

TRAFFIC CONDITIONS ANALYSIS BASED ON AN ADVANCED TRAVELLER INFORMATION SYSTEM OF VILNIUS CITY

Marius Jakimavicius

*Vilnius Gediminas Technical University, Saulėtekio ave. 11, LT-10223 Vilnius, Lithuania.
E-mail: mjakimavicius@hnit-baltic.lt*

Abstract. As a subsystem of an Intelligent Transportation System (ITS), an Advanced Traveller Information System (ATIS) disseminates real-time traffic information to travellers. To help travellers better make their route choice decisions, there is a strong need to predict traffic congestion and disseminate the predicted congestion information to travellers. This paper describes methodology used for optimal driven route calculation based on real time traffic data in Vilnius city WEB based application for drivers. The paper also discusses about traffic conditions and impacts when is closed one of the main Vilnius street. Furthermore, a comprehensive traffic modeling procedure is presented, which forecasts and computes very important traffic modeling indicators like driving time, driving downtime, driving distance, fuel consumption.

Keywords: advanced traveller information system, route planning, real-time traffic data, travel time, traffic modeling.

1. Introduction

The deployment and operational efficiency of Advanced Traveller Information Systems (ATIS) entail the accurate modeling of driver route choice behavior under real-time traffic information and the calibration of the associated model parameters. Driver en-route routing decisions are influenced by personal attributes, response attitude to the supplied information, and situational factors such as time-of-day, weather conditions, trip purpose, and ambient traffic conditions (Jarašūnienė 2007; Stan 1995). The latent preferences of drivers towards possible routes are typically difficult to capture accurately because they are significantly affected by past experience, subjective interpretation of the traffic information provided, and personal attitudes dynamically changing traffic conditions. Most existing models are limited in their ability to capture the interacting effects of various situational factors, and typically cannot adjust model parameters in a within-day context. The latter capability is critical for consistency-checking procedures for the real-time operational deployment of advanced information systems. Driver route choice models under information provision have traditionally adopted the econometric theory of random utility maximization (Akiva and Lerman 1985).

(Mahmassani and Liu 1999) used a multinomial framework to model and calibrate the commuter joint pre

trip departure time and route-switching behavior in response to ATIS, based on data from a laboratory interactive dynamic simulator. The study suggests that commuters switch routes if the expected travel time savings exceed indifference band which varies with the remaining trip time to destination. (Aty *et al.* 1997) developed logic models to capture the effect of traffic information on commuter route choice using stated preference data. They analyzed the influence of travel time variability, and the effect of information on it. The choice between a longer route with reliable travel time and a shorter route with an uncertain travel time is investigated based on notions of risk aversion and risk-taking in route choice. Developed logic models to predict drivers' route diversion decisions under traffic information provided via variable message signs (Peeta *et al.* 2005; Möhring *et al.* 2005). They showed that a strong correlation exists between message content and driver route diversion decisions, which can be a control variable in operational strategies to enhance network performance (Peeta and Gedela, 2001). (Khattak and de Palma 2007) use ordered probit models to investigate the effect of weather on traveller behavior, and suggest that commuters change their travel patterns systematically under adverse weather.

In the context of route driver behavior under information provision, qualitative phenomena such as inertia, compliance, delusion, freezing, and perception of traffic information, have recently been identified. (Srinivasan

and Mahmassani 2000) developed a multinomial model with a nested choice structure to examine inertia and compliance. Inertia represents the propensity to remain on the current path, while compliance represents the tendency to choose the path recommended by the traffic information system.

Many authors performs traffic modeling based on micro-simulation approach, describes both the traffic network and dynamic entities, namely vehicles, traffic lights, and pedestrians. The framework allows defining systematically the necessary components and their behavior of a model oriented to event driven simulation, which can be executed in a distributed way. In the model, the vehicles are conceived as mobile agents with decision making capabilities that interact with the environment and other entities within the traffic network, performing diverse activities according to numerous situations arisen during the simulation (López-Neri *et al.* 2010; Tolba *et al.* 2005)

Other scientist's presents the methods of selecting studied period of traffic impact analysis based on the cluster analysis, and puts forward the concept for the construction projects classification. It determines the analysis period according to the similarity between the same categories. Meanwhile, with the residential project sampling survey data of continuous traffic volume (Chen *et al.* 2009)

GIS could be also applied for the search for rational car routes when it is necessary to be at a specific spot of the network on the specific time. The system offers to a user a rational route, time of departure and calculated expenses depending on the set parameters and reel time traffic data. In other papers that analyze application of GIS technologies in transport task solution, an application of multi-modal networks could be spotted. They are applied when solving route choice tasks within the overall urban transport system: cars, public transport, railway transport, and even pedestrians (Abdelghany *et al.* 2001; Jakimavicius and Burinskiene 2007). The assessment of transport jams on the street network is necessary when solving the task of the choice of the fastest route. A search algorithm, the results of which depend on the time set by a system user, has been programmed as the street capacity is different depending on the time of the day (Peeta and Whon Yu 2005; Jakimavicius and Macerinskiene 2006). The general public might be the user of IS, which helps to choose a rational driving route. Applying ESRI technologies, a system user is given WEB based GIS application, which has functioned allowing to set the beginning and the end of the trip, and the interim stopping places (if necessary). IS user is given a map with the marked rational driving route according real time traffic data. The system also could forecast rational driving route according historical traffic data.

2. Vilnius city transport system indicators and description of information system for drivers

Growing Lithuanian economy and increasing quality of the living conditions prompts population's mobility,

the motorization level and increasingly high transport flow on the countries streets and roads (Jakimavicius and Burinskiene 2007; Burinskiene and Paliulis 2003).

Average percentage number of Vilnius city automobiles quantity is increasing per year about 3%. Number of personal cars in Vilnius city rose from 265 automobiles for 1000 inhabitants in 1999 till 560 in 2010 year. Sharp bounce of motorization level invokes a lot of transportation problems. The main Vilnius city transport system indicators form Vilnius municipality enterprise company "Susisiekimo paslaugas" are presented in Table 1.

Table 1. Transport system indicators in Vilnius city, 2008, 2009 and 2010

Indicator	2008	2009	2010
Street network density (km/km ²)	3.1	3.3	3.6
Public transport network density (km/km ²)	0.74	0.61	0.76
Average traffic flow in peak hours (aut./h)	1550	1567	1588
Percentage number of trucks in average flow	2.1	2.2	2.0
Average speed in peak traffic flow (km/h)	31	31.3	30.5
Modal split			
- pedestrian trips in %	33.1	30.8	32.8
- trips by bicycles in %	0.3	0.3	0.3
- trip by public transport in %	40.9	38.2	37.2
- trips by car in %	25.7	30.7	29.7
Transit of trucks in peak hours in %	10.1	11.2	11.4

Many scientific researches analyze transport information system from the point of intelligent transportation according route planning functionality (Szucs 2009).

Developed Vilnius information system for drivers has route planning functionality. System user can optimal route planning tasks according real time traffic information data (see Fig 1 and Fig 2).

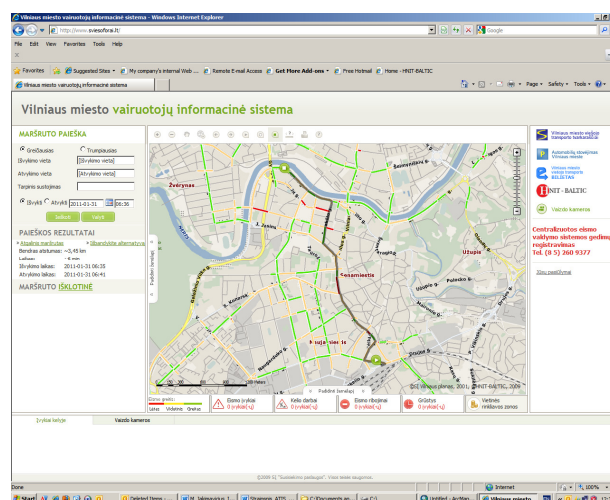


Fig 1. Optimal route calculation for morning peak hours

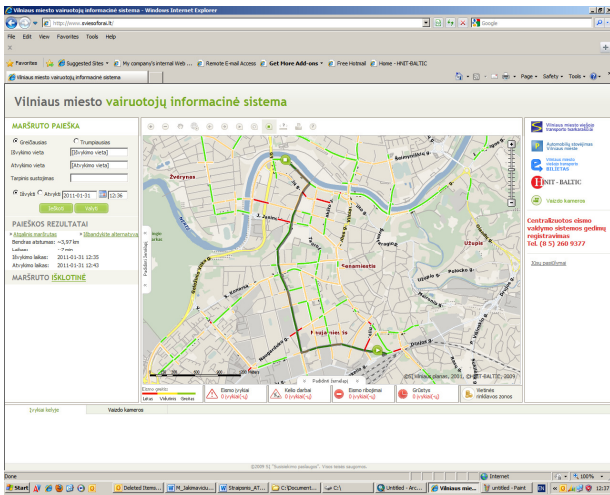


Fig 2. Optimal route calculation for midday hours

3. Methodology of Vilnius city traffic modeling

A transportation model can be described as being a mathematical model of a certain geographical area and the transportation system in this area, focusing on how traffic is generated in each geographical area, how it is distributed between origins and destinations of trips, and how it is assigned to the various transportation networks within the area. Vilnius city is divided into these transportation zones (see Figure 3).

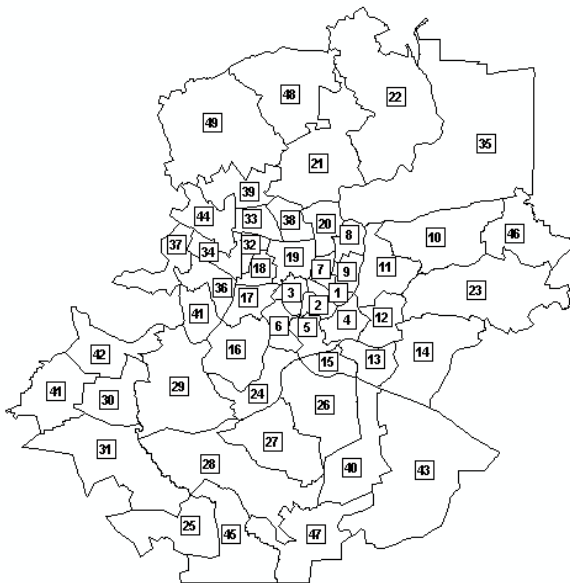


Fig 3. Transport analysis zones of Vilnius city

The aim of the model was to represent travel times and traffic flows during the morning rush hour in Vilnius under different assumptions of the transport system, distribution of the population, employment and car ownership. Therefore, the study area of the model includes the whole of Vilnius. The used zone system consists of 51 zones.

For each zone in the study area, it was necessary to obtain information about the population, the number of

working places and the travel pattern to and from other zones. Model calibration was based on actual traffic volumes (morning peak hour 2009). The population of each zone was calculated from a register of voters and an address table. Information about the number of employees in each zone was obtained from Vilnius comprehensive plan GIS database.

Attribute data was related to zones, streets and public transport network GIS objects. This united attribute and geographic data is stored in the GIS database which structure is suitable for performing modeling with Traffic Analyst software. Stored GIS databank contains the following data for the base year:

- Population and employment by zones;
- Number of trips by car and by truck and by public transport between the zones;
- Travel time by car between zones;
- Number of registered cars per resident.

The size of the model area, the level of detail of the model, and the complexity of the mathematics involved can all vary substantially, depending on the purpose of the specific transport model. Transport models from most of these applications are developed at many different scales from cities of 20,000 inhabitants, say, to major metropolitan areas of millions. In general, transport models have a wide range of uses and therefore, also vary greatly in complexity and data requirements. For Vilnius city transportation model was created using Traffic Analyst software.

Traffic Analyst consists of a collection of geoprocessing tools, supported by an underlying data model and some specialized editing tools. The Traffic Analyst geoprocessing tools implement all calculation functions commonly used in transportation models. Using ArcGIS Geoprocessing to combine these tools allows the users to build exactly the modeling functionality needed, making it possible to build models ranging from simple to very complex transportation models.

The use of the ArcGIS Geoprocessing framework also makes it possible to freely blend Traffic Analyst tools with ESRI Geoprocessing tools, user-made scripts and tools, and other 3rd party Geoprocessing tools, thus allowing a very large degree of flexibility.

Trip generation

Underpinning the Traffic Analyst tools is an implicit data model for the data necessary for a transportation model. These can roughly be divided into:

- Socio-economic data – associated with the zones usually used to subdivide the area being modeled;
- Travel patterns (Trip Matrices) and descriptions of travelers' preferences;
- Infrastructure networks – Road, Rail, Light Rail etc.
- The transit network – the public transport lines and timetables (bus, rail, light rail etc.).

Calculations by Traffic Analyst software:

Calculates trip production, P and trip attraction, A for each unique combination of zone, i and category, k :

$$P_{ik} = f_{1k} \cdot P_{1k} + f_{2k} \cdot P_{2k} + \dots \quad (1)$$

$$A_{ik} = g_{1k} \cdot A_{1k} + g_{2k} \cdot A_{2k} + \dots \quad (2)$$

Where f and g are generation parameters. These are combined with zone specific socio-economic data such as population or number of workplaces in order to perform the calculation.

Trip balancing

Performs balancing calculation of generated trips. This is done to ensure that the total number produced trips equals the total number of attracted trips. The calculation can be performed as:

$$P_i = fP_{oi} + (1-f)P_{oi} \frac{\sum A_0}{\sum P_0}, \quad (3)$$

$$A_i = (1-f)A_i + fA_{0i} + \frac{\sum P_0}{\sum A_0}. \quad (4)$$

Where f is the balancing factor

Trip distribution

Calculates deterrence matrix on the basis of a Cost Matrix and gravity model parameters. The deterrence value for traffic from zone i to zone j for category k is calculated as:

$$fC_{ijk} = C_{ijk}^{-\alpha} e^{-\beta C_{ijk}}. \quad (5)$$

This tool typical use of this tool is to transform a 24 hour matrix (symmetric) into e. g. a morning rush hour traffic matrix (asymmetric). This can be done either by the use direction distribution parameters or by using an existing or estimated OD matrix. In the first case the calculation is performed as:

$$OD_{ij} = \alpha_1 PA_{ij} + (1 - \alpha_2) PA_{ji}, \quad (6)$$

$$OD_{ji} = (1 - \alpha_1) PA_{ji} + \alpha_2 PA_{ij}. \quad (7)$$

And in the second case the calculation is performed as:

$$OD_{ij}^{NEW} = \frac{OD_{ij}^{OLD}}{OD_{ij}^{OLD} + OD_{ji}^{OLD}} (PA_{ij} + PA_{ji}). \quad (8)$$

Modal split

Modal split performs calculation on an OD matrix with traffic for all modes. The matrix is split up into an OD matrix for each mode using a logit model with non-correlated alternatives. The probability for a given mode k , can be calculated as:

$$P_{ijk} = \frac{e^{-\beta C_{ijk}}}{\sum_m e^{-\beta C_{ijm}}}, \quad (9)$$

$$T_{ijk} = T_{ij} P_{ijk}. \quad (10)$$

Car assignment

An important part of most transportation models is the ability to simulate the flow of car traffic, and to calculate the related effects (such as resulting speeds of the traffics flows and the resulting average travel lengths and -times between zones).

The Car Assignment tool is used to perform these calculations. In overall terms, the approach is the following:

The area being modeled is described using the following model data:

1. The area is described by dividing it into a number of zones.
2. Travel patterns are described as trip matrices, describing the number of trips between each pair of zones.
3. The road network in the area being modeled is described using a network of links and nodes. This network is connected to the model zones.
4. Various parameters describe the car travelers' preferences regarding choice of route.

The figure below shows an overview of input and output data for the Car Assignment tool.

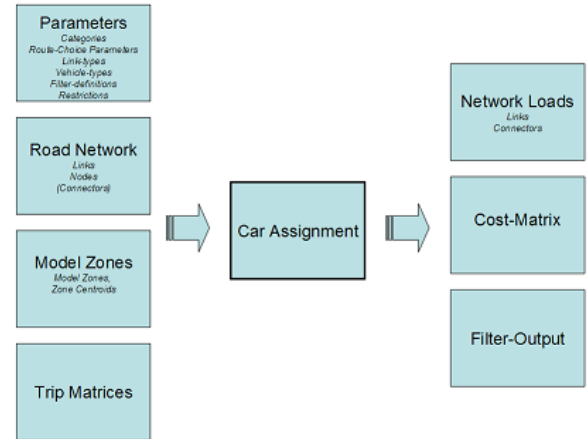


Fig 4. Input and output data of car assignment tool

Using these data the following calculations are carried out:

- For each pair of model-zones, the best travel route through the network is calculated (how the 'best' route is defined, is described in more detail below).
- The amount of traffic between the pair of zones (described in the trip matrices) is added to each link in the travel route.
- Optionally, if road capacity data was included in the network data, the travel time for each link is updated, as a function of the amount of traffic on the link.

Depending on how the Car Assignment tool is used, these steps can be repeated a number of times. When the calculations are done, the main outputs are:

- Traffic flows, in the form of an amount of traffic per road link.
- Travel Costs, described in the form of average travel costs (length and distance) between each pair of zones.

The Traffic Analyst Car Assignment tool is a static assignment tool. That is, the calculation output represents a static average of the period being modeled. This is the most widely used traffic assignment modeling approach.

4. Results of Vilnius city traffic modeling

Two different Vilnius city transport system scenarios have been modeled for evening peak hours. The first scenario presents traffic situation when Konstitucijos street is open and the second scenario presents Vilnius city traffic situation when Konstitucijos street is closed. This scenario presents Vilnius city traffic information on the 1st of September, 2010 when F1 pilot D. Coulthard provided show drives in this Vilnius street. Have been modeled traffic situation according present transport and socio-economic data and present Vilnius city streets network.

Land-use is possible to be modified through changes in the size of the population and the number of workplaces in each zone. There are possibilities to analyses different levels of expansions, the growth of new suburbs, relocation of working places and other land-use strategies. Car ownership in 2010 was estimated 560 cars per 1,000 inhabitants. The total number of car trips in the region is calculated as a function of changes in the total population and the car ownership as compared to the base year situation. The consequence is that if the population and car ownership is unchanged as compared to the base year situation but the total number of workplaces increased, then the total number of car trips will be the same as for the base year situation. If the workplaces are relocated, for example to more central areas, it will have an effect on the trip's pattern for cars but not on the total number of trips.

The trip frequencies in the Trip Generation model are estimated and based on the travel behavior in 2010. Hence, it is the level of car use for the base year situation that is included in the model. If there is reason to believe that the cars will be used to a higher extent in the future then the way to implement that in the Model is to increase the car ownership a slightly in addition to the increase of the number of registered cars per capita.

Street Network 2010 – means the current street network and other infrastructure, i.e. length of the streets, number of lanes, modes allowed, and volume-delay function index.

Social Data 2010 – current situation, i.e. total number of inhabitants is 548835 and the rough number of workplaces is 365000.

Detailed traffic modeling results are presented in Table 2.

Table 2. Vilnius city transport system modeling results

Indicator	Konstitucijos street is open	Konstitucijos street is closed
Length of street network, km	1790	1789
Driving time, h.	28250	44200
Driving downtime, h.	21200	27120
Driven distance, km	882541	91214
Fuel consumption 1 aut-km, litr.	0,0954	0,1210

5. Conclusions

1. Urban transport system analysis model was developed for Vilnius conditions, which estimates the fuel consumption, average travel distance and driven time by car in evening peak hours depending on Konstitucijos street functionality. This model should be used when evaluating new projects of the transport's infrastructure (by-passes, new bridges) and when evaluating the economic efficiency of traffic organization projects.
2. For evaluating urban areas land use scenarios according transport system sustainability successfully could be used integrated traffic modeling methods with GIS software, also for urban areas transport system detailed analysis in order to calculate traffic indicators could be used traffic modeling software.
3. Hence, various developments have strengths and weaknesses. Konstitucijos street in Vilnius city has a very important communication. When this street is closed there are negative spin-offs in the overall transportation sustainability and livability of the Vilnius. Fuel consumption rises over 20 %, driving time rises over 35 %.

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