one company, yet it has separated accountancy for infrastructure management and for transport.
- partly integrated railway traffic systems; railway traffic system is organized in the following manner - the infrastructure manager is represented by an institutionally separated company, who does not execute the maintenance activities themselves - it hires specialized maintenance companies, which are usually railway companies themselves.

Railway traffic system in the Republic of Slovenia is organized as a partly integrated railway traffic system. This type of organization of railway traffic system is rarely found within Europe and is even rarer in other parts of the world. Within this form of railway traffic system there are various systems; the difference is mainly in the transfer of competence and responsibility from the formal infrastructure manager to the performer of maintenance services (authorised manager).

3. RAILWAY TRAFFIC SYSTEM WITHIN EU MEMBERS

Due to the separation of infrastructure and transport part of railway companies within the EU members, the railway traffic management was organized in Traffic management centres; their main tasks are the remote control of the railway traffic, the coordination between traffic management, energetic, maintenance work, traction, distribution of carriages and the supervision of passenger security.

Traffic remote control demands IT solutions for the traffic management itself and for maintaining the control over other functions and instruments which cannot be controlled locally due to unoccupied positions on railway stations.

Traffic remote control makes possible that one operator - section regulator - manages traffic on a defined section of the railway line in extent of several kilometres and several number of stations. This way one worker in Traffic management centre can replace personnel, working in local stations, controlled by section regulator.

4. RAILWAY TRAFFIC MANAGEMENT IN THE REPUBLIC OF SLOVENIA

The function of railway traffic management within public railway infrastructure in the Republic of Slovenia is installed between infrastructure management and transporter; this is a consequence of the fact that this function is performed by the infrastructure manager indirectly through public service.

The function of railway traffic management within public railway infrastructure is performed by authorised manager as a public service within HSŽ for the infrastructure manager (Public agency for railway transport of The Republic of Slovenia)

The function of railway traffic management is multilayered; it contains the processes of work preparation (preparation of technological processes, preparation and coordination of internal and international timetables) and the processes of train traffic execution (according to defined procedures and valid regulations).

The problems of railway traffic management are mainly: different technical equipment of railway lines, different equipment of traffic posts with safety and telecommunication installations and the lack of systems for direct management and control over railway traffic.

The new function of railway traffic management will have to ensure a simple, rational and efficient system of traffic management as well as a system which would be compatible with the railway traffic management functions in comparable EU countries.

The railway traffic management system will have to reach the following objectives:

- larger and more efficient usage of the railway network, enlargement of railway transport share within the transport market,
- automation of train routes setting processes,
- assurance of adequate support for train disposition,
- compatibility with timetable construction systems, energetic systems,
- rational and quality infrastructure maintenance,
- assurance of greater quality of transport services,
- assurance of transparency and simplicity of operations,
- provision of the necessary information to the transporters,
- being as comparable as possible to railway traffic management systems of neighbour countries.

The basic task of railway traffic management is the actual management of railway traffic and shunting work through providing and setting of train routes for trains within the station area and on open railway line between stations. Great emphasis must be placed on the operating safety of train traffic and shunting. Proper train traffic can be ensured only with regular and timely information, relating to the train journey.

Within the public railway infrastructure in the Republic of Slovenia the traffic management is run classically - decentralised railway traffic management (with exception of the Ljubljana - Jesenice line and Divača – Koper line).

The movements inspector within his station manages train traffic and shunting work as well. Train traffic on railway lines is indirectly run by the traffic controller.

4.1 Traffic managed locally – by the movements inspector

Conventional regulation of the train traffic is performed by decentralized railway traffic management. Individual traffic posts are locally occupied by movements inspectors, who regulate train traffic within a defined range on their own accounts. That means that the movements inspector directly manipulates the train route setting on one side and is responsible for traffic disposition within his range on the other side.

The responsibilities of the movements inspector include regular and timely provision of information as well as train route setting in adequate succession and on adequate track, so that the passengers can enter and exit the train safely. On a double track stops the movements inspector has to ensure adequate time for the passengers to enter and exit safely and make sure that train stops on the track closest to passenger facilities.

4.2 Centralized traffic management - by the dispatcher

The movements inspector has to coordinate work within the station mainly from the view of regular train route setting (he has to organize work for composition of trains); his dispatcher has to coordinate the work of movement inspectors in order to optimise train traffic and synchronize the running of trains within his section.

Traffic operative department performs the disposition function for the entire public railway infrastructure at three locations. Traffic operative department carries out control over the traffic performance and orders changes for train traffic management; within which the disposition function of traffic management is already centralised, function of train traffic management, however, is still decentralised (performed of individual occupied traffic posts - on individual stations).

5. PROPOSAL OF A MODEL FOR RAILWAY TRAFFIC MANAGEMENT IN THE REPUBLIC OF SLOVENIA

In order to construct a model we predominantly use combined modelling, thus trying to take advantage of the best qualities of different models. The principal advantage of the mentioned approach is keeping the basic functional connections within the model which ensures easy understanding of model functioning and more flexible use of the model. A model represents the reality (sometimes a simplified version of reality) transferred into graphical and comprehensive form. A model should increase the understanding, explaining, changing or maintaining the characteristics, evolution and perhaps even the management of the system. [3]

A model has to be as simple as possible; we have to acknowledge that the construction of a universal model is impossible, whereas a construction of an over-complex model is impractical and not economical.

5.1 Specifics of the elements of railway traffic management model

The elements of railway traffic management model are:

- railway infrastructure;
- railway traction units and hauled vehicles;
- local traffic management;
- central traffic management;
- systems of traffic management and traffic accompaniment;
- level of security in railway traffic;
- the price of service production in railway traffic;
- legal framework of service production in railway traffic;
- logistic activities of railway transport;
- interoperability of railway system.

5.2 Values of elements of railway traffic management model

It is possible to determine a share of aforementioned elements in railway traffic management model realization, based on hypothetical values of coefficients of model elements. While evaluating the model elements we have to consider their current state and importance in the year 2006 and their estimated values in years 2011 and 2016. The values of individual elements are shown in Table 1 and Graph 1.

Table 1 - Values of elements of railway traffic management model

	Elements of railway traffic management model	Input y_{it}			Increment
		2006	2011	2016	Δy_i,2016
1.	Railway infrastructure	30	50	80	50
2.	Railway traction units and hauled vehicles	30	50	70	40
3.	Local traffic management	80	60	50	- 30
4.	Central traffic management	20	40	80	60
5.	Systems of traffic management and traffic accompaniment	30	50	70	40
6.	Level of security in railway traffic	80	90	95	15
7.	The price of service production in railway traffic	30	25	20	- 10
8.	Legal framework of service production in railway traffic	40	60	80	40
9.	Logistic activities of railway transport	40	60	70	30
10.	Interoperability of railway system	30	50	80	50

5.3. The matrix of growth of the railway traffic management model

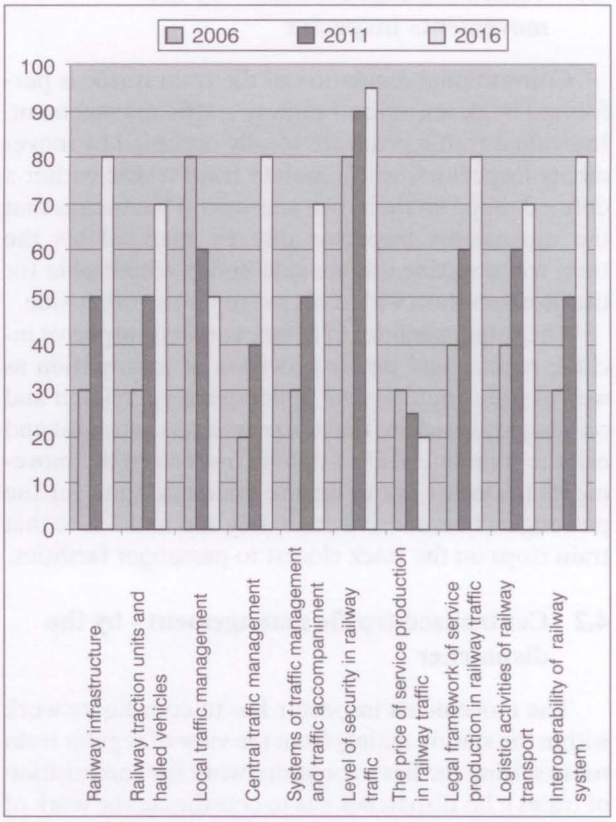
Interactions between the elements of railway traffic management model can be expressed by the matrix of growth, particularly with its direct and indirect values in the period between 2006 and 2016 (The values of growth of the railway traffic management model elements are represented in Table 2).

The elements highlighted in the diagonal of Table 2 represent the direct levels of growth of the railway traffic management model elements. Table 2 shows that the railway infrastructure has grown by 62.5%, railway traction units and hauled vehicles have grown by 57.1%, local traffic management has reduced by 60% during the period between years 2006 and 2016.

The elements outside of the main diagonal represent the indirect levels of growth of the railway traffic management model elements. The elements in the first line (the first element excluded) mark the growth of railway infrastructure according to all the other elements. The elements in the first column (the first element excluded) mark the growth of all the other elements according to railway infrastructure. Similar system of interpretation can be used with all the lines and columns for the remaining elements of railway traffic management model.

Research and evaluation of the elements of railway traffic management model provide direct levels of growth of the railway traffic management model. The direct levels of growth of the railway traffic management model in 2016 are represented in Graph 2.

The presented model can help us with anticipation of indirect levels of growth between the listed elements of railway traffic management. The railway infrastructure will grow by 62.5% between the years 2006 and



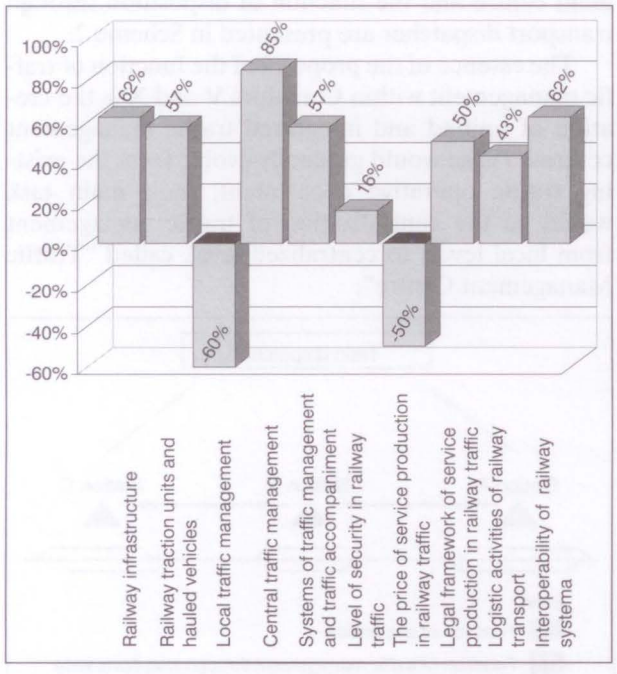
Graph 1 - Elements of railway traffic management model

2016 comparing to other elements, which influence the realization of railway traffic management model.

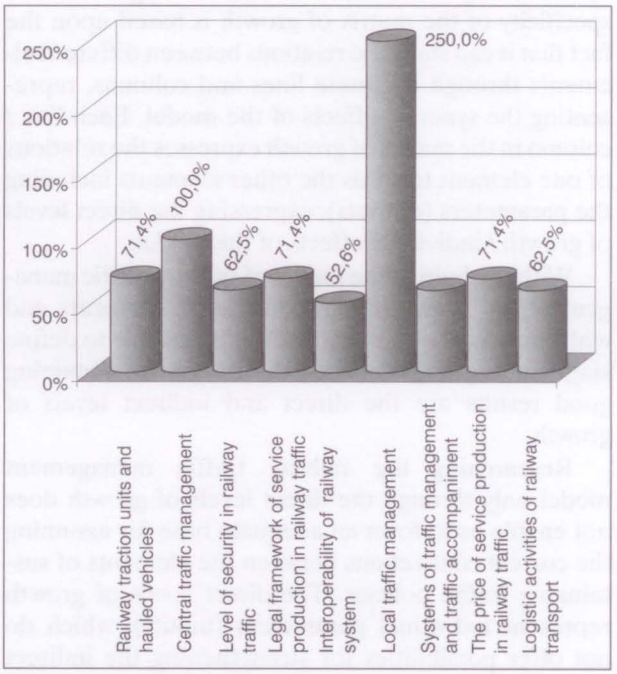
The indirect growth level of railway infrastructure by comparison to railway traction units and hauled vehicles, systems of traffic management and traffic accompaniment and logistic activities of railway transport will amount to 71.4%. The indirect growth level of railway infrastructure by comparison with central traffic management, legal framework of service produc-

Table 2 - Levels of growth of the elements of railway traffic management model (from 2006 to 2016)

	Railway infrastructure	Railway traction units and hauled vehicles	Local traffic management	Central traffic management	Systems of traffic management and traffic accompaniment	Level of security in railway traffic	The price of service production in railway traffic	Legal framework of service production in railway traffic	Logistic activities of railway transport	Interoperability of railway system
Railway infrastructure	62.5%	71.4%	100%	62.5%	71.4%	52.6%	250%	62.5%	71.4%	62.5%
Railway traction units and hauled vehicles	50%	57.1%	80%	50%	57.1%	42.1%	200%	50%	57.1%	50%
Local traffic management	-37.5%	-42.8%	-60%	-37.5%	-42.8%	-63.1%	-150%	-37.5%	-42.8%	-37.5%
Central traffic management	85%	85.7%	120%	85%	85.7%	63.1%	300%	85%	85.7%	85%
Systems of traffic management and traffic accompaniment	50%	57.1%	80%	50%	57.1%	42.1%	200%	50%	57.1%	50%
Level of security in railway traffic	18.5%	21.4%	300%	18.5%	21.4%	15.7%	75%	18.5%	21.4%	18.5%
The price of service production in railway traffic	-12.5%	-14.2%	-20%	-12.5%	-14.2%	-10.5%	-50%	-12.5%	-14.2%	-12.5%
defaultLegal framework of service production in railway traffic	50%	57.1%	80%	50%	57.1%	42.1%	200%	50%	57.1%	50%
Logistic activities of railway transport	37.5%	42.8%	60%	37.5%	42.8%	31.5%	150%	37.5%	42.8%	37.5%
Interoperability of railway system	62.5%	71.4%	100%	62.5%	71.4%	52.6%	250%	62.5%	71.4%	62.5%



Graph 2 - Direct levels of growth of railway traffic management model



Graph 3 - Indirect levels of growth of railway infrastructure according to other elements of railway traffic management model

tion in railway traffic and interoperability of railway system will amount to 62.5%. The indirect growth level of railway infrastructure by comparison with local traffic management will amount to 100%; by comparison with the price of service production in railway traffic it will amount to 52.6%; by comparison with the price of service production in railway traffic it will amount to 250%. Indirect growth levels of railway infrastructure by comparison with other listed elements of railway traffic management model are presented in Graph 3.

5.4 Influence of the model of railway traffic management on efficient and rational railway traffic management

Through the model based on the matrix of growth the traffic management systems can be formed and movements of railway traffic management can be estimated according to different assumptions and also independently of past / present interactions between the elements or their changes through the development plan.

The model of railway traffic management, based on the matrix of growth, has multi purpose effects. The matrix of growth treats the structural relations between elements in a specific manner; it enables us to include all the relations within sustainable traffic policy simultaneously. The elements of railway traffic management model are usually independent of each other, therefore, their movements must be observed by simulating direct and indirect levels of growth. The specificity of the matrix of growth is based upon the fact that it can show the relations between different elements through adequate lines and columns, representing the synergic effects of the model. Each line / column in the matrix of growth expresses the relations of one element towards the other elements including the parameters (outputs), expressing the direct levels of growth / individual effects of the model.

With the help of the model of railway traffic management, by evaluating its constitutive elements and with analysis of obtained results it is possible to define single and synergic effects; the reason for obtaining good results are the direct and indirect levels of growth.

Researching the railway traffic management model only through the direct levels of growth does not enable us to form an adequate base for assuming the correct connections between the elements of sustainable traffic policies. The direct levels of growth represent individual parameters (inputs), which do not offer possibilities for strengthening the indirect levels of growth or restoring the independence of movement. The presented model introduces a new theoretical approach, comprising relative changes of the elements and connects the elements of railway traffic management in integral dynamic system for providing the services of railway traffic management.

The presented model of railway transport management would represent a good foundation for a rationalization of the system of railway traffic management in the Republic of Slovenia.

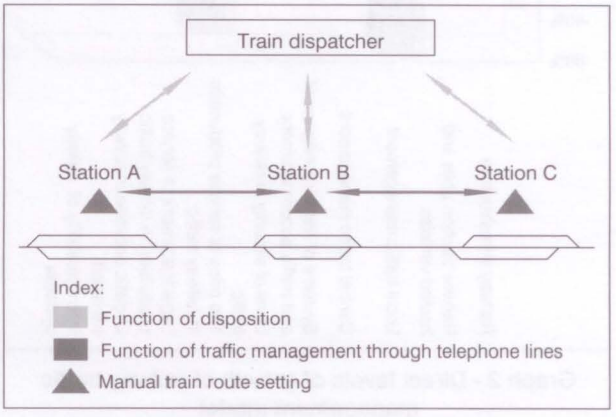
6. NEW FUNCTION OF RAILWAY TRAFFIC MANAGEMENT IN THE REPUBLIC OF SLOVENIA

Scheme 1 presents the decentralised system of railway traffic management operated by the movements inspectors on locally occupied stations and operating the function of disposition through train dispatchers.

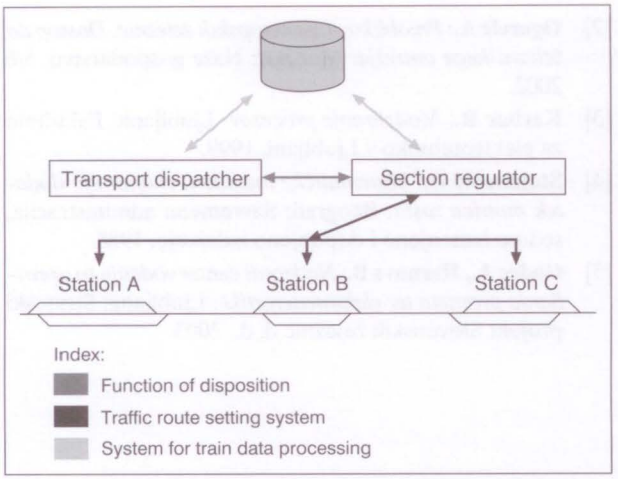
The duties of the movement inspectors and dispatchers in conventional traffic management are taken over by the section regulators in regional traffic management centres and local movement inspectors located in occupied stations. Transport dispatcher has the possibility of disposing the traffic in a larger control range than the section regulator. Unlike the dispatcher performing conventional train surveillance; the transport dispatcher can intervene at the process level of traffic route setting. His disposition decisions can be directly transformed into commands for subsequent traffic route setting; yet, he does not have the possibility to interfere with the security level of the signal box.

The centralised system of railway traffic management through section regulators in traffic management centre and the function of disposition through transport dispatcher are presented in Scheme 2.

The essence of the proposal of the function of traffic management within Corridors V and X is the creation of unified and integrated traffic management centres. These would gradually evolve from the existing traffic operative department; their main task would be the centralization of traffic management from local levels to centralized level, called "Traffic Management Centre".



Scheme 1 - Decentralised system of railway traffic management



Scheme 2 - Centralised system of railway traffic management

7. CONCLUSION

In order to improve the railway traffic system it is important to offer quick, frequent and reliable connections. Crucial for achieving the best competitive position is the possibility to assure higher travelling speed, larger number of trains and provision of traffic routes to a large number of transporters.

The article tries to indicate some possibilities about the response of the railway traffic management function in the Republic of Slovenia to the issues of railway traffic systems restructuring (particularly about separation of infrastructure and traffic management on one hand and individual transporters on the other).

The matrix model of growth offers a possibility to include all the relations within railway traffic management model system at the same time. The elements of railway traffic management model are independent as a rule; their movements have to be observed as a simulation through direct and indirect levels of growth. With the help of the matrix of growth it is possible to observe relations between different elements through adequate lines and columns, representing the synergic effects of the model. Every line / column of the matrix of growth expresses a relation of the element with other elements, including the parameters (outputs), which express the direct levels of growth or separate model effects.

With the help of the model of railway traffic management, by evaluating its constitutive elements and with analysis of obtained results it is possible to define single and synergic effects; the reason for obtaining good results are the direct and indirect levels of growth.

A research of railway traffic management growth based on direct levels of growth is not adequately grounded to accurately connect different elements of railway traffic management. Direct levels of growth represent independent parameters (inputs), which do not offer possibilities for strengthening indirect levels of growth or possibilities for restoring independent movements. Introducing indirect levels of growth of railway traffic management or matrix of growth fulfils an important part of research in railway traffic management theory.

With the help of presented model of railway traffic management, the system of railway traffic management in the Republic of Slovenia could be rationalized. In the period from 2006 to 2016 the railway infrastructure would grow by 62.5%, railway traction units and hauled vehicles by 57.1%, local traffic management would decrease by 60%, central traffic management would grow by 85%, system of traffic management and accompaniment would grow by 57.1%, level of security in railway traffic would grow by 15.7%, the price of service production in railway traffic would decrease by 50%, the legal framework of service production in railway traffic would grow by 50%, logistic activities by 42.8% and interoperability of railway system would grow by 62.5% if the railway traffic management model was implemented.

This article describes justifications of the new function of railway traffic management in the sense of centralizing local traffic management through traffic management centres. According to the present and the future needs this is the only way to achieve the most flexible, real-time traffic management with very short time responses to outer impulses.

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POVZETEK

VODENJE ŽELEZNIŠKEGA PROMETA V FUNKCIJI NOVEGA UPRAVLJAVCA INFRASTRUKTURE

Članek podaja pregled današnje decentralizirane oblike vodenja železniškega prometa na javni železniški infrastrukturi v Republiki Sloveniji, ki je posledica zastarele in dotrajane opremljenosti postaj in prog s signalnovarnostnimi napravami.

V članku je predstavljen novi model vodenja železniškega prometa kot osnova za učinkovito delovanje in prilagajanje vodenja železniškega prometa v Sloveniji sistemom vodenja prometa v državah Evropske unije.

Članek podaja prednosti, ki jih dosega centraliziran sistem vodenja železniškega prometa ter dokazuje, da se z uporabo predlaganega modela lahko reši problem decentraliziranega vodenja prometa v funkciji novega upravljavca infrastrukture.

KLJUČNE BESEDE

vodenje prometa, centralizacija železniškega prometa, center vodenja prometa, model vodenja železniškega prometa

LITERATURE

[1] *Izboljšanje tehnike upravljanja železniškega prometnega podsistema ob upoštevanju kriterija nezmanjšane prometne varnosti*, zaključno poročilo. Maribor: Univerza v Mariboru, 2005.

[2] **Ogorelc A.**: *Preoblikovanje evropskih železnic. Dostop do železniškega omrežja.* Maribor: Naše gospodarstvo, 5/6 2002.

[3] **Karbar R.**: *Modeliranje procesov*. Ljubljana: Fakulteta za elektrotehniko v Ljubljani, 1999.

[4] **Stojanović D.**: *Matematičke metode u ekonomiji, dodatek matrica rasta*. Beograd: Savremena administracija, sedmo izmenjeno i dopunjeno izdajanje, 1988.

[5] **Godec A., Hernavs B.**: *Nadzorni center vodenja in upravljanja prometa ter elektroenergetike*. Ljubljana: Strateški projekt Slovenskih železnic d. d., 2003.