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Prognostic trend model of passenger transport performance of the Croatian maritime traffic system

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SUMMARY

This research analyses the dynamics and the modelling trend of the development of passenger transport performance of the Croatian maritime traffic system. Passenger transport performance represents a transport value which is, regarding its characteristic, a qualitative transport demand indicator in public passenger traffic, and expressed by the realized passenger transport operation in public maritime passenger traffic. Adequate mathematical statistic analysis of passenger transport performance has been performed at the level of maritime traffic system, forming in turn a mathematical prognostic trend model of the development dynamics of this traffic value. The prognostic trend model of the passenger transport performance is presented by a respective equation, with the calculation of the related determination coefficient as a measure of quality which determines the level of statistical significance of the description of the given data using the model equation. The law of development of the studied transport value during the considered time period is described by the computer calculated obtained model equation. During research, the scientific methods of mathematical statistics, modelling methods, and computer software «Microsoft Excel» have been used.

***Key words**: dynamics, model, maritime traffic system, prognosis, passenger transport performance, development, trend.*

1. INTRODUCTION

The study of the development of the traffic system, as well as its subsystems in the increasingly dynamic economic environment, especially regarding the strong connection between the economic and transport development represents an important object of the scientific research interest and work [1]. The traffic demand has a crucial significance in determining and managing the traffic policy, determining the development level of the traffic system, as well as the level of its usage, primarily its technical stratum i.e. the traffic infrastructure and transport means [2].

The set problem of this research consists in studying the dynamics and the possibility of forming a mathematical prognostic model of the passenger transport performance of the maritime traffic system, as a subsystem of the national traffic system.

The research objective consists in determining the possible laws according to which passenger transport performance expressed by the realized passenger transport operation in public passenger transit (pkm, i.e. passenger kilometers) assumes its values in the function of time.

Based on the research problem the research object has been defined: *to study the passenger transport performance of the Croatian maritime traffic system with the aim of forming a suitable mathematical prognostic trend model*.

The basic scientific hypothesis has been set: *based on the performed research it is possible to determine scientifically the existence of the laws in the studied transport value, and to form its mathematical prognostic trend model*.

The need to set this hypothesis results from the definition of the traffic system as a complex dynamic system, which is liable to the laws and axioms according to the general system management theory, requiring for the management of the traffic system and its subsystems the implementation of the mathematical theory for designing mathematical models of concrete problems in the area of traffic and transport technology [3]. Traffic demand is of stochastic character so that mathematical modelling requires the usage of the mathematical statistic method and the probability theory, with determining the development trend of the traffic value. The trend represents the development tendency of the traffic value in time and is represented by the function of time.

The implementation of the results of this work is reflected in the following:

– the application value of this research consists also in using the results of studying this traffic value to form the theoretical development model of the passenger transport performance, i.e. to formulate the functional law which defines the tendency of change and the direction of the development process of this traffic value within the traffic system;
– the research results on the established law of the traffic value, as well as the formed mathematical model represent the means and aid in decision-making regarding the development and management of the traffic system development process, especially regarding the transport demand management using ITS (Intelligent Transport Systems).

The mathematical model is defined as a mathematical expression in which variables represent the elements of the process or system which is being studied, links between the elements or the processes, and the laws are described by mathematical relations and operators [4].

The work provides analytic modelling of the passenger transport performance, in which the model is in analytical form (e.g. equation systems). It can be also claimed that these are stochastic models (whose behaviour cannot be predicted in advance), so that the probabilities of the changes in the system are determined (the determination coefficient value).

Transport modelling has a significant role in all more complex decision-making processes, and especially in transport development modelling. Regarding the dynamic characteristic of the changes in economic and traffic system, analytical methods are preferable for the traffic analysis, since they detect the changes in shorter time periods, so that the object and results of research and modelling are better oriented, see Ref. [5] pages 47-107.

2. DYNAMICS OF PASSENGER TRANSPORT PERFORMANCE OF THE CROATIAN MARITIME TRAFFIC SYSTEM

By analysing a relatively longer time period, e.g. from 1992 to 2002, it is possible to obtain knowledge about the longer-term dynamic trend of the passenger transport performance of the Croatian traffic system as well as the maritime subsystem. Further on, the dynamics of passenger transport demand starting from 1992 to 2002 with cross-sections for 1995 and 1998 has been given in this work, Tables 1 and 2.

Table 1 Development dynamics of the passenger transport performance of the maritime subsystem and the traffic system of the Republic of Croatia in the time period 1992-2002 [6, 7]

YEAR	*MARITIME SUBSYSTEM*	*TRAFFIC SYSTEM*
1992	*261*	*5118*
1995	*280*	*5719*
1998	*283*	*5963*
2002	*389*	*6168*

NOTE: Data refer to the number of passenger kilometers in millions

Table 2 Share of maritime subsystem in passenger transport performance of the Croatian traffic system in 1992 and 2002 [6, 7]

YEAR	*1992*		*2002*	
MARITIME SUBSYSTEM	*261*	*5.10%*	*389*	*6.31%*
TRAFFIC SYSTEM	*5118*	*100.00%*	*6168*	*100.00%*

In accordance with the data from Tables 1 and 2, in the studied time period it is possible to conclude that there is an increase in the passenger transport performance of *49 %* of the maritime traffic system with the average annual change rate of *4.07 %*, as well as an increase in the passenger transport performance of *20.5 %* of the Croatian traffic system, with an average annual positive change rate of *1.88 %*.

In accordance with the faster increase in the passenger transport performance of the maritime traffic subsystem as compared with the overall Croatian traffic system, the relative share of the maritime subsystem in the structure of the overall transport performance is also increased. Within the considered ten-year time period the share of maritime traffic system increased by *1.2 %*.

The aforementioned leads to the conclusion that the increase in the passenger transport performance of the maritime traffic subsystem is more dynamic than at the level of the national traffic system.

3. PROGNOSTIC TREND MODEL OF PASSENGER TRANSPORT PERFORMANCE OF THE MARITIME TRAFFIC SYSTEM

The work further provides a graphical presentation and makes a mathematical statistic analysis of the traffic values given in Table 3 during the studied eight-year time period from 1998 to 2005.

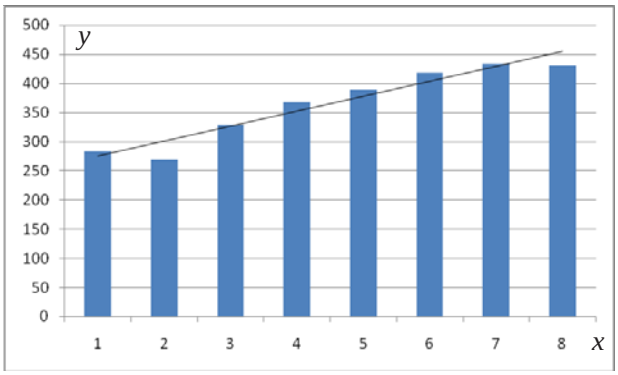
The prognostic trend model of the development dynamics of the passenger transport performance of the Croatian maritime traffic system has been described by an equation of a linear trend. The coefficients of the model have been calculated by means of the computer program «Microsoft Excel» and together with the determination coefficient R^2 and the trend equation graph are presented in Graph 1. The determination coefficient R^2 is used to measure the connection strength of the considered variable in the mathematical model and the time.

If the connection is functional the value of the determination coefficient $R^2=1$, and the closer R^2 to this value, the stronger the connection, see Ref. [8] pages 125-131. When the value of the determination coefficient R^2 is greater than *0.77* it may be concluded that the determined mathematical model of the prognostic trend of the studied variable is statistically significant, see Ref. [8] pages 406-407.

Relevant diagnostic model is also made. ANOVA table for regression model is made and calculated *F* value is *74.43*, with significance *0.00013*, which means that the model of regression is siginificant. *T*-tests for significance of coefficients of regression model are also made and calculated *P*-values are less than *0.05* (*P*-values are $2{,}96\cdot10^{-6}$ and *0.00013* for intercept and slope coefficient, respectively) that shows their significance, see Ref. [9] pages 335-353.

The second model has been made on the basis of the data from the period 1998-2005. It is noteworthy that based on this model, the predicted passenger transport performance in maritime traffic in 2003 amounted to *420.2* million pkm (pkm = passenger kilometers), and the actually realized passenger transport performance in 2003 amounted to *418* million pkm, which means that the error in prediction amounts to *0.53 %*. For 2004 the error is greater and amounts to *4.20 %* which continues to be in accordance with the expectations.

Graph 1. Dynamics of passenger transport performance of the Croatian maritime traffic system in the period from 1998 to 2005 and the prognostic model graph. The equation of linear trend is y=25.57x+249.6, where y is the transport performance of the Croatian maritime traffic system (expressed in millions of pkm), and x represents the years, x=1 for 1998 upto x=8 for 2005. The determination coefficient is $R^2=0.925$.



According to the carried out mathematical statistic analyses of the studied values from Table 3 over the time period from 1998 to 2005, a statistically significant ($p<0.05$) mathematical prognostic trend model has been determined for the passenger transport performance of the Croatian maritime traffic system, see Ref. [8] pages 406-407.

4. OSCILLATIONS OF PASSENGER TRANSPORT PERFORMANCE OF MARITIME TRAFFIC SYSTEM

Regarding the available data about the passenger transport performance, i.e. realized passenger transport operation according to the statistical information provided by the State Bureau of Statistics of the Republic of Croatia [10-12], it is possible to give an overview of its oscillations during the year (Table 4).

Table 3 Development dynamics of the passenger transport performance of the Croatian maritime traffic system in the time period from 1998 to 2005 [6, 7]

MARITIME TRAFFIC SYSTEM	***PASSENGER KILOMETERS - PKM (in millions)***							
	1998	***1999***	***2000***	***2001***	***2002***	***2003***	***2004***	***2005***
Passenger transport performance	*283*	*269*	*328*	*367*	*389*	*418*	*433*	*431*
Relative share of maritime system in satisfying the total passenger transport performance	*4.7%*	*5.0%*	*5.8%*	*6.1%*	*6.3%*	*6.4%*	*6.7%*	*6.1%*

Table 4 Quarterly oscillations of passenger transport performance of the Croatian traffic system

Quarter	*2003*		*2004*		*2005*	
I-III.	*40*	*9.57%*	*44*	*10.16%*	*52*	*12.06%*
IV-VI.	*104*	*24.88%*	*100*	*23.09%*	*100*	*23.20%*
VII-IX.	*219*	*52.39%*	*230*	*53.12%*	*217*	*50.35%*
X-XII.	*55*	*13.16%*	*59*	*13.63%*	*62*	*14.39%*
TOTAL	*418*	*100.00%*	*433*	*100.00%*	*431*	*100.00%*

According to data from Table 4, it is clear that during the third quarter (July, August, and September) about *52 %* of passenger transport operation, i.e. passenger transport performance of the Croatian maritime traffic system, is realized, and during the second quarter about *24 %* of the total passenger transport performance is accounted for on the average, which combined in these periods of the year account on the average for about *76 %* of the overall transport performance. There is obvious connection between the share of the passenger transport performance of the Croatian traffic system with the duration of the tourist season.

5. CONCLUSION

The found mathematical prognostic trend model represents a scientifically founded basis in predicting the passenger transport performance in the Croatian traffic system in the future. The dynamics of the passenger transport performance in the Croatian traffic system within the studied time period is characterized by the increase in the passenger transport performance with an average annual positive change rate of *4.07 %* of the maritime traffic subsystem, whereas for the national traffic system it amounts to *1.88 %*.

Within the structure of the total passenger transport performance of the Croatian traffic system, the maritime subsystem has increased its relative share by *1.2 %*. During the third quarter (July, August, and September) in the year, about *52 %* of passenger transport performance of the Croatian maritime traffic system is realized.

The mathematical statistical analysis of data regarding the realized passenger transport operation in the time period from 1998 to 2005 has determined a statistically significant ($p<0.05$) trend model for the maritime traffic system of the Republic of Croatia.

6. LITERATURE

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MODEL RAZVITKA PUTNIČKOGA PRIJEVOZNOG UČINKA HRVATSKOGA POMORSKOG PROMETNOG SUSTAVA

SAŽETAK

Ovim se istraživanjem izučava dinamika i mogućnosti modeliranja razvitka putničkoga prijevoznog učinka pomorskoga prometnog sustava Republike Hrvatske. Izučavana prometna veličina po svom je obilježju kvalitatitvni pokazatelj prijevozne potražnje u javnom putničkom prometu, a koja se iskazuje izvršenim putničkim transportnim radom u javnom pomorskom putničkom prometu. Primjenjuje se odgovarajuća matematičko-statistička analiza putničkoga prijevoznog učinka na razini pomorskoga prometnog sustava, te je potom oblikovan matematički prognostički trend model dinamike razvitka ove prometne veličine. Model izučavane prometne velične predstavljen je odgovarajućom jednadžbom, uz izračun pripadajućeg koeficijenta determinacije kao mjerom kvalitete koja utvrđuje razinu statističke signifikantnosti opisa zadanih podataka pomoću jednadžbe modela. Jednadžba modela opisuje zakonitost razvitka izučavane prometne veličine tijekom promatranoga vremenskog razdoblja. Pri istraživanju i formuliranju rezultata istraživanja posebice su korištene znanstvene metode matematičke statistike, metode modeliranja, odnosno računalni program «Microsoft Excel».

***Ključne riječi**: dinamika, model, pomorski prometni sustav, prognoza, putnički prijevozni učinak, razvitak, trend.*