

Development of Trend Model of the Passenger Demand for Public Bus Transport

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Abstract—The subject matter and research problem of this paper is the study of the development dynamics and trend of the passenger transportation demand in the City of Zagreb public bus transport system. The purpose of the study is to scientifically establish the possibility for applying mathematical forecasting models in management and optimization of the transport process. The aim of the study is forecasting of passenger demand in the public passenger transport system for purposes of the transport operator management. The transport parameter studied here is expressed by the number of passengers carried in the City of Zagreb public bus passenger transport system that is operated by the public transport operator Zagrebački Holding d.o.o. Division Zagreb Electrical Tram. In accordance with the aim of the research, the following hypothesis has been put forward: in forecasting the passenger transportation demand it is possible to apply scientifically proven single-variable mathematical forecasting trend models. The hypothesis has been confirmed. A mathematical forecasting model has been designed that allows us to quantify, i.e. forecast the future passenger demand for transport services. Such transport demand trend model is exceptionally useful to the management of the public passenger transport operator as it allows it to plan, organize and manage its operations. The transport parameter model is represented by a corresponding equation with the respective coefficient of determination. The coefficient of determination is a measure of quality that denotes the level of statistical significance of the description of set data by means of a model equation. The model equation describes the development regularity of the studied transport parameter during the observed period 2004-2008. In creating the model variants, the following scientific methods were used: mathematical statistics, modelling, and the Microsoft Excel computer software.

Index Terms—Trend forecasting model, passenger transportation demand, public bus passenger transport

I. INTRODUCTION

Public passenger transport is a fundamental prerequisite for the functioning of urban agglomerations

as it guarantees the normal functioning of the society and economic development. Public passenger transport can be defined as an organized system of passenger transport that includes transport services within an urban agglomeration, as well as transport services between the city proper and the suburban areas with the majority of passengers using the public transport routes and lines on a daily basis or during workdays. The study of the development dynamics of the passenger transportation demand on a specific territory in a specific period of time and development of forecasting trend models for such demand are significant scientific research tools in the field of traffic and transport technology. The research problem of this study consists in examining the dynamics and the possibility for developing a mathematical forecasting model for the passenger transportation demand within the public bus transport system, a subsystem of the City of Zagreb public passenger transport system. The aim of the study is to examine the various forecasting trend models and to establish regularities, if any, according to which passenger transportation demand acquires its values in a function of time. The subject matter of research is defined as the basic research problem: to examine the transport demand in the City of Zagreb public bus transport system with the aim to develop a mathematical forecasting trend model for the passenger transportation demand in the transport system operated by Zagrebački Holding d.o.o. Division Zagreb Electrical Tram, the public transport operator of the City of Zagreb. The main scientific hypothesis has been put forward as follows: based on the conducted research, it is possible to scientifically establish a regularity of the studied transport parameter for the City of Zagreb public passenger transport system and to develop a mathematical forecasting trend model for the transport demand within the public passenger transport system. The research findings provide the decision makers responsible for the future development of the transport system in the studied territory with scientifically based information on the regularities of processes within the system. The applied value of this research also consists in developing, on the basis of research findings for the passenger transportation demand, a theoretical

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transport demand development model, i.e. in formulating a functional law that defines the change trend and orientation of the transport parameters development process within the transport system. The research findings on the studied parameter, the established regularities, and the developed mathematical models represent means and tools that will help in making decisions on the public transport system development and the management of development process.

II. TRANSPORT MODELLING

Transport demand plays a crucial role in defining and implementing the transport policy, it determines the level of development of the transport system as well as the utilization level, notably of its technological stratum, i.e. the traffic infrastructure and the transport units [1]. The findings about the development dynamics of passenger demand and its potential regularities, i.e. the development trends in transport systems, represent a scientifically proven basis for defining the overall work organization and the required transport capacities, as well as a basis for making strategic decisions on the further development of the public passenger transport system. The need for putting forward the mentioned hypothesis arises from the definition of the transport system which is identified as a complex, dynamic system that is subject to specific regularities according to the general system management theory. The management of the transport system and its subsystems requires the use of a mathematical theory of model development for concrete problems in the field of traffic and transport technology. Transport demand being of stochastic nature, mathematical modelling must apply methods of mathematical statistic and probability theories along with determining the development trend of transport parameters. The trend means a development tendency of a transport parameter in time and is represented as a function of time. Mathematical models and optimization methods in the transport system represent the use of quantitative methods aimed at solving complex problems of the transport system. As regards the applied method, analytical modelling of passenger transportation demand was used with models in analytical form (equation system), which is why solutions are also given in analytical form. Also, the models used are stochastic in nature (their behaviour cannot be foreseen), and, therefore, the probability of system status change is determined (value of the coefficient of determination). Transport modelling has a significant role in all complex decision-making processes, especially so in the modelling of transport development. Considering the dynamism of changes in the economic and transport systems, the preferred methods of transport analysis are the analytical methods that allow the detection of changes in shorter periods of time, resulting in better orientation of the subject matter and research and modelling results [2]-[5]. When analysing modelling in transport, notably development and application of transport demand models, among the relevant transport parameters in passenger transport Jovanović also mentions the number of passengers carried [5].

III. DEVELOPMENT OF A FORECASTING TREND MODEL FOR PASSENGER TRANSPORTATION DEMAND

Following is a graphical presentation and mathematical-statistical analysis of the passenger transportation demand as expressed in the number of passengers carried based of the fare sold by the operator.

TABLE I. NUMBER OF PASSENGERS CARRIED IN THE PUBLIC BUS TRANSPORT SYSTEM IN THE CITY OF ZAGREB FOR THE PERIOD 2004-2008 – OPERATOR ZAGREBAČKI HOLDING D.O.O. DIVISION ZAGREB ELECTRICAL TRAM

Year	No. of passengers carried (in '000)
2004	79,705
2005	80,421
2006	85,111
2007	99,739
2008	94,061

Source: Zagrebački Holding d.o.o. Division Zagreb Electrical Tram - Development and Operation Figures, June 2009

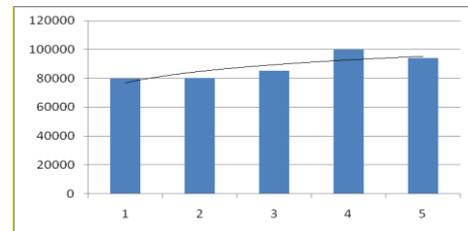


Figure 1. Logarithmic model of passenger transportation demand in the public bus transport system in the City of Zagreb for the period 2004-2008 (x = 1 for 2004) Source: Table 1

$$y = 11466 \ln(x) + 76829 \quad (1)$$

$$R^2 = 0.69 \quad (2)$$

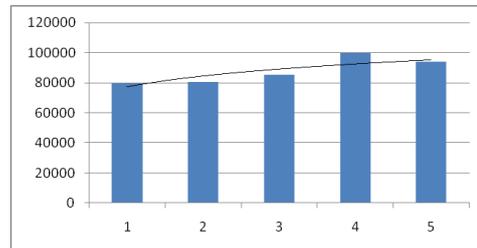


Figure 2. Double logarithmic model of passenger transportation demand in the public bus transport system Source: Table 1

$$y = 77180x^{0.13} \quad (3)$$

$$R^2 = 0.69 \quad (4)$$

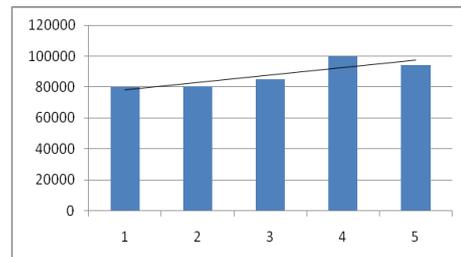


Figure 3. Linear model of passenger transportation demand in the public bus transport system Source: Table 1

$$y = 4803x + 73398 \quad (5)$$

$$R^2 = 0.75 \quad (6)$$

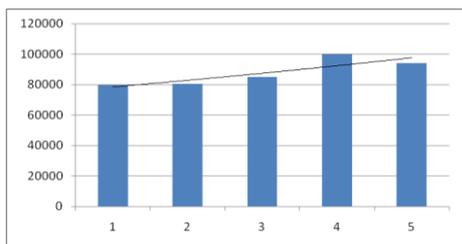


Figure 4. Exponential model of passenger transportation demand in the public bus transport system Source: Table 1

$$y = 74237e^{0.054x} \quad (7)$$

$$R^2 = 0.77 \quad (8)$$

The forecasting trend model for the development dynamics of individual transport parameters has been obtained with the aid of the computer program Microsoft Excel. The trend model has been developed using the trend equation and the coefficient of determination (R^2). The trend model graph is shown in the diagram. The coefficient of determination (R^2) denotes the strength of association between the observed variable in the mathematical model and time. If this association is functional, the coefficient of determination has a value of $R^2 = 1$, and the closer R^2 comes to this value, the stronger the association [3]. When the coefficient of determination R^2 has a value exceeding 0.77, it means that the developed mathematical model for the forecasting trend of the studied variable is statistically significant ($p < 0.05$) [4].

IV. DISCUSSION

In accordance with the performed mathematical-statistical analyses of the passenger transportation demand in the public bus transport system for the stated period of time, the exponential trend model has been found to be statistically significant ($p < 0.05$).

TABLE II. TREND MODELS FOR PASSENGER TRANSPORTATION DEMAND IN THE PUBLIC BUS TRANSPORT SYSTEM IN THE CITY OF ZAGREB FOR THE PERIOD 2004-2008 – OPERATOR ZAGREBAČKI HOLDING D.O.O. DIVISION ZAGREB ELECTRICAL TRAM.

Forecasting trend model	Model equation	Coefficient of determination
Logarithmic model	$y = 11466 \ln(x) + 76829$	$R^2 = 0.69$
Double logarithmic model	$y = 77180x^{0.13}$	$R^2 = 0.69$
Linear model	$y = 4803x + 73398$	$R^2 = 0.75$
Exponential model	$y = 74237e^{0.054x}$	$R^2 = 0.77$

Source: Figure 1 ; 2 ; 3 and 4

Of the other forecasting trend models used in this analysis, the logarithmic model with $R^2=0.69$ has been found to be the least suitable with regard to the value of the coefficient of determination. Pursuant to the mathematical-statistical analysis, the exponential forecasting trend model is the most acceptable and is the only one to meet the criterion of statistical significance.

From this it follows that a scientifically valid forecast of the passenger transportation demand in the City of Zagreb public bus transport system (Figure 4) can be obtained using the exponential forecasting trend model of passenger transportation demand, as it has the highest value of the coefficient of determination $R^2 = 0.77$.

V. CONCLUSIONS

The development dynamics of passenger transportation demand in the City of Zagreb public transport system in the period of time under observation is characterized by the following: an increase in the passenger transportation demand with an average annual positive rate of change of 4.2% in the public bus transport system, i.e. an increase in the number of passengers carried in 2008 by approx. 18% in comparison to 2004.

The society has a vast interest in an increasing development (quantitative and qualitative) of the public passenger transport system, partly also because of the effects of such development that are expressed in a more intensive development of economy and an increase in the social labour productivity.

Pursuant to the development goals of this sector, which consist in developing a modern, efficient and quality urban passenger transport system, it is highly important to create mathematical forecasting trend models of the passenger transportation demand. Such models can be successfully used as a valid basis for making strategic decisions that will lead to improvement and optimization of the public passenger transport system.

The developed mathematical exponential forecasting trend model represents a scientifically proven basis for projecting the passenger transportation demand in the City of Zagreb public transport system in the coming period.

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