Journal of Trends in the Development of Machinery and Associated Technology
Vol. 18, No. 1, 2014, ISSN 2303-4009 (online), p.p. 187-190

HIGHWAY EMPIRICAL TRAFFIC FLOW PATTERNS AND REGRESSION ANALYSIS

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ABSTRACT
The aim of this paper is to analyze highway empirical traffic flow patterns including regression analysis at the highway tollgate station Josanica at the north exit of the capital of Bosnia and Herzegovina Sarajevo. The traffic flow analysis in this paper includes determination of arrival and service time pattern distributions and development of traffic flow time series regression forecasting models of the traffic flow. Data for this research are retrieved from the highway software system. Research shows that it is possible to build reliable regression forecasting models to predict number of vehicles per month, per week and per day in certain week as well as per defined time periods during a day. Time needed to pay at the toll station (service time) is measured by observation. This study presents arrival pattern distribution and service time distribution. Results obtained by this research will be used for the simulation of waiting line models and improvement of the existing system as well as for the highway service facilities demand forecasting.
Keywords: traffic flow, toll station, regression, arrival rate, service time.

1. INTRODUCTION
Traffic management and control at highways can play of a crutial role on financial impact of a highway project. Traffic demand forecast, as well as traffic flow pattern, are necessary for sucessfull traffic management.
Study [1] shows that the traffic uncertainty as general issue can be represented in different ways. Individual randomness leads to traffic flow uncertainty since every driver picks times and routes according to her/his preferences and demands and thus increases traffic uncertainty. Paper [2] shows that forecasting models are highly influenced by traffic uncertainty. This study provides theoretical evidence for fifteen minutes time horizon in short-term traffic forecasting. The paper combines classical measurement dispersion coefficient and uncertainty measurements associated with traffic flows, which may result in travel time uncertainty. Study [3] analyzes different methods of traffic forecast based on real data. This study emphasis that neural networks are commonly used to forecast traffic flow, speed data or travel times up to fifteen minutes. In this study the constant and the linear models for short-term forecast are examined and compared with a forecast based on heuristics. The results show that the constant model provides a good prediction for short horizons while the heuristic model is better for long-term forecast. The results can be improved with a model that combines the short and long term forecast methods. Research [4] proposes a self-diagnosing intelligent highway surveillance system and design effective solutions for both daytime and nighttime traffic surveillance

as well as regression based mechanism for estimating the traffic flow parameter.

In paper [5] a quantitative method to obtain traffic patterns from historical data is developed. The method is based on the cluster analysis technique and allows use of previous knowledge, which makes the interpretation and practical use of the results much easier. Paper [6] analyses lane occupation in three-lane highway preceding a tollgate station. Distribution depends on following variables: speed, flow and density, but also on type of vehicles, visibility, brightness and weather. Research [7] recognizes seasonal pattern in traffic data and simple seasonal adjustment approach is explored for modeling seasonal heteroscedasticity in traffic-flow series. Four types of seasonal adjustment factors are proposed with respect to daily or weekly patterns. Empirical results show that the developed model can capture and model the seasonal heteroscedasticity in traffic-flow series. Papers [8] and [9] are focused on toll road traffic forecasting accuracy. Analysis takes into account database for a period of four years containing information on 104 international toll roads, bridges, and tunnels. The research is focused on the ramp-up period, which is considered to be the most uncertain period of a toll facility. According to this research actual traffic volumes are 77% of the forecast levels with quite large standard deviation of 26%. There is no evidence of significant improvement in forecasting results between first and fifth year. Errors in forecasts of truck usage are even more variable than those made for cars with the standard deviation estimated to be 33%. Inaccuracies in traffic forecasts are larger for toll roads (76% of the forecast) than for non-toll roads (96% of the forecast), and on average, overestimation of traffic is more prevalent in countries with no history of tolling than those with a history of tolling. Paper [10] evaluates of the accuracy of traffic forecasts on 183 road projects (170 highways, ten bridges and three tunnels around the world). According to this paper the forecasting errors were at least ±20%, and there has been no improvement in the accuracy of trafic forecasting over the past 30 years.

In this paper highway empirical traffic flow patterns are analyzed implementing regression analysis, at the highway tollgate station Josanica at the north exit of the capital of Bosnia and Herzegovina Sarajevo. The traffic flow analysis includes determination of arrival and service time pattern distributions and development of traffic flow time series regression forecasting models of the traffic flow. Data for this research are retrieved from the highway software system of the Public Company Motorways of the Federation of Bosnia and Herzegovina.

2. DATA COLLECTION AND REGRESSION ANALYSIS

Traffic flow at Josanica toll station is analyzed using data retrieved from the highway software system. Data were retrieved on daily basis for the time period from the 1st January 2013 until the 31st December 2013. During this time period 2.053.629 vehicles are registered by the system. First, regression analysis was performed in order to develop a reliable model to predict monthly traffic flow. Figure 1. depicts scatter plot and linear regression trend line of the number of vehicles vs. month number along with the equation of the regression line and coefficient of determination. From Figure 1. it is clear that there are two trends. The first trend is from January until August. The slope of the regression trend line shows an increase of traffic flow by the rate of 12.260 per month.

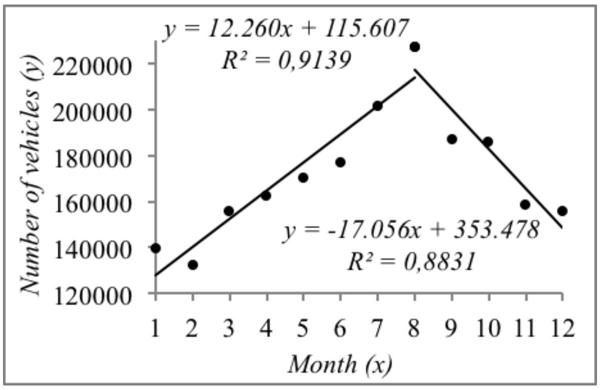

Figure 1. Scatter plot and linear regression trend lines of number of vehicles vs. month number.

Coefficient of determination is $R^2 = 0{,}9139$, which means that 91,39% of variability of number of vehicles is explained by a number of month. Coefficient of correlation is $r = 0{,}9560$ and shows strong linear relation between number of vehicles and a month in a year. According to the regression line traffic flow decreases by the rate of 17.056 vehicles per month from August until December. The value of the coefficient of determination is $R^2 = 0{,}8831$, while coefficient of correlation $r = 0{,}9397$.

The next step in the analysis is to develop model of traffic flow on a weekly basis. For each, out of 52 weeks in a year data were sorted as number of vehicles per day (i.e. Monday = 1, Tuesday = 2, …, Sunday = 7). For all 52 weeks during 2013 year regression analysis is performed. Results show that there are the same trends and patterns in all 52 weeks. To show these trends and patterns, two weeks are randomly selected in year 2013 as follows: week number 19 (from 6th May until 12th May) and week number 34 (from 19th August until 25th August). Scatter plots and regression trend lines with equations of the trend lines and values of the coefficients of determination are presented in Figures 2.

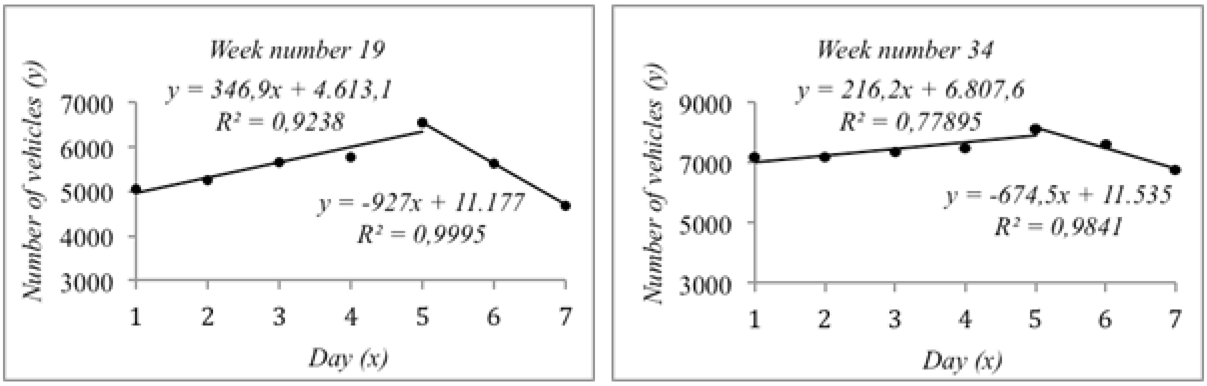

Figure 2. Number of vehicles vs. day in the week number 19. (left), and number 34 (right)

The next step is to develop model of the arrival pattern. Data are retrieved from the highway software system on randomly selected day Friday, the 6th November, from 6:00 hours a.m. until 10:00 hours p.m. The number of vehicles is counted during one-minute time intervals with no clustering. Since observation is done during 16 hours time period it means that there are 960 one-minute intervals. Scatter plot and linear trend regression lines of vehicle arrivals during 960 one-minute time intervals with trend lines equations and the values of the coefficients of determination are depicted in Figure 3. The scatter plot shows that as the time increases there is increase in number of vehicle arrivals, and later in the afternoon, after 6 p.m., there is decrease in number of vehicle arrivals.

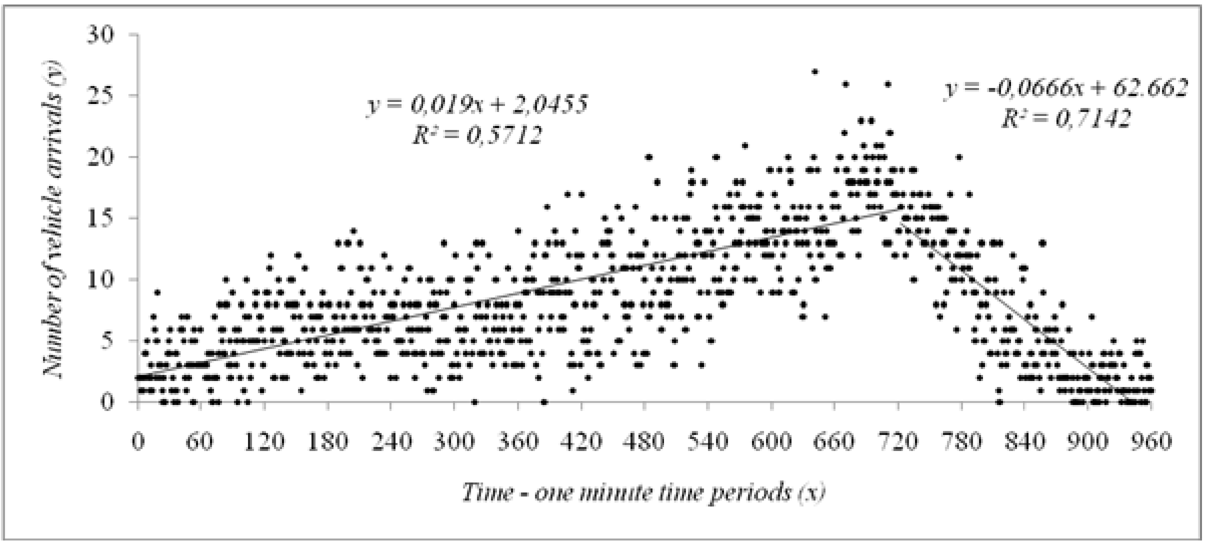

Figure 3. Scatter plot and regression trend lines of vehicle arrivals during one minute time period.

3. ARRIVAL *PATTERN AND SERVICE TIME*

From data presented in Figure 3. it is possible to develop empirical vehicles arrival pattern distribution which is shown in Figure 4. Calculated expected number of vehicle arrivals, which is the average of these empirical data, is 8,34 vehicles per minute.

The final step in this research is to examine service time distribution at the toll station. Service time data are collected by observation and measurement of time needed to approach the toll station, get the service at the toll station (i.e. pay the road toll) and leave the toll gate station. The sample consists of 400 vehicles, and for each vehicle service time is measured. Empirical service time histogram is depicted in Figure 5. Calculated value of the expected service time, which is mean value of discrete random variable, is 0,32 min per vehicle.

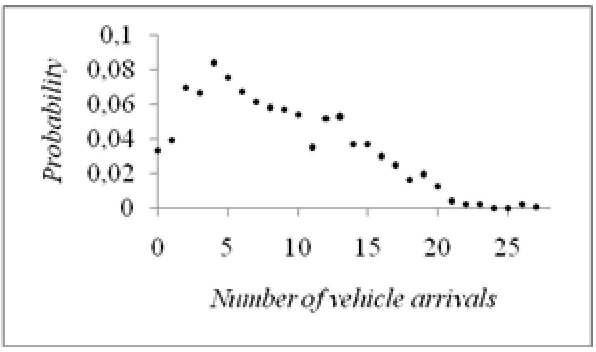

Figure 4. Empirical service time histogram

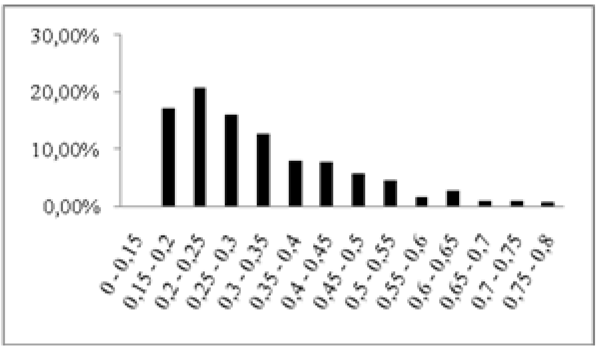

Figure 5. Empirical arrival pattern distribution.

4. CONCLUSION

In this paper historical traffic data are used to analyse temporal variation in the traffic flow at the highway tollgate station Josanica at the north exit of the capital of Bosnia and Herzegovina Sarajevo. The results show noticeable traffic flow patterns on daily, weekly and monthly bases. Within a day, traffic flow variation shows steady increase of vehicle arrivals until 6:00 p.m., and after 6:00 p.m. a decrease in traffic flow is registered. Within a week, traffic flow for all 52 weeks in a year, show the same trends, steady increase of traffic flow from Monday to Friday, and a decrease in traffic flow from Friday to Sunday. Linear regression analysis produces high coefficients of determination for both trends – from Monday to Friday and from Friday to Sunday. Regression analysis on monthly basis shows presence of strong trends. From January to August increasing trend in the traffic flow is registered, while this trend is decreasing from August to December. Also, linear regression models indicate high coefficients of determination for these two trends.

The future work should take into account overall traffic flow including all highway gates, as well as numerical simulations of highway traffic flow.

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