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METHODOLOGICAL TRAFFIC LOAD SURVEY OF THE ROAD SV. LEOPOLDA BOGDANA MANDIĆA WITH A QUEUING MODEL

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Abstract

The traffic in Osječko–Baranjska County is strongly marked by the regional road named *Sv. Leopolda Bogdana Mandića* (so-called "*Čepinska cesta*"). With its high traffic density and specific significance, this road is negatively characterized by traffic jams, waiting, minor and major accidents. Statistical data for the Republic of Croatia indicate that this is one of the roads with the heaviest traffic load in the country. In an experimental study conducted using traffic, operational and statistical methods of measurement, the problem of *Poisson queuing model* with a single waiting point was recognized. High frequency of vehicles exceeds the expected and assumed number of clients in a queue, which increases the average waiting time in the queuing model. For this reason, stationary traffic counting is undertaken in order to establish the traffic load. These results, as well as those for waiting times, confirm it is necessary to propose a new traffic organization for this road, which would decrease avarage waiting times and eliminate unneccesary halts. This in turn would increase the flow rate and minimize negative traffic situations.

JEL classification: C41

Keywords: traffic density, stationary traffic counting, peak periods, Poisson queuing model, rationalization, statistical analysis

1. Introduction

The traffic on the road named *Sv. Leopolda Bogdana Mandića* is not channelled in an optimum way, which is reflected in frequent traffic loads. This road has a significant impact on linkage between the city area and its satellite towns. At the same time it also passes through an industrial area in which most of the Osijek-based companies are situated, thus additionally increasing the traffic load by people driving to and from their jobs, especially in the peak periods.
Such a situation has been confirmed by traffic counting, where, based on the previous hourly traffic count data and current (real) count results, we confirmed the issues of waiting and halts. Existing results do not differ from the previous results, and they announce great struggle to find possible solutions.

This queuing as well as any other is characterized by irregular or accidental arrivals (although the average number of arrivals in a unit of time is known to us, it cannot be accurately predicted for each specific period), and also by the fact that the time for each service is different (the average service time is known, but it cannot be applied to every situation) (Gaither, 1987, 371).
All queuing models do not strive for a single, the best solution, because, as a rule, there is no such solution, but they describe the queuing behaviour by using the estimated parameters, like average waiting time per time unit or average service time. By changing these parameters different results are obtained and optimum solution is the solution considered the most realistic one in a certain moment (Barković, 1999, 204).
Only one of the many possibilities for application of the queuing model theory as quantitative method is presented in this paper. The model analyzed here is the Poisson single server queue. $((M/M/1) : (GD/\infty/\infty)$.
Possible improvements have been established, based on the collected data, with the aim of achieving safer and faster vehicular traffic flow with minimum delays and queues.
For the purpose of presenting the count results, descriptive parameters have been used on the road named *Sv. Leopolda Bogdana Mandića*, as the most represented and flexible ones in this type of predictive observation. Descriptive research methods are sometimes called normative research methods, because their primary function is to provide understanding of complex meanings of many discrete events. With such approach we research the traffic situations that demand application of observation techniques as the main method of data collecting. The dynamics of the traffic is reflected in turbulent observations.

2. DEVELOPMENT OF THE ROAD TRAFFIC

The first roads in Slavonia were built by the Romans at the beginning of the Christian era. The Romans had real road building teams, traffic signs along the roads, road maps showing the number and the type of the road, distance from the settlement and a station, signposts, lodging houses, and everything required by modern traffic, as it is shown on the Peutinger map[28]. In oldest of times simple footpaths turned into unsurfaced roads, and these were trodden until they

[28] Peutinger map is a road map of the Western Roman Empire, the only known surviving map of the Roman roads. It dates back to the 3rd or 4th century Anno Domini. One copy was obtained by the German humanist, Konrad Peutinger (1465-1547) from Nürnberg. The map was named after him: Tabula Peutingeriana. It is made in 8 sections on four sheets. Croatian countries are situated on the second sheet, i.e. section III: SEGMENTVM III. a Marcomannis ad Sarmatas vsque, i IV: SEGMENTVM IV. a Sarmatis vsque ad Hamaxobios. The Adriatic Sea is elongated in the west-east direction. The following Croatian countries can be found on the map: Isteria, LIBVRNIA, DALMATIA, Pannonia Superior, Pannonia Inferior.

became real roads. Travelling was fast and safe, because the road network system was good both for passenger and goods traffic. At Roman times main roads respected natural advantages and they were linking East to West and North to South through the Pannonian Plain (Dmitrović, 2007, 18).
Land traffic was characterized by the lack of hard topped roads, and by weak linkage of Slavonia to east-west and north-south directions. On most of the roads travelling was possible only during nice weather. All of this represented a large disadvantage in the traffic and economy of Osijek, Slavonia and Croatia (Pavličević, 1994, 29).
The road traffic was developing rapidly through history, especially at the time of the first cars, which resulted in even better and improved construction of the road network system. Roads covered large distances, all with the goal of transporting people and goods, which shows that traffic has played an important role in the social and economic development from the trodden pathways until today.

2.1. Road network system of Osijek – Baranja County

The dynamics of construction of roads and crosses in the period 1888 – 1892 can be observed in the "Account of the built ceramite roads and crosses in the town of Osijek" of November 20, 1892 (Davidović, 1982, 53). A conclusion can be drawn that construction of ceramite roads contributed to significant progress of overall infrastructure, but it also was an economic warning to introduce new materials and techniques in construction of town roads, which resulted in good town roads. Also, the regulatory basis in the form of the *Regulation Statute for City of Osijek* from 1901 was adopted, defining the wideness of newly designed roads.
Osijek is situated in the star-shaped intersection of roads leading to the following directions; Osijek – Beli Manastir, Osijek – Dalj – Erdut, Osijek – Vukovar, Osijek – Vinkovci, Osijek – Đakovo, Osijek – Našice and Osijek – Valpovo. This implies good linkage of the city with the neighbouring centres, but there is also an inevitable need for thorough modernization of these road directions (JAZU, Centar za znanstveni rad Osijek, 1981, 184). The purpose of the roads outside of settlements is to link the surrounding settlements and towns with regional centres in order to make the road network system dynamic and to provide safe and fast arrival for selected itinerary. The centre of Osijek-Baranja County has a central connection with roads outside of settlements that bypass or go through the city centre, which sometimes results in traffic delays and waiting. The road named *Sv. Leopolda Bogdana Mandića* (also called 'Čepinska cesta') is one of the linkages on the traffic route Osijek – Đakovo and vice versa, and entrance into the city from the direction of Đakovo additionally loads this road, which then results in traffic delays.

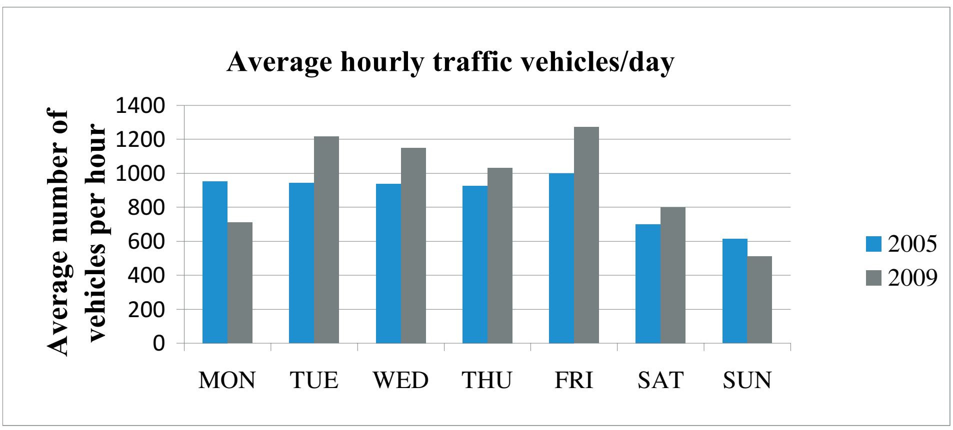
3. THE *SV. LEOPOLDA BOGDANA MANDIĆA* ROAD

This road is characterized by significant traffic load, which is shown by evaluation of situation. The traffic load is significant and it is in interaction with everyday traffic issues. Traffic issues reflect in waiting and frequent traffic jams that result from an insufficiently developed traffic organization, which causes problems in the usual traffic flow. There is a whole range of unsolved problems on this road, and among the larger ones is a level crossing, where the traffic is stopped at certain times when trains are passing, which causes unnecessary queuing. The vicinity of shopping centres and industrial facilities add additional load to this road, bringing people into direct collision with observed road issues, especially during periods when movements toward shopping centres are increased.

2.2. Evaluation of the previously observed and of the existing traffic situation

Stationary traffic counting (recording) of vehicles in movement that pass through the observed section in a time unit provides data about arrival and leaving of units on the observed section of the route. Hourly recording during peak periods was conducted seven days in a week, for the purpose of confirming and presenting the vehicular traffic flow on the *Sv. Lepolda Bogdana Mandića* road. By evaluation of the collected data for (2005/2009), new considerations are established, demanding rational dimensioning of the observed road.

Chart 1. Average hourly traffic per day on the *Sv. Leopolda Bogdana Mandića* road (D7) in 2005/2009



Source: Hrvatske ceste d.o.o., Traffic count on the roads of the Republic of Croatia, Zagreb, 2005, and Authors, 2009

The Chart 1 provides traffic count results by days through hourly traffic load out of summer months. The average hourly traffic on a weekday (Friday), considering both of the observed periods (2005/2009), reaches the highest average number of vehicles per hour of 954 (2005), and 1273 (2009) vehicles. By comparing data from these two years, a conclusion can be made that there are no specific deviations in terms of extreme values. However, as it can be observed, Monday and Sunday record opposite results, considering the assumed range of obtained data in 2009 in significantly higher values.

Reducing the number of vehicles and queuing results would result in an increased flow of vehicles through the observed section in a unit of time. The subject issues are supported by the presented data, with emphasis on rational elimination of the problem as a measure for further development of the road traffic.

Infrastructural facilities along the road also cause problems in terms of reduced traffic flow, for example, level crossing at the same level as the road, forbidden left turn from the observed *Sv. Leopolda Bogdana Mandića* road to Sv. Ana road. Shopping centres (Lidl, Interspar), other companies and petrol stations additionally attract clients and create problems when joining traffic in the main road.

4. METHODOLOGICAL SURVEY OF THE POISSON SINGLE SERVER QUEUE

Queues are, undoubtedly, everywhere around us. They are formed whenever units entering a system in order to be served, or entering the places providing the service, "wait" (Runzheimer, 2007, 427). On *Sv. Leopolda Bogdana Mandića* road, a queue consists of all vehicles waiting to come to the first position in a queue in order to join the traffic in the roundabout (i.e. they are waiting for service). The number of vehicles, i.e. traffic flow volume, represents the average (expected) number of clients arriving in a unit of time (λ), and the capacity of observed passing through represents the average (expected) number of clients that were served in a unit of time (μ).

In order to present a quantitative approach to the analysis of queuing on the *Sv. Leopolda Bogdana Mandića* road, we selected the *Poisson model* which implies a single server queue, general service discipline, and no limitations in terms of the allowed number of units in the system and source capacity. Written in Kendall's notation, this is the expression:

(M/M/1) : (GD/∞/∞)

The assumption of the model is that the average number of vehicle arrivals does not depend on the number of clients (vehicles) in the system ($\lambda_n = \lambda$ for all *n*), or on the average service rate ($\mu_n = \mu$ for all *n*). The percentage of time during which servers are occupied, i.e. the system utilization, can be calculated in the following way:

$$\Psi = \frac{\lambda}{\mu}$$

The probability that there are no units in the system:

$$p_0 = 1 - \Psi$$

In order for such a queuing model to function and in order to satisfy the condition of system stability, the following requirement must be met: $\Psi < 1$, that is $\lambda < \mu$. Otherwise the queuing model will strive for infinity and service provider will not serve all the clients (vehicles), because their arrival rate per unit of time would exceed the number of services that a service provider can perform.

Basic system parameters (Barković, 2002, 414):

- *Expected number of units (clients) in the system*

$$L_s = \frac{\Psi}{1 - \Psi}$$

- *Expected number of units (clients) in the queue*

$$L_q = \frac{\Psi^2}{1 - \Psi}$$

- *Expected waiting time in the system*

$$W_s = \frac{L_s}{\lambda} = \frac{1}{\mu(1 - \Psi)}$$

- *Expected waiting time in the queue*

$$W_q = \frac{L_q}{\lambda} = \frac{\Psi}{\mu(1 - \Psi)}$$

There were on average 710 vehicles (λ) in a time period of one hour that passed through the observed road, and the average service time, i.e. time needed for a vehicle to enter the roundabout is 5.01 seconds. In other words, on average 718 vehicles (μ) entered the roundabout within an hour. As the λ parameter (the number of vehicles entering the system) is smaller than the μ parameter (the number of serviced vehicles), this implies the stability of the system. The following solutions were obtained by using the Poisson model ((M/M/1): (GD/∞/∞):

- $\Psi = 0.99$ (the probability that there are vehicles in the system is 99%)
- $p_0 = 0.011$ (the probability that the system is empty, i.e. that there are no vehicles in the system is 1.11%)
- $L_s = 88.75$ (the average (expected) number of vehicles in the system is 89)
- $L_q = 87.76$ (the average (expected) number of vehicles in the queue is 88)
- $W_s = 0.125$ (the expected (average) waiting time in the system is 0.125 hours, i.e. 7.5 minutes)
- $W_q = 0.1236$ (the expected (average) waiting time in the queue is 0.1236 hours, i.e. 7.42 minutes)

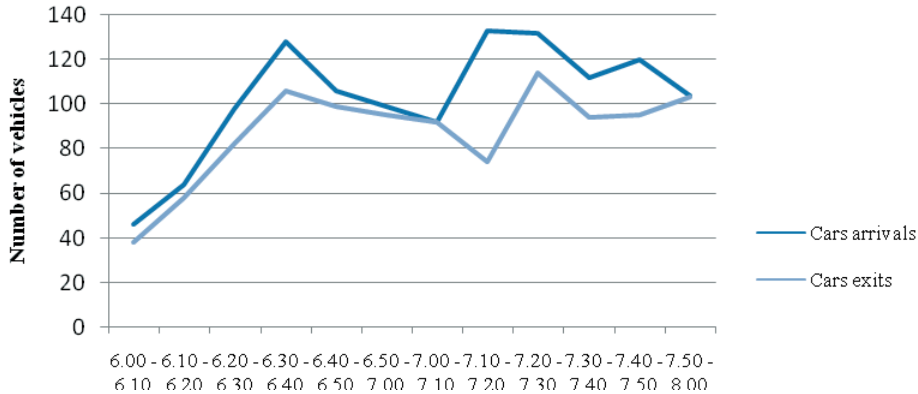
Achievements of the Queuing model theory have enabled development of various models of service level, i.e. methods for determining intersection efficiency measures, like the average delay and length of the waiting line.[29]

5. STATISTICAL DATA ANALYSIS OF A SINGLE SERVER QUEUING MODEL

Experimental study conducted by counting, i.e. measuring fluctuation of vehicles in the morning time interval on the *Sv. Leopolda Bogdana Mandića* road has given satisfying results of descriptive parameters. The stated interval represents a highly frequent, but also turbulent time frame determined by basic economic factors.

[29] http://www.gradst.hr/files/users/dcvitanic/teorija_prometnog%20toka.pdf Access (27-02-2009)

Chart 2. Car Arrivals and Exits in the period 6.00 – 8.00 h



Source: Authors, 2009

According to the Chart 2 we clarify the data for the traffic count on a weekday, or more precisely, on Monday. The morning period from 6.00 – 8.00 a.m. has been determined as the observed time period, when, due to economic factors, traffic starts and grows. The following vehicles passed through the road in the observed interval: personal vehicles, cargo vehicles, buses, motorcycles, mopeds, bicycles. The lowest value of frequency distribution was recorded with the number one, while the highest value was the quantity of 167 vehicles in ten minutes, with the average deviation of 10.63 vehicles in six time intervals within an hour (7.00 – 8.00 h), while in an earlier period (6.00 – 7.00 h) 146 vehicles passed. Most vehicles are personal cars, in ten minutes of the time interval (6.00 – 7.00 h) there were 584 cars, with the average of 97.33 cars and average deviation of 9 cars (δ^2 = 81.11 cars). In a somewhat more dynamic interval (7.00 – 8.00 h) there were 726 cars in traffic. In about ten minutes there were on average 121 cars, with the average deviation of 10.04 cars (δ^2 = 100.83). Waiting time on the level crossing, being on average 3 minutes, has extreme values.

The basic descriptive parameters of the observed road have been verified in the dynamics, and supported by SPSS calculation (statistical data processing software), v. 16.

6. CONCLUSION

From calculations it can be observed that the probability that there are vehicles in the system amounts to 99%. Vehicles intending to go to the city through the *Sv. Leopolda Bogdana Mandića* road during the peak period can expect that on average there will be 88 vehicles queuing before them and that they will have to wait for approximately 7.5 minutes. As we talk about the average values, it is possible for vehicles to leave the system in a much shorter period, but it is also possible for them to lose as much as fifteen minutes of their time on this road, depending on the moment in which they go through. The result of methodological accounts indicates the necessity for a new proposal for improvements in dealing with issues on the section of the *Sv. Leopolda Bogdana Mandića road.*

For the purpose of solving traffic load problems, channelization of the road should be conducted through gradual delevelling. Level crossing should be conducted at two levels, thus avoiding the conflict with the road traffic while the swing-gate is down and unnecessary waiting. By removing the ban for turning left to the road named *Sv. Ana*, a possibility would be provided for drivers whose intention is not to enter the roundabout, but they do so because they have no choice, to leave the *Sv. Leopolda Bogdana Mandića* road here. Evaluation of the observed roundabout reveals the need for directing the traffic to larger number of exits, for example, to connect entrance to “Interspar” to the *Vinkovačka ulica* road, because vehicles heading in that direction would not have to enter the roundabout.

Conclusions of dynamics were made by methodological measuring through statistical parameters. Namely, large average number of vehicles in the minimum time interval of ten minutes records high average number of vehicles, or, more precisely, cars (as the most represented vehicle on the observed road) with their extreme and non-linear movements. A conclusion can be drawn that the *Sv. Leopolda Bogdana Mandića* road implies the high traffic level in Osijek– Baranja County, whose final result is queuing and overall traffic „nervosity“. Considering the growing dynamics of economic trends, the observed road will record ever larger and more dynamic results also in the future traffic flow.

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