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TRAFFIC MODEL AS AN INSTRUMENT OF MEASURING IMPACT OF DISABLING ONE STREET LANE ON BUS MOVEMENT IN THE RUSH HOURS

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Abstract

The article contains the modelling of the traffic disturbance of the public transport buses, caused by the failure of the water supply system. The failure occurred on the Władysława IV Street in Gdynia, on the stretch between Kilinskiego Street and Marshal Pilsudski alley, around the noon. The consequences of fault have been removed by workers about 5 pm. however, it turned out that, under the asphalt was formed the gap by the water. For the safety the traffic was closed (at 5 PM) on the section from the Kilinskiego Street and the Marshal Pilsudski alley. All the public transport and also individual transport was diverted on the parallel Świętojańska Street. The article presents a model of buses delays, as a function of time. The methodology of assessment and verification of the model is also presented. The data were collected from the TRISTAR – Tricity Intelligent Traffic Control and Management System, especially from the reporting points for buses. Data from the accident are compared with the data during a normal day without failure. The data represent the travel times of buses (which are going on the bus lane) on the stretch from the Armii Krajowej Street to the bus stop: Wzgórze Świętego Maksymiliana Street.

Keywords: *transport, road transport, modelling*

1. Introduction

The Tricity is a metropolitan area in the North of Poland, consisting of three cities such as Gdansk, Gdynia and Sopot. They are situated adjacent to one other, in a row on the coast of Gdansk Bay, the Baltic Sea, in northern Poland. The Tricity Metropolitan area has a population more or less above one million citizen. The most important task for Tricity authorities is traffic flow management from neighbouring cities. The congestion was one of the most bothersome problem for citizen. Cities of Tricity Agglomeration started to work out conceptions of traffic management systems called TRISTAR in 2002. Tricity's Agglomeration Intelligent Transportation System includes agglomeration of three cities: Gdansk, Gdynia and Sopot, Fig. 1. The Intelligent Transport Systems (ITS) can significantly contribute to a more efficient transport system in urban areas. Intelligent Transportation Systems provide tools such as advanced management traffic systems to improve transportation systems. It aims at improving flow and safety of traffic and boosting interest in public transportation in the Tri-City. Traffic Management System of Public Transport Vehicles in Intelligent System Tristar transport is responsible for providing timely and carried out on a regular trip. Public transport vehicles are equipped with special sensors is the ability to track vehicles in real time. Module Vehicle Location of Public Transport is responsible for it that provides the location of the geographical location of specific vehicle, on-board computer provides this information and it is located in the vehicle, Fig. 1. Cooperation with the module Priorities for Public Transport Vehicles, the system provides a good level by means of sending information. With this data, the system can decide on granting priority to public transport vehicles [1] Oskarbski 2016.

2. Description of modelled stretch of the network and failure

2.1. The modelled stretch of the network

Gdynia is a city in northern Poland in Pomeranian Voivodeship, and is an important seaport of Gdansk Bay on the south coast of the Baltic Sea. It has about 248 000 inhabitants and 135 km^2 [2]. Bus lane on the Wladyslawa IV Street is approximately 900 meters long starts at the intersection of Kilinskiego Street with Władysława IV Street and ends near the bus stop on Avenue of Marshal Pilsudski, Fig. 1.

Fig. 1. The localization of Wladyslawa IV Street / mapa.trojmiasto.pl

2.2. Failure description

The incident took place 10/06/2016, it was the failure of water supply on the bus lane in Gdynia on Wladyslawa IV street. The failure resulted in long delay in the traffic not only buses but also for all traffic participants. Failure of water supply took place near a bus stop "Kilińskiego". „Employees PEWIK Gdynia removed the fault at 5 P.M. During the work was discovered that the water washed the significant amount of sand, creating a large hole under the asphalt. For the safety of the movement of closed Wladyslawa IV Street, making detour Swietojanska Street [3],

The measurement of time passage was from the departure from the bus stop Army street until arrival at the bus stop "Hill St. Maximilian", Fig. 2. The route is approximately 1000 m and in the area, there are five intersections including four with traffic lights.

3. Characteristics of the output data

3.1. Factors resulting in differences of travel time

There are two kind of variables, deterministic and random, that affect the travel time. These are:
- number of intersection with traffic lights, deterministic,
- the time of waiting for the green light at intersections with traffic lights, random,

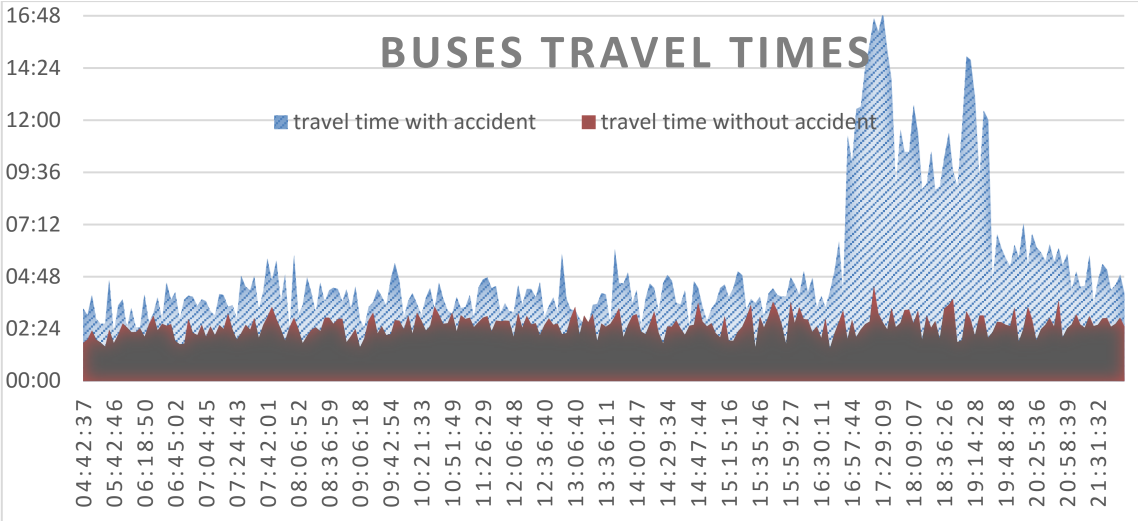

Fig. 2. The graph of travel time for the buses of the incident and also to compare the travel times in the day without incident

– number of bus stops, deterministic,
– number of passengers getting on and getting off at bus stops, random,
– volume of traffic on sections where the bus does not move on the bus lane, approximated by deterministic step function depending on the time of day,
– number of vehicles parked on the parking spaces along the bus lane, random,
– the variety of buses: hurried / normal buses, because hurried buses not stop at the bus stop "Kilińskiego" on the route.

Scheduled time between stops is 3 minutes and 4 minutes at peak hours.

The data travel time on the route where the incident had occurred comes from the FAS. FAS are one of the programs to support efficient management of public transport in the Tricity. FAS program is used to supply and read the data from the reporting points, which are located throughout the road network, which are moving public transport vehicles. FAS also give you the ability to monitor and analyse programs of traffic lights. Reads the telegrams, which are sent constantly by traffic lights in the multi-database, prepares and offers various possibilities for assessing whether analyse. FAS in particular, create so-called Tracked courses, which are all the rides such as buses based on received telegrams. On the tracking of the course are based on further analysis, e.g. Travel times, schedule of travel time or assessment reporting points. FAS system consists of various software modules that operate independently and communicate with the database FAS [1]. In the Article [4] authors said that the average travel time between bus stops is equal:

$$T_{śr} = 115.56\, L^{0.57}\, e^{0.05LP} + 1.51 LP \cdot TP_{śr}\,, \tag{1}$$

where:
$T_{śr}$ – average travel time between bus stops,
L – distance between bus stops,
LP – number of bus stops between intersections,
$TP_{śr}$ – the average total service time bus stops.

There are many ways to measure transport system efficiency, which can result in different conclusions. Efficiency can be assessed by, Levine J., Grengs J., Qingyun Shen & Qing Shen (2012):
– conventional roadway planning evaluates roadway efficiency based on motor vehicle travel speeds,
– traffic network planning evaluates roadway efficiency based on automobile access, and so recognizes the reduced travel distances that re result from more connected road networks and

two-way streets,
- multi-modal transport planning recognizes that travel demands are diverse because not everybody can drive, and transport costs (including road space, parking, vehicle, travel time, accident risk and environmental costs) and benefits vary,
- accessibility-based transport planning recognizes that mobility is seldom an end in itself; the ultimate goal of most transport is access to services and activities such as education, employment, shopping and recreation,
- economic efficiency refers to the degree that consumer benefits provided by a good exceeds the costs of producing that good (roads can be considered a good consumed by users),
- planning efficiency refers to the degree that planning activities are comprehensive and integrated, so that individual, short-term decisions support strategic, long-term goals.

In the article, we use public bus delays time as a measure of transport system efficiency.

3.2. Mathematical model of route time

Bus travel time (T_p) is the random variable specified by formula (2):

$$T_p = T_{average} + l_{stop} T_{stop} + l_{intersection} T_{intersection}\,, \tag{2}$$

where:
$T_{average}$ – the average travel time,
l_{stop} – number of bus stops,
T_{stop} – waiting time at a bus stop,
$l_{intersection}$ – number of intersections,
$T_{intersection}$ – time waiting for the green phase.

The random variable $T_{intersection}$ is distributed with cumulative distribution function given by (3):

$$F_{T_{intersection}}(t) = \begin{cases} 0, & \text{for} \quad t \le 0, \\ \dfrac{t_z}{t_z + t_c}, & \text{for} \quad 0 < t \le t_z, \\ \dfrac{t_z}{t_z + t_c} + \dfrac{t - t_z}{t_z + t_c}, & \text{for} \quad t_z < t \le t_z + t_c, \\ 1, & \text{for} \quad t_z + t_c \le t, \end{cases} \tag{3}$$

where:
t_c – time between phases green,
t_z – minimum green phase.

Stop random variable T_{stop} is distributed with cumulative distribution function, (4), of a particular model:

$$F_{T_{stop}}(t) = \begin{cases} 0 & \text{for} \quad t \le a, \\ \dfrac{t-a}{b-a} & \text{for} \quad a < t \le b, \\ 1 & \text{for} \quad b \le t\,. \end{cases} \tag{4}$$

Because random variables T_{przys} and $T_{światła}$ are independent then random variable $T_p - T_{average}$ has the following cumulative distribution function, (5) [6]:

$$F_{T_{śp}}(t) = \int_0^\infty F_{T_{światła}}(t-\tau)\,\mathrm{d}F_{T_{przys}}(\tau)\,. \tag{5}$$

Random variable is a variable with shifted triangular distribution, Fig. 4, and parameters dependent restrictions on the minimum times of the green and the modal value of the number of passengers waiting at the bus stop [3].

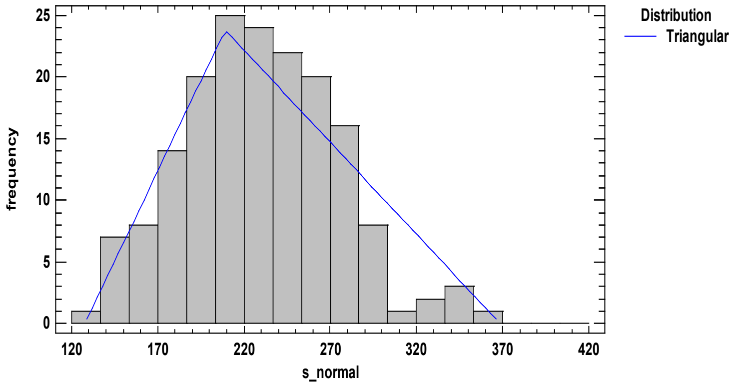

Fig. 3. The Frequency Histogram of empirical data and triangular density function, Smolarek L., Ziemska M.

4. Statistical analysis of the data

4.1. Two-Sample Comparison

The procedure is designed to compare two samples of data of the incident (delay_f) and also to compare the travel times in the day without incident (delay_m). The Statgraphics Centurion was used to calculate various statistics and graphs for each sample, and several tests to determine whether there are statistically significant differences between the two samples.

Tab. 1. The summary statistics for the two samples of data

Coeff. of variation	9.02449E13%	1.27613E14%
Standard deviation	228.921	44.8223
Average	2.53666E–10	3.51E–11

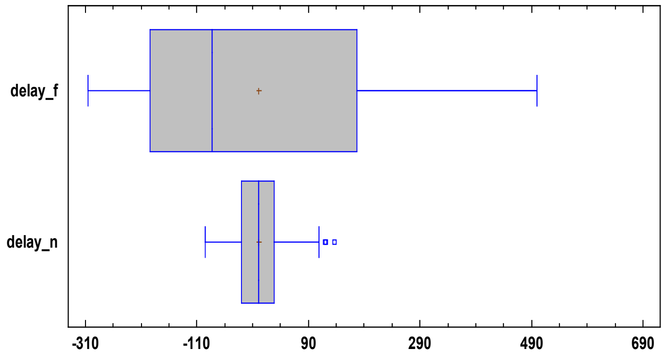

Fig. 4. The Box and Whiskers Plot

Box-and-Whisker Plot, Fig. 4, displays a five number summary of each sample with an indication of any outside points. Other tabular options can be used to test whether differences between the static statistics from the two samples are statistically significant.

Tab. 2. The Kolmogorov-Smirnov Test

Estimated overall statistic DN = 0.492537Standard deviation
Two-sided large sample K-S statistic = 3.41732
Approximate P-value = 0

This test was performed by computing the maximum distance between the cumulative distributions of the two samples. In this case, the maximum distance is 0.492537, which you can see visually at Quantile Plot, Fig. 6. or Frequency Histogram, Fig. 7. Of particular interest is the approximate P-value for the test. Since the P-value is less than 0.05, there is a statistically significant difference between the two distributions at the 95.0% confidence level. The Quantile Plot displays the empirical cumulative distribution for a column of numeric data [7].

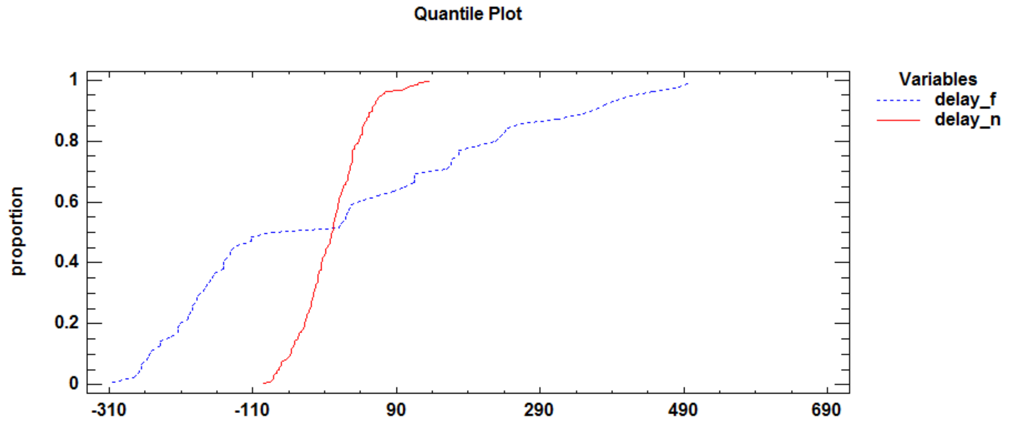

Fig. 6. The Quantile Plot

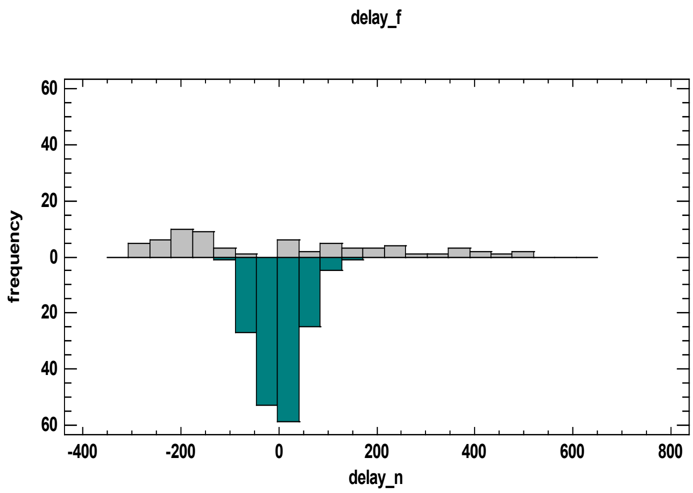

Fig. 7. The Frequency Histogram

5. Equations

Models of changes of delay as a function of time (time of day) will be presented. The model is the sum of a polynomial of the fourth degree, an example (6) and the random disturbance with the gauss probability distribution, Fig. 8.

$$\text{delay} = -0.0003t^4 + 0.0065t^3 - 0.0405t^2 + 0.1106x + 0.0683\,. \tag{6}$$

The use of a detour in the initial phase resulted in a reduction in delays, but because of its smaller capacity and routing of all traffic on a detour caused traffic jams on the tour.

6. Conclusions

The efficient transportation systems are those that could move people to their destination quickly, easily, and comfortably. Detection of incidents on the road based on changes in transit times require:

– define standard parameters of traffic flows (based on. Initial measurements),

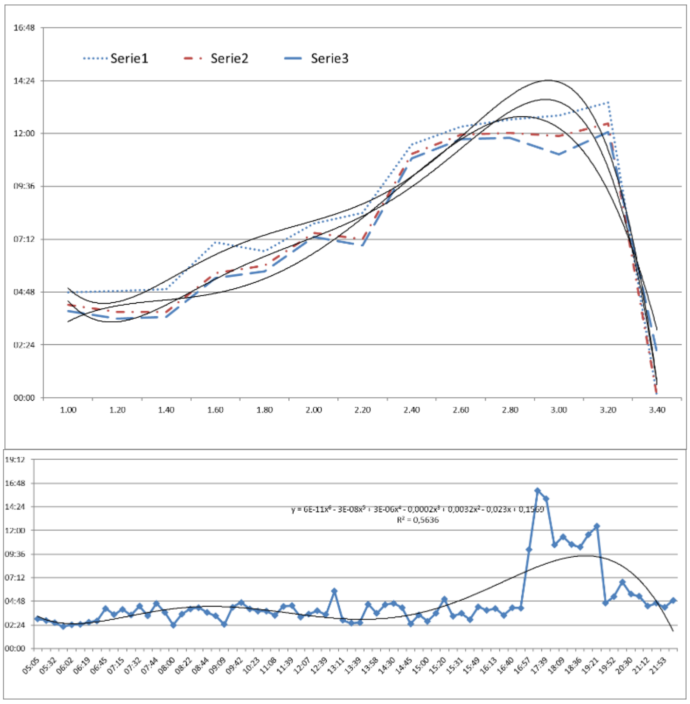

Fig. 8. The examples of delays

– define thresholds for the average journey times on the sections in different traffic conditions (different times of day, on different days of the week), determine the travel times in conditions of freedom of movement [5],
– matching detour through alternate routes tailored to the road network in the vicinity.

Investigations on distribution of transit times before and during the accident indicated that in the case of buses run on bus lane travel time they can be used for failure detection. Intelligent Transport Systems are a suite of public transport planning, operations management and customer service. Therefore, it is necessary to develop rules for use of the detour, that is, determined when and to what extent they should be started if it is necessary.

Traffic management at a time when there are failures in the traffic should not only focus on the detection of events, road management alternatives but also operations management, efficient information for road users by radio, variable message signs, passenger information boards, etc.

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