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DEVELOPMENT OF BUS TRANSPORT SYSTEM MODELLING IN THE CITY OF ZAGREB

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Preliminary notes
The research objective of this paper is the study of the development dynamics of the public urban bus passenger transport system of the City of Zagreb, referring to a 16-year period of time from 1995 to 2010. The purpose of this work and the carried out analysis of the studied values that refer to passenger transport demand and supply, quality of transport service as well as the level of the life standard of the public urban transport system users, serves to create a valid basis for decision-making relating to the traffic process management at a strategic level and planning of further development of the urban passenger transport system. In accordance with the mentioned purpose the research objective has been set and it refers to the establishing of legality of the transport process using the methods of analysis and synthesis, modelling, and adequate mathematical and statistical methods. The objectives of this paper refer to establishing the statistical significance of prognostic trend models of the studied variables, connection between the development dynamics of the passenger transport demand and the development dynamics of individual traffic supply variables as well as the level of life standard of the urban passenger transport users, and the design of the model of single and multiple linear regression in order to determine the legality of the transport process. According to the results of this research it may be concluded that during the observed period there is no harmonisation of the development dynamics of the traffic values related to the transport supply and the quality of the transport service of the bus transport system with the existing development dynamics of the passenger transport demand.

Keywords: *bus transport system, development, modelling, public urban passenger transport*

Modeliranje razvitka autobusnoga transportnog sustava Grada Zagreba

Prethodno priopćenje
Predmet istraživanja ovog rada jeste izučavanje dinamike razvitka sustava autobusnoga javnog gradskog putničkog transporta Grada Zagreba, a odnosi se na 16 godišnje vremensko razdoblje od 1995. do 2010. godine. Svrha ovoga rada i provedene analize izučavanih veličina koje se odnose na putničku transportnu potražnju i ponudu, kvalitetu transportne usluge kao i razinu životnog standarda korisnika usluga sustava javnog gradskog transporta sastoji se u stvaranju validne osnove za donošenje odluka vezanih za upravljanje prometnim procesom na strateškoj razini i planiranjem daljnjeg razvitka sustava javnoga gradskog putničkog transporta. Sukladno navedenoj svrsi postavljen je i cilj istraživanja koji se odnosi na ustanovljavanje zakonomjernosti prometnog procesa uz korištenje metoda: analize i sinteze, modeliranja i odgovarajućih matematičko statističkih metoda. Ciljevi ovog rada odnose se na ustanovljavanje statističke značajnosti prognostičkih trend modela izučavanih varijabli, povezanosti između dinamike razvitka putničke transportne potražnje i dinamike razvitka pojedinih varijabli prometne ponude kao i razine životnog standarda korisnika usluga javnoga gradskog putničkog transporta, te oblikovanju modela jednostruke i višestruke linearne regresije kako bi se utvrdila zakonomjernost prometnog procesa. Prema rezultatima ovog istraživanja može se zaključiti da tijekom promatranog razdoblja ne postoji usklađenost dinamike razvitka prometnih veličina vezanih za prometnu ponudu i kvalitetu transportne usluge autobusnog transportnog sustava s postojećom dinamikom razvitka putničke transportne potražnje.

Ključne riječi: *autobusni transportni sustav, javni gradski putnički transport, modeliranje, razvitak*

1 Introduction

Urban passenger transport represents the basic assumption for the functioning of urban agglomerations, since it facilitates normal social functioning and smooth economic development. According to Banković, the increase in the size of cities results in an increased need to include an increasing number of subsystems of public urban and suburban passenger transport [1]. Public urban passenger transport can be defined as a system of organized line transport of passengers in the area of a defined urban agglomeration, as well as the transport between the narrow city territory and the suburban settlements on the sections and lines on which the majority of passengers are commuters. The significance of the bus transport system as the basic subsystem in almost every system of urban passenger transport should be noted. It is necessary to determine the strong connection of the realized or desired level of the transport service quality and its price, and that the traffic system affects directly the efficiency and effectiveness of the economic and overall social system [2]. The transport capacity and the operation of the system are evaluated according to the values such as e.g. average number of buses daily in operation, total number of passenger places and the total number of realized seat-kilometres, studying also the transport values that refer also to the dynamics of the travelled distance, number and length of lines, average travelling speed on urban and suburban lines, and the average age of the bus. Apart from these, the values that are related to the level of the life standard of the public urban transport users are studied as well. The transport modelling often represents a significant part and basis of the business decision-making process in the optimisation of the transport system [3]. The scientific problem studies the harmonisation of the relations of the traffic values from the area of traffic supply with the trend and dynamics of the passenger transport demand, which is expressed by the number of carried passengers in the system. Since this is a quantitative research, the paper uses dynamic measures of the average annual growth rate and determining of the trend in the values of traffic supply and demand in the system of urban passenger transport, and the correlation and regression analysis. Regarding their characteristics the studied values are mainly quantitative indicators of the transport supply in the system of public urban transport which in the City of Zagreb is operated by the public carrier "Zagrebački holding d.o.o. Subsidiary Zagrebački električni tramvaj (Zagreb Electric Tram)". Traffic planning is determined by the need for continuous increase in the capacities of the traffic system in order to satisfy the increase in the transport demand [4]. The focus of attention of the transport planners and managers is not just to anticipate and insure the necessary traffic infrastructure and suprastructure, but rather also its maximal usage with priority recognition of the transport service users' requirements [5]. Thus, according to Padjen the transport demand has crucial significance for determining and pursuing of the traffic policy, determines the development level of the traffic system, as well as the level of its usage, first of all its technical stratum i.e. traffic infrastructure and transport means [6, 7]. The knowledge about the development dynamics of the studied values and its possible laws, i.e. development trends in the traffic system represent the scientifically founded base of dimensioning the entire work organisation, necessary transport capacities and making of strategic decisions of further development of bus traffic system as one of the subsystems of urban passenger transport system of the City of Zagreb. The traffic demand is of stochastic character and in mathematical modelling it is necessary to use the methods of mathematical statistics and the theory of probability, along with determining the traffic volume development trend. The trend represents the development tendency of the traffic volume in time and is represented by the function of time. The implementation of the results of this paper is reflected first of all in that the research results provide the decision-makers regarding further traffic system development in the studied area with scientifically founded information on the legality of the process within the system. The research results about the established legalities, as well as the designed mathematical models are the means and assistance in decision-making about the development and management of the traffic system development process. The transport modelling plays a significant role in all the more complicated decision-making processes, and especially when referring to the modelling of the traffic development [8, 9, 12, 14]. Regarding the dynamic character of change in the economic and transport system for the traffic analyses more desirable are the analytic methods that detect the changes within shorter periods of time, so that the subject and results of research and modelling are better directed [10, 13, 14].

2 Research results

Further in the paper graphical presentation is given and statistical analysis of the studied values performed. The data on the passenger transport demand are expressed by the number of carried passengers based on the realised sales of tickets according to the ZET register. The prognostic trend model of the development dynamics of individual traffic values (only statistically significant models are presented) has been obtained by means of computer software "Microsoft Excel" and is determined by the equation of linear trend model and determination coefficient (R^2) as a measure of representativeness, and the dynamics has also been graphically presented. It should be noted that along with the size of the sample analysed in the paper (N = 16) the following holds: when the value of the determination coefficient R^2 is greater than 0,247 a conclusion follows that the determined mathematical model of prognostic trend of the studied variable is statistically significant with the risk level $p <$ 0,05, i.e. if R^2 is greater than 0,388 with the risk level $p <$ 0,01 [11, 13, 14]. The interconnection as well as the level of correlation between the studied values in the observed period is determined by means of the coefficient correlation matrix, and thus the statistically significant value of the correlations coefficient (r) is greater than 0,497 with risk level $p <$ 0,05, i.e. greater than 0,623 with risk level $p <$ 0,01 [12, 13, 14].

Table 1 Transport demand and elements of transport supply, and the life standard of the users in bus transport system of the City of Zagreb in the time period from 1995 to 2010 – transport company Zagrebački holding d.o.o., Zagreb, Subsidiary Zagrebački električni tramvaj [15, 16]

Year	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}
1995	84 700	266	39 447	11 632	3 094	115	1 240	17,5	27,2	25 984	1 983	165 911	10,2	36,53
1996	79 662	230	38 837	13 683	3 147	115	1 240	17,4	27,2	26 491	2 239	184 766	10,0	39,50
1997	81 890	233	41 198	14 013	3 265	117	1 257	17,3	27,1	26 824	2 688	197 638	9,4	39,87
1998	79 634	231	40 273	14 498	3 349	117	1 263	17,1	27,3	27 041	3 017	211 373	9,8	42,05
1999	80 117	234	42 382	14 316	3 350	119	1 296	17,0	27,1	27 177	3 510	226 770	9,5	41,81
2000	83 208	230	41 369	14 017	3 224	121	1 339	16,8	27,0	26 457	3 832	240 062	10,4	38,75
2001	87 861	230	39 973	14 091	3 241	121	1 393	16,9	26,3	26 530	4 131	254 373	11,2	36,89
2002	88 557	229	39 230	13 987	3 203	122	1 356	20,0	15,6	26 225	4 374	264 931	12,0	36,17
2003	84 513	228	38 812	13 706	3 125	125	1 375	20,0	20,7	26 146	4 680	278 593	11,5	36,98
2004	79 705	229	38 329	13 258	3 036	125	1 378	18,5	28,6	26 058	4 929	290 279	11,1	38,09
2005	80 421	229	35 250	12 777	2 926	126	1 412	18,5	28,8	25 975	5 239	300 306	10,7	36,37
2006	85 111	226	34 318	12 451	2 814	125	1 306	18,6	28,5	25 563	5 516	313 164	10,1	33,25
2007	99 739	227	33 170	12 396	2 814	132	1 389	16,6	28,5	26 275	5 806	323 539	9,8	28,20
2008	94 061	236	34 744	11 992	2 830	132	1 413	18,4	28,9	26 558	6 145	334 067	9,6	30,07
2009	87 155	255	48 529	11 969	3 052	140	1 497	18,0	29,0	28 188	6 229	331 751	4,9	35,00
2010	81 688	263	47 720	11 844	3 115	140	1 379	17,4	26,7	29 019	6 291	327 612	5,8	38,13
Arithmetic mean	84 876	236	39 599	13164	3 099	125	1 346	18	27	26 657	4 413	265 321	10	37
Standard deviation	5 650	13	4 277	993	178	8	73	1	4	877	1 433	55 873	2	4
Variation coefficient / %	6,7	5,5	10,8	7,5	5,7	6,4	5,4	5,9	13,2	3,3	32,5	21,1	19,3	10,2
Change rate / %	–0,24	–0,08	1,28	0,12	0,05	0,92	0,71	–0,04	–0,12	0,74	8,00	4,64	–3,69	0,29

Note to Table 1:

Y	Carried passengers (in 000)
X_1	Average number of buses operating daily
X_2	Number of passenger places
X_3	Realized places km/average number of buses operating daily
X_4	Realized places km (in 000 000)
X_5	Number of lines
X_6	Length of line network (km)
X_7	Commercial speed in urban traffic (km/hour)
X_8	Commercial speed in suburban traffic (km/hour)
X_8	Travelled vehicle kilometers (in 000)
X_{10}	Average net income (HR Kuna)
X_{11}	Number of passenger cars
X_{12}	Average age of buses (years)
X_{13}	Offered places km/passengers

Table 2 Matrix of correlation coefficient values (r) of the studied values of bus traffic system of the City of Zagreb in the period of time from 1995 to 2010

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1,000													
2	–0,065	1,000												
3	–0,390	0,626**	1,000											
4	–0,391	–0,639**	0,016	1,000										
5	–0,564	0,040	0,570*	0,743**	1,000									
6	0,418	0,339	0,273	–0,637**	–0,526*	1,000								
7	0,438	0,055	0,136	–0,371	–0,431	0,825**	1,000							
8	0,003	–0,174	–0,187	–0,062	–0,239	0,131	0,268	1,000						
9	–0,053	0,168	–0,053	–0,383	–0,342	0,183	0,047	–0,627**	1,000					
10	–0,137	0,601**	0,847**	–0,174	0,307	0,552*	0,268	–0,308	0,130	1,000				
11	0,470	0,035	–0,016	–0,526*	–0,647**	0,924**	0,853	0,278	0,130	0,274	1,000			
12	0,483	–0,029	–0,078	–0,505*	–0,676**	0,900**	0,848	0,303	0,127	0,213	0,997**	1,000		
13	0,008	–0,677**	–0,701**	0,509*	0,062	–0,668**	–0,328	0,313	–0,423	–0,861**	–0,392	–0,340	1	
14	–0,889**	0,040	0,520*	0,646**	0,875**	–0,540*	–0,514	–0,168	–0,128	0,250	–0,636**	–0,658**	0,0	1

Source: Table 1

Notes to Table 2: Boundary values of determination coefficient R^2 (N=16) and the number of degrees of freedom (df)=14 for value r>0,497 with risk level * p<0,05; for value r>0,623 with risk level ** p<0,01. The value of correlation coefficient (r) is obtained by adequate procedure with MS Excel and Statistica software.

Variable 1	Carried passengers (in 000)
Variable 2	Average number of buses operating daily
Variable 3	Number of passenger places
Variable 4	Places km/average number of buses operating daily
Variable 5	Realized places km (in 000 000)
Variable 6	Number of lines
Variable 7	Length of line network (km)
Variable 8	Commercial speed in urban traffic (km/hour)
Variable 9	Commercial speed in suburban traffic (km/hour)
Variable 10	Travelled vehicle kilometres (in 000)
Variable 11	Average net income (HR Kuna)
Variable 12	Number of passenger cars
Variable 13	Average age of buses (years)
Variable 14	Offered places km/passenger

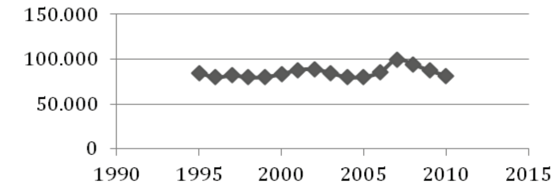

Figure 1 Carried passengers in bus traffic system of the City of Zagreb in the time period from 1995 to 2010 [15]

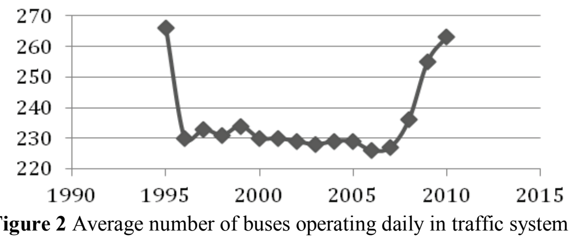

Figure 2 Average number of buses operating daily in traffic system of the City of Zagreb in the time period from 1995 to 2010 [15]

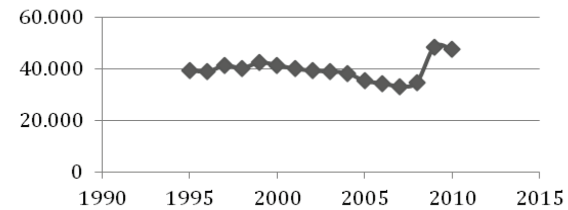

Figure 3 Transport capacity (total number of passenger places) in bus traffic system of the City of Zagreb in the time period from 1995 to 2010 [15]

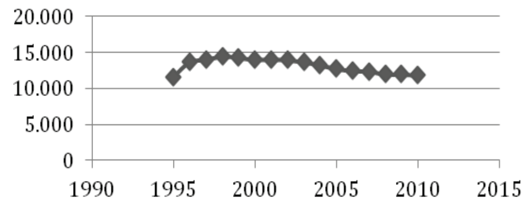

Figure 4 Dynamics of realized places km/average number of buses operating daily in traffic system of the City of Zagreb in the time period from 1995 to 2010 [15]

$$Y = -121{,}01 \cdot x + 255\,485, \quad (1)$$

$$R^2 = 0{,}336; \; (p < 0{,}05). \quad (2)$$

Note: (valid for all further equations of mathematical prognostic trend models): x = 0 for 1995.

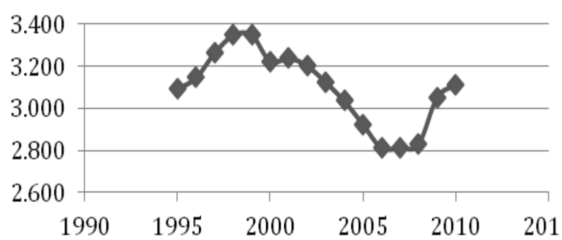

Figure 5 Travelled place kilometres in bus traffic system of the City of Zagreb in the time period from 1995 to 2010 [15]

$$Y = -24{,}199 \cdot x + 51\,557, \quad (3)$$

$$R^2 = 0{,}42; (p < 0{,}01). \quad (4)$$

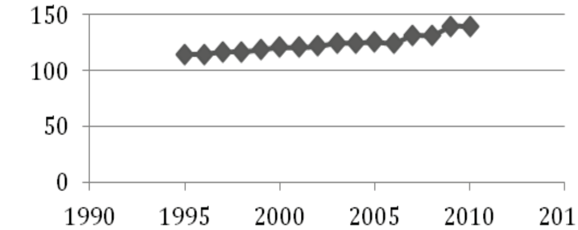

Figure 6 Number of bus lines in the traffic system of the City of Zagreb in the time period from 1995 to 2010 [15]

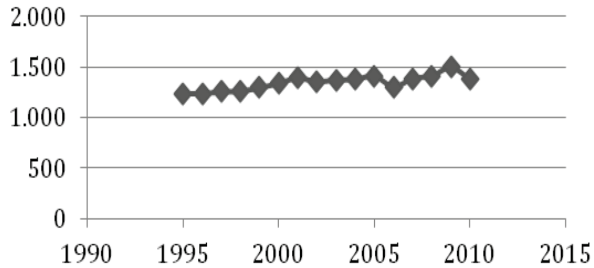

Figure 7 Length of bus line network (km) in the traffic system of the City of Zagreb in the time period from 1995 to 2010 [15]

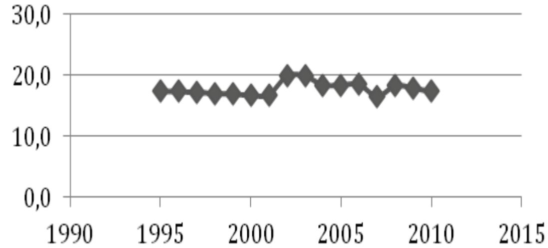

Figure 8 Travelling speed (km/h) on bus urban lines in the traffic system of the City of Zagreb in the time period from 1995 to 2010 [15]

$$Y = -0{,}4917 \cdot x + 1021{,}4, \quad (5)$$

$$R^2 = 0{,}387; (p < 0{,}05). \quad (6)$$

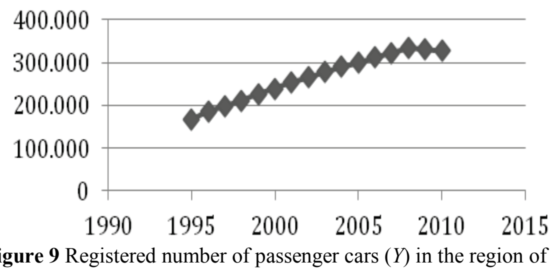

Figure 9 Registered number of passenger cars (*Y*) in the region of the City of Zagreb in the time period from 1995 to 2010 [16]

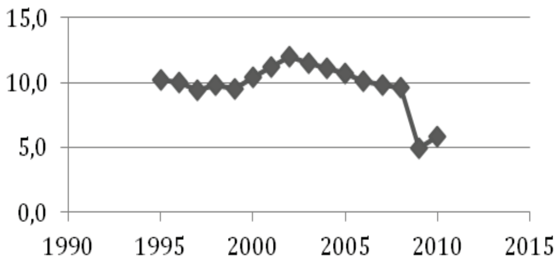

Figure 10 Average age of buses (in years) in the traffic system of the City of Zagreb in the period from 1995 to 2010 [15]

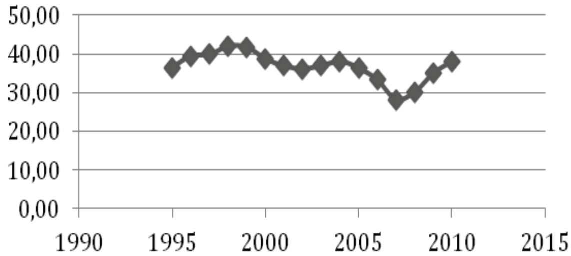

Figure 11 Realized places km/passenger in bus traffic system of the City of Zagreb in the period from 1995 to 2010 [15]

Further in the paper simple and multiple regression analyses of the studied variables are performed. The objective of regression analysis is to express or describe the correlation between the studied variables by adequate analytical and mathematical expression, i.e. regression model [13]. The basic aim of this model is, along with the explanation of the correlation of the studied phenomena, the possibility of forecasting the values of passenger transport demand in bus transport system of the City of Zagreb for certain values of one or several independent variables. After the performed mathematical calculations using MS Excel software out of the simple regression models as statistically significant the following models are highlighted whose variables are in direct proportional relation to the increase in standard of living and passenger demand:

1) boundary significance of the model referring to the influence of average net income of the employed in the City of Zagreb – variable X_{10}

Multiple *R*	0,470
R Square	0,221
Significance *F*	0,066

$$Y = 76\,694 + 1{,}854 \cdot X_{10} \quad (7)$$

2) boundary significance of the model which refers to the registered number of passenger cars in the City of Zagreb – variable X_{11}

Multiple *R*	0,482
R Square	0,233
Significance *F*	0,058

$$Y = 71\,930 + 0{,}049 \cdot X_{11} \quad (8)$$

As statistically significant the following multiple regression model is highlighted:

Multiple *R*	0,917
R Square	0,841
Significance *F*	0,0009

$$Y = 166\,560{,}2 - 145{,}29 \cdot X_5 + 19\,492 \cdot X_6 + \\ + 9{,}47 \cdot X_{10} - 0{,}269 \cdot X_{11} - 1640{,}34 \cdot X_{13}. \quad (9)$$

This model confirms the significance of the variable which refers to the average net income of the employees in the City of Zagreb – variable X_{10} , resulting in the conclusion about the increase of passenger demand in accordance with the increased standard of living of the bus transport users.

3 Argument

Using the statistical analysis of the data regarding the studied values presented in Table 1, the following can be observed: a) value Y refers to the transport demand expressed by the number of carried passengers, b) values X_1, X_2, X_3, X_4, X_5, X_6, X_9 and X_{12}, X_{13} refer to the transport supply of the bus transport system, c) values X_7, X_8 are related to the quality of the transport service, d) values X_{10} and X_{11} are related to the level of the life standard of the existing and potential urban bus transport service users. The statistical processing of the value data in Tab. 1 allows the following conclusion: a) negative average annual change rate of the passenger transport demand is –0,24 %; b) out of nine values regarding transport supply seven of them feature positive annual average change rate (number of passenger +1,28 %, realized places-km /average number of buses operating daily +0,12 %, realized places-km +0,05 %, number of lines +0,92 %, length of line network +0,71 %, vehicle kilometres +0,74 % and places-km per passenger +0,29 %), whereas two variables have negative annual average change rate (average number of buses operating daily –0,08 %, and average age of buses –3,69 %); c) both variables that are connected with the quality of transport service mark a slight negative decline of the value (commercial speed on urban lines by –0,04 %, and on suburban lines by –0,12 %), d) variables that are related to the life standard level of the existing and potential service users mark a significantly higher constant positive increase (average net income with positive average annual change rate of +8,0 % and the number of passenger cars +4,64 %). According to the processed data about the transport supply in the public urban and suburban bus transport of the City of Zagreb it may be claimed that during the studied period, comparing the situation in 2010 and in 1995 the average number of buses operating daily was reduced by 1,13 %, the total passenger capacity expressed in the number of passenger places was increased by 20,97 %, the number of totally realized place-kilometres was increased by 0,68 %. At the same time the average travelling speed on urban lines was reduced by 0,57 %, and on suburban lines by 1,84 %. The average age of the transport means as an important factor related to technical roadworthiness and reliability of transport means in exploitation, as well as with the transport service quality, was reduced by 43,14 %. On the other hand, passenger transport demand in bus traffic system of the City of Zagreb during the observed period of time was reduced in 2010 by 3,55 % in relation to 1995. By analyzing the time series of the previously mentioned variables it is possible to state the statistically significant mathematical prognostic trend models for: a) realized place kilometres (continuous trend of decline at $p < 0,01$); b) number of bus lines (continuous growing trend at $p < 0,01$); c) total length of line network (continuous growing trend at $p < 0,01$); d) average net income in the City of Zagreb (continuous growing trend at $p < 0,01$); e) registered number of passenger cars (continuous growing trend at $p < 0,01$). Consequently, the continuous increase in the number and lengths of bus line network may be evaluated as positive, since it affects the increase in the availability of bus traffic system to an increasingly wide range of potential users. The positive correlation of passenger transport demand with the increase in income as well as the number of registered passenger cars can be interpreted in two ways; on the one hand, as increased need for travelling due to the relative growth of the life standard, and on the other hand, as reaction to increasing traffic congestions in road traffic network, recession, and the similar.

4 Conclusion

In this work the development dynamics of the bus traffic system in the City of Zagreb has been studied, i.e. the passenger transport demand variable on one side and several variables of transport supply related to the elements of the quality of transport service of the bus traffic system of the City of Zagreb recognizing the variables that indicate the level of the life standard of this service users. The passenger demand i.e. the number of carried passengers in bus system was obtained from ZET based on the number of sold tickets. The research has determined the correlation between the development of the passenger transport demand and the elements of the transport supply expressed through the number and length of the bus line network, as well as the standard of living of the public transport users in the City of Zagreb. The designed regression model has confirmed the significance of the variable which refers to the average net salary of the employees in the City of Zagreb (value X_{10}), resulting in the conclusion about the increase of the passenger demand in accordance with the increase of the life standard of the service users. In compliance with the carried out research the following conclusion can be made. The bus system carries annually ca. 80 to 100 million passengers. The last four years (from 2007 to 2010) marked a continuous falling trend in the number of carried passengers (value Y) and this number in 2010 is at the bottom mentioned margin. In spite of such negative trend in the same period there is a continuous growing trend in the average number of operating buses daily (value X_1), although regarding such a trend of passenger demand the number of operating buses should be reduced. The discrepancy between the transport supply and demand has continued in this four-year period also through constant increase in the total transport capacity (number of passenger places) of the bus system (value X_2), which was stopped as late as 2010. The commercial travelling speed as a significant element of the transport service quality on urban lines (value X_7) ranges from 16 to 20 km/h (the last three years marked a continuous falling trend), and on suburban lines (value X_8) from 26 to 29 km/h (the last two years marked a continuous falling trend). The average age of the buses (value X_{12}), especially in the period from 2002 to 2008 has a continuous falling trend, which is extremely favourable especially if you take into consideration that at the beginning of this period it amounted to 12 years, and at the end even below five years (which is the result of strong investment jump due to the purchase of new buses), but after that this extremely favourable trend has stopped and the average age after the year 2008 has been rising again. It may be assessed as positive that there is a continuous increase in the number of the bus lines (value

X_5) and length of bus line network (value X_6), since it affects the increase in the availability of the bus traffic system to an increasingly wide range of users. Positive correlation of passenger transport demand with the increase in income (value X_{10}) as well as the number of registered passenger cars (value X_{11}) can be interpreted in two ways; on the one hand, as increased demand for travelling due to the relative increase in the standard of living, and on the other hand as the reaction to increased traffic congestions in the road network, and the current recession. According to the results of this research it may be concluded that during the studied period there has not been harmony between the dynamics of the development of the studied traffic variables, especially the elements of the transport supply and the transport service quality of the bus traffic system with the existing dynamics of the passenger transport demand development.

5 References

[1] Banković, R. Javni gradski putnički prevoz, Naučna knjiga, Beograd, 1982, pp. 184-212.

[2] Vickerman, R. The Concept of Optimal Transport Systems, prema Hensher D. A., Button K.: Handbook of transport systems and traffic control, University of Sidney, George Mason University, Elsevier Science Ltd, Oxford, 2001, pp. 47-58.

[3] Hensher, D. A.; Button, K. Handbook of Transport Modelling, University of Sidney, George Mason University, Elsevier Science Ltd, Oxford, 2000, pp. 1-10.

[4] Banister, D. Transport planning, according to Hensher D. A., Button K.: Handbook of transport systems and traffic control, University of Sidney, George Mason University, Elsevier Science Ltd, Oxford, 2001, pp. 9-19.

[5] Dunn, J. A. Driving forces - the automobile, its enemies and politics of mobility, Washington, Brooking institution, 1998, according to Hensher D. A., Button K.: Handbook of transport systems and traffic control, University of Sidney, George Mason University, Elsevier Science Ltd, Oxford, 2001, p. 10.

[6] Padjen, J. Prijevozna potražnja i oblik hrvatskoga državnog prostora – važne determinante prometne politike Hrvatske. // Ceste i mostovi, 3-4(2002), pp. 71-80.

[7] Padjen, J.; Žuljić, S. O nekim pitanjima razvoja gradskoga prometa, Zagreb, Ekonomski institut, 1979.

[8] Rajsman, M.; Jurić, R. Dinamičko iskorištenje prijevoznih kapaciteta u prigradskom putničkom cestovnom prometu. // Suvremeni promet, HZDP, Zagreb, 19, 3-4(1999), pp. 297-303.

[9] Rajsman, M. Statično iskorištenje prijevoznih kapaciteta u prigradskom putničkom cestovnom prometu. // Promet, 5, 3-4(1993), pp. 93-99.

[10] Vickerman, R. The Concept of Optimal Transport Systems, according to Hensher D. A., Button K.: Handbook of transport systems and traffic control, University of Sidney, George Mason University, Elsevier Science Ltd, Oxford, 2001, pp. 47-58.

[11] Serdar, V.; Šošić, I. Uvod u statistiku, Školska knjiga, Zagreb, 1998, pp. 47-107, pp. 406-407.

[12] Rajsman, M. Model razvitka prometnoga sustava Središnje Hrvatske. // Doktorska disertacija, Fakultet prometnih znanosti, Sveučilišta u Zagrebu, Zagreb, 2005, pp. 187-194.

[13] Papić, M. Primijenjena statistika u MS Excelu, ZORO, Zagreb, 2005., pp.133-159.

[14] Rajsman, M.; Tolić, I.; Papić, M. Development of tram transport system modelling in the City of Zagreb. // Tehnički vjesnik – Technical Gazette, 19, 4(2012), pp. 965-971.

[15] Podaci o razvoju i poslovanju Zagrebački holding d.o.o. Podružnica ZET, Zagreb, 2012.

[16] Statistički godišnjak Grada Zagreba, Zagreb, 2012.

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