MODELLING OF THE CITY OF ZAGREB TRAFFIC SYSTEM WITH SPECIAL EMPHASIS ON PUBLIC PASSENGER TRANSPORT

Univ.-Prof. Dr.-Ing. Marijan Rajsman
University of Zagreb
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1. TRAFFIC SYSTEM

• Questions:

1) What is the purpose of the traffic system and its meaning?

2) What are the goals of the traffic system?
1. TRAFFIC SYSTEM

Questions:

What is the purpose of the traffic system and its meaning?
1. TRAFFIC SYSTEM

• Questions:

What are the goals of the traffic system?
THE PURPOSE OF THE TRAFFIC SYSTEM

• is to enable the functioning of the people's community

and also its

• undisturbed total social development
THE GOAL OF THE TRAFFIC SYSTEM

• is to meet the transport demand which exists in its area

• with the appropriate transport supply of a certain quality of service
QUESTION

• Which are the most important trends today in the world?
POPULATION MEGA TRENDS

- population growth,
- population ageing,
- migration and
- urbanization
by 2030, 60 percent of the global population will live in cities ...

by 2030 this number will swell to about 5 billion
• The urbanization of the human population is a constant and an unstoppable process.

• The constant growth trend of the urban population is an important factor of development of the human civilization.
2. TRANSPORT DEMAND

TRAFFIC (TRANSPORTATION) SYSTEM
TRANSPORT DEMAND AS A FUNDAMENTAL FACTOR IN SIZING

- TECHNICAL SUBSYSTEM
- TECHNOLOGICAL SUBSYSTEM
- ORGANIZATIONAL SUBSYSTEM
- ECONOMIC SUBSYSTEM
The basic factor in the process of modeling of management and development of the traffic system is the existing and forecasted transport demand.

In this sense, modelling the transport system development based on the study of the current status and trends of transport demand is a key for its optimization.
3. MODELLING THE DEVELOPMENT OF TRAFFIC SYSTEM

Significant scientific research tools are

- the study of the development dynamics of the passenger transportation demand
  - on a specific territory
  - in a specific period of time

- the development of forecasting trend models for such demand
THE TREND

a development tendency of a transport and economic parameter in time and is represented as a function of time
SCIENTIFIC PROBLEM

• is oriented on analyzing the harmonization of relation between
  
  • the traffic values from the area of traffic supply
    • number of vehicles, departures, number and length of lines, etc
  
  and the trends and dynamics

• of passenger transport demand
  • indicated by
    • the number of transported passengers and
    • the passenger transport work in the system
4. MODELLING PUBLIC PASSENGER TRAFFIC SYSTEM OF THE CITY OF ZAGREB

The **prognostic trend model** has been obtained with the aid of the program Microsoft Excel.

This model is represented by **the trend equation** and for the purpose of establishing of **the level of significance** the **coefficient of determination** \((R^2)\) is used.

**The graph** of model is shown in the diagram.
Within the traffic system of the City of Zagreb and its gravitational area, the public passenger transport is dominated by:

- **bus (43%)** transport system
- **tram (50%)** transport system
- and
- **the railway (7%)** transport system

number of transported passengers
THE DYNAMIC OF THE RAILWAY PASSENGER TRANSPORT

The number of transported passengers in the railway traffic of the City of Zagreb

\[ Y = 2,911.4 \times x + 688.9 \]  \hspace{1cm} (1)

\[ R^2 = 0.80 \]  \hspace{1cm} (2)
The realised passenger transport work in the suburban railway traffic of the City of Zagreb

\[ Y = 43,062 \times + 17.1 \]  
\[ R^2 = 0.79 \]
BUS TRANSPORT SYSTEM
TRANSPORT DEMAND AND ELEMENTS OF TRANSPORT SUPPLY, AND THE LIFE STANDARD OF THE USERS IN BUS TRANSPORT SYSTEM

dependent variable (Y) represents the number of transported passengers during one year on the other side there are being observed 13 different independent variables (X_i, i = 1,...,13).

<table>
<thead>
<tr>
<th>Y</th>
<th>X_7</th>
<th>X_8</th>
<th>X_9</th>
<th>X_10</th>
<th>X_11</th>
<th>X_12</th>
<th>X_13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carried passengers (in 000)</td>
<td>Commercial speed in urban traffic (km/hour)</td>
<td>Commercial speed in suburban traffic (km/hour)</td>
<td>Travelled vehicle kilometres (in 000)</td>
<td>Average net income (HR kuna)</td>
<td>Number of passenger cars</td>
<td>Average age of buses (years)</td>
<td>Offered places km/passengers</td>
</tr>
<tr>
<td>Average number of buses operating daily</td>
<td>X_1</td>
<td>X_2</td>
<td>X_3</td>
<td>X_4</td>
<td>X_5</td>
<td>X_6</td>
<td>X_7</td>
</tr>
<tr>
<td>Number of passenger places</td>
<td>X_5</td>
<td>X_6</td>
<td>X_7</td>
<td>X_8</td>
<td>X_9</td>
<td>X_10</td>
<td>X_11</td>
</tr>
<tr>
<td>Realized places km/average number of buses operating daily</td>
<td>X_2</td>
<td>X_3</td>
<td>X_4</td>
<td>X_5</td>
<td>X_6</td>
<td>X_7</td>
<td>X_8</td>
</tr>
<tr>
<td>Realized places km (in 000.000)</td>
<td>X_3</td>
<td>X_4</td>
<td>X_5</td>
<td>X_6</td>
<td>X_7</td>
<td>X_8</td>
<td>X_9</td>
</tr>
<tr>
<td>Number of lines</td>
<td>X_4</td>
<td>X_5</td>
<td>X_6</td>
<td>X_7</td>
<td>X_8</td>
<td>X_9</td>
<td>X_10</td>
</tr>
<tr>
<td>Length of line network (km)</td>
<td>X_5</td>
<td>X_6</td>
<td>X_7</td>
<td>X_8</td>
<td>X_9</td>
<td>X_10</td>
<td>X_11</td>
</tr>
</tbody>
</table>
The value of correlation coefficient (r) is obtained by adequate procedure with MS Excel.
DYNAMICS OF REALIZED PLACES KM/AVERAGE NUMBER OF BUSES IN OPERATING DAILY

\[ Y = -121.01x + 255,485 \]  \hspace{1cm} (1)

\[ R^2 = 0.336 \ (p < 0.05) \]  \hspace{1cm} (2)
TRAVELLED PLACE KILOMETRES IN BUS TRAFFIC SYSTEM

Y = -24.199x + 51,557 (3)

R² = 0.42 (p < 0.01) (4)
REALIZED PLACES KM/PASSENGER IN BUS TRAFFIC SYSTEM

\[ Y = -0.4917x + 1,021.4 \]  \hspace{1cm} (5)

\[ R^2 = 0.387 \quad (p < 0.05) \]  \hspace{1cm} (6)
REGRESSION MODEL

\[ Y = 166,560.2 - 145.29 \times X_5 + 19,492 \times X_6 + 9.47 \times X_{10} - 0.269 \times X_{11} - 1,640.34 \times X_{13} \]

\( X_5 \) ... Number of lines
\( X_6 \) ... Length of line network
\( X_{10} \) ... Average net income
\( X_{11} \) ... Number of passenger cars
\( X_{13} \) ... Offered places km/passenger
TRAM TRANSPORT SYSTEM
Very interesting variables are especially: $X_2$, $X_3$, $X_4$, $X_5$, $X_6$, $X_7$, $X_9$, $X_{10}$, $X_{11}$, $X_{12}$

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
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<tr>
<td>1</td>
<td>Transported passengers</td>
<td>8</td>
<td>Covered vehicle kilometers (in 000)</td>
</tr>
<tr>
<td>2</td>
<td>Number of powered tram cars</td>
<td>9</td>
<td>Average net salary</td>
</tr>
<tr>
<td>3</td>
<td>Number of tram trailers</td>
<td>10</td>
<td>Number of personal vehicles</td>
</tr>
<tr>
<td>4</td>
<td>Length of lines (km)</td>
<td>11</td>
<td>Number of passenger places</td>
</tr>
<tr>
<td>5</td>
<td>Average age tram vehicles</td>
<td>12</td>
<td>Average daily number of trams in traffic</td>
</tr>
<tr>
<td>6</td>
<td>Commercial speed (km/hour)</td>
<td>13</td>
<td>Vehicle kilometers/average no. of trams in traffic (in 000)</td>
</tr>
<tr>
<td>7</td>
<td>Offered passenger-km per passenger</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
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<td>1.0000</td>
<td>0.6874</td>
<td>-0.7042*</td>
</tr>
<tr>
<td>2</td>
<td>0.6874*</td>
<td>1.0000</td>
<td>-0.9066*</td>
</tr>
<tr>
<td>3</td>
<td>-0.7042*</td>
<td>-0.9066*</td>
<td>1.0000</td>
</tr>
<tr>
<td>4</td>
<td>0.4340</td>
<td>0.4922</td>
<td>-0.4816</td>
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<td>5</td>
<td>-0.1636</td>
<td>-0.1778</td>
<td>-0.0904</td>
</tr>
<tr>
<td>6</td>
<td>-0.7573*</td>
<td>-0.7961*</td>
<td>0.8851*</td>
</tr>
<tr>
<td>7</td>
<td>-0.8933*</td>
<td>-0.6731*</td>
<td>0.7605*</td>
</tr>
<tr>
<td>8</td>
<td>-0.7765*</td>
<td>-0.9264*</td>
<td>0.9172*</td>
</tr>
<tr>
<td>9</td>
<td>0.5628*</td>
<td>0.7485*</td>
<td>-0.9090*</td>
</tr>
<tr>
<td>10</td>
<td>0.5517*</td>
<td>0.7405*</td>
<td>-0.9083</td>
</tr>
<tr>
<td>11</td>
<td>0.1315</td>
<td>0.3904</td>
<td>-0.1193</td>
</tr>
<tr>
<td>12</td>
<td>-0.6838*</td>
<td>-0.7884*</td>
<td>0.6627*</td>
</tr>
<tr>
<td>13</td>
<td>-0.4769</td>
<td>-0.6191*</td>
<td>0.8653*</td>
</tr>
</tbody>
</table>

Boundary values of correlation coefficient $R$ (N=14) and the number of degrees of freedom (df)=12 for value $R > 0.497$ with risk level * $p < 0.05$; for value $R > 0.623$ with risk level ** $p < 0.01$.

* statistically significant $p < 0.05$

The value of correlation coefficient (r) is obtained by adequate procedure with MS Excel.
With regard to the values of Pearson correlation coefficient (R) it can be concluded that there is a statistically significant connection

- between the passenger transport demand (number of transported passengers)

and

- the number of powered tram cars,

- the average net salary paid and
TRAM TRANSPORT SYSTEM

• Number of driving tram cars (y)

\[ y = 2.008x + 246.9 \quad (7) \]
\[ R^2 = 0.6016 \quad (p < 0.05) \quad (8) \]

Critical value of the determination coefficient indicating the statistical significance of the linear prognostic trend model for 12 levels of freedom is \( R^2 = 0.53 \) (for \( p < 0.05 \)), i.e. \( R^2 = 0.64 \) (for \( p < 0.01 \)).

OBS (applicable for all further equations of the linear trend model): \( x = 0 \) for 1995.
TRAM TRANSPORT SYSTEM

• Number of trailer vehicles \( (y) \)

\[
y = -4.239x + 183.0 \quad (9)
\]

\[
R^2 = 0.853 \quad (p < 0.01) \quad (10)
\]

x = 0 for 1995

Critical value of the determination coefficient indicating the statistical significance of the linear prognostic trend model for 12 levels of freedom is \( R^2 = 0.53 \) (for \( p < 0.05 \)), i.e. \( R^2 = 0.64 \) (for \( p < 0.01 \)).
TRAM TRANSPORT SYSTEM

• Commercial speed in the tram transport system (y)

\[ y = -0.165x + 15.48 \quad (11) \]
\[ R^2 = 0.8495 \quad (p < 0.01) \quad (12) \]

x = 0 for 1995

Critical value of the determination coefficient indicating the statistical significance of the linear prognostic trend model for 12 levels of freedom is \( R^2 = 0.53 \) (for \( p < 0.05 \)), i.e. \( R^2 = 0.64 \) (for \( p < 0.01 \)).
• Average paid net salary of the employees (y) in the area of the City of Zagreb

\[ y = 316.9x + 2088 \quad (13) \]

\[ R^2 = 0.9943 \quad (p < 0.01) \quad (14) \]

Critical value of the determination coefficient indicating the statistical significance of the linear prognostic trend model for 12 levels of freedom is \( R^2 = 0.53 \) (for \( p < 0.05 \)), i.e. \( R^2 = 0.64 \) (for \( p < 0.01 \)).
The registered number of personal vehicles ($y$) in the area of the city of Zagreb can be modeled as:

$$y = 12788x + 173005$$  \hspace{1cm} (15) \hspace{1cm} x = 0 \text{ for } 1995$$

The critical value of the determination coefficient indicating the statistical significance of the linear prognostic trend model for 12 levels of freedom is $R^2 = 0.53$ (for $p < 0.05$), i.e. $R^2 = 0.64$ (for $p < 0.01$).

$$R^2 = 0.996 \hspace{1cm} (p < 0.01)$$  \hspace{1cm} (16)
there is a statistically significant correlation between

the passenger transport demand in tram transport system
and
the level of average net salary paid in the city of Zagreb,

with value $r = 0.5628$ at the level of $p < 0.05$.  

$$Y = 5.4979 X_9 + 161.782$$ (17)
TRAM TRANSPORT SYSTEM

\[ Y = 0,1337 \times_{10} + 150.347 \]  \hspace{1cm} (18)

• there is a statistically significant correlation between

• the passenger transport demand

• the number of registered personal vehicles in the city of Zagreb,
Creation of mathematical forecasting trend models for the development of passenger transportation demand is important for:

- determining the **transport capacities**, 
- planning and introducing **new technologies**, 
- optimizing the system **organization** or 
- improving the **efficiency**
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 passengers in the City of Zagreb
TRAM TRANSPORT SYSTEM

By analyzing the time series of previously indicated variables, it is possible to conclude statistically significant mathematical prognostic trend models for:

• a) number of powered tram cars (constant increasing trend with $p < 0,05$),

• b) number of tram trailers (constant reduction trend with $p < 0,01$),

• c) speed of travel (constant reduction trend with $p < 0,01$),

• d) offered passenger-kilometers per passenger (constant reduction trend with $p < 0,05$),

• e) average net salary in the city of Zagreb (constant increasing trend with $p < 0,01$).
THE PURPOSE OF THE MODELLING OF TRAFFIC SYSTEM

• 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
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E-mail: mrajsman@fpz.hr