# Telematics system for increasing the road safety by predicting the occupancy of the parking areas on the highways

Z. LOKAJ, M. SROTYR, T. ZELINKA, M. JERABEK, P. KUMPOST
Department of Applied Informatics in Transportation
Czech Technical University in Prague
Konviktska 20, Prague 1, 110 00
CZECH REPUBLIC
lokajzde@fd.cvut.cz, srotymar@fd.cvut.cz, zelintom@fd.cvut.cz, jerabem1@fd.cvut.cz, kumpopet@fd.cvut.cz http://www.fd.cvut.cz

*Abstract:* - The paper presents the telematics system which deals with a problem of lack of parking places for trucks. This problem can lead to very dangerous situation with improper parking of these trucks. The presented telematics system provides information about the predicted occupancy of parking areas along the highways. This information will help to optimize the usage of existing parking and it is useful for truck drivers in their decision making process of selection the appropriate place for parking, which will contribute to the fluency and safety of traffic as a whole.

*Key-Words:* -electronic toll, parking, telematics, prediction

## 1 Introduction

With the lack of parking spaces for heavy goods vehicles face the entire road network in the Czech Republic. The worst situation is on highways, where we often encounter dangerous situations parked truck right onto the ramp to gas stations or their exits. This situation is similar throughout Europe; the importance of this issue is demonstrated by the Action Plan for the Deployment of Intelligent Transport Systems in Europe, which contains measures "Development of appropriate measures including best practice guidelines on secure parking places for trucks and commercial vehicles and instructions for parking and reservation telematics systems". The high traffic intensity raises a number of transportation problems related to the lack of parking spaces, and therefore is accurate and accessible information about available parking spots very valuable in everyday use and also very important for the planning of efficient and safe transport.

The project, which partial result describes this article, is focused on creating a telematics system that will be based on the input data of the toll system to predict the occupancy of individual parking spaces to provide information to optimize the usage of existing parking areas on the highway network. The outputs of the model will be forwarded to appropriate channels for drivers who thereby greatly facilitate decisions about the appropriate place for parking and thus contribute to the overall fluency and traffic safety as a whole.

Reasons for system of increasing the usage of parking facilities for trucks on the highway network in the Czech Republic using prediction models are especially:

- increasing the intensity of freight transport on the highway network in the Czech Republic, for the reason that road freight transport is still cheaper than the railway, resulting in the observed lack of capacity
- 30-40% of road accidents are caused by driver fatigue, due to the extending of driving and ignoring the mandatory rest breaks
- priorities of the EU, increasing parking capacity on highways handles projects as CONNECT, Easyway, Intelligent truck parking, etc.
- inefficient use of parking lots
- uneven distribution of load of parking lots
- driving round highways and finding a parking space, which means the formation of undesirable emissions, congestion on local roads, noise and hazards caused by parking in places that are not intended to (emergency stopping lanes, ramps, etc.)
- lack of information on capacity and current vacancies in the parking areas
- determining the need for construction of new parking lots
- increased demand for parking due to the Just-in-Time
- reduction of investment in transport infrastructure construction, which increases the

demand for optimizing the use of existing infrastructure

The expected benefits of implementing an information system to increase parking utilization capacity are divided by system participants, because for each group are different.

The Benefits of implementing the system from the perspective of truck drivers

- knowledge of the current traffic situation before entering to the parking lot
- reduce the risk of stressful situations for drivers due to pressure on compliance with statutory breaks and thus enhance the security (reducing the risk of accidents due to fatigue during driving overtime)
- increased comfort while driving
- higher probability of finding a free parking place - eliminates the need for finding alternative places
- more effective route planning associated with savings of distance traveled and time

The Benefits of implementing the system from the perspective of car park operators

- increase the satisfaction and comfort of drivers
- optimized parking and better use of existing parking capacity
- elimination of the problem of exceeding the capacity of parking areas
- an increase in revenues from products and services offered on the parking lots due to optimized parking
- Optimization planning - supplying, staffing shifts, etc.

The Benefits of implementing the system from the perspective of the State

- reduce the externalities arising from traffic accidents, i.e. disposal costs, damages, costs for emergency operations, the cost of treating injuries, reducing state revenues due to the loss of the taxpayer (in the case of death)
- reduce the externalities arising due to leaving the highway network (emissions, noise and damage to roads)
- financial savings for the construction and maintenance of highway infrastructure, which arise due to fewer required newly built parking lots and also because there is no need to look for alternative parking outside the toll network
- achieving the objectives of the European "TEN-T" program by using telematics systems
- use of the toll system as a source of current traffic data (composition and characteristics of traffic flow) for the prediction model
- increase traffic safety
- reduce accidents
- increase driver satisfaction
- increase the usage of parking areas, and thus the potential increase in tax revenues (the driver will use more parking at us and there will be motivated to refuel, buy goods and services)

The Benefits of implementing the system from the perspective of roads administrator

- effective planning of maintenance of highways infrastructure
- effective planning the construction of parking areas on the highway network
- reduction of required maintenance and the associated costs on roads close to the highway network
- reducing the number of traffic restrictions associated with the construction and maintenance of new parking areas

The proposed application assumes the electronic toll collection data as the main source of data for the prediction model. , Such approach is fully in line with European initiatives, in particular the Action Plan for the Deployment of Intelligent Transport Systems in the EU and Directive 2010/40/EU on the framework for the deployment of Intelligent transport systems.[1]

The Action Plan analyzes the six priority areas for action, including a set of actions with a timetable for the expected realization. These areas were designed on the basis of information provided by stakeholders from the public and private sectors. For ITS applications that should be implemented in the short or medium term it is expected to meet their maturity, sufficient interoperability and the ability to operate in Europe as a catalyst. Currently the interoperability is considered as a key aspect leading to a pan-European individual ITS applications penetration. Strong emphasis is therefore also concentrated on technical standardization.

Projects related to intelligent parking areas for heavy goods vehicles involved in particular areas of activity 1 - Optimal use of road, traffic and travel data and 3 - The safety and security of road transport. Other areas of activity only touch this subject, and their main focus does not correspond to the solved issues, therefore there will be discussed only two mentioned areas.

The Directive 2010/40/EU provides a framework to support coordinated and coherent deployment and use of Intelligent Transport Systems (ITS) within the Union, in particular across borders between Member States and sets out the general conditions necessary for this purpose. The Directive defines the development of specifications for actions within the priority areas, which are discussed below. Possibly also leads to development of the necessary technical standards. The Directive is applied to applications and services in the field of road transport and application interfaces with other transport modes. Simultaneously are also respected the national security and defense.

For the purposes of the Directive are set out priority areas for the development and use of specifications and standards. Within these areas are specified the most important priority areas that clearly indicate the direction of the EU in the field of ITS. The area of smart parking concerns Priority Area 2 - Continuity of services of ITS in the field of management of freight traffic.

From the above it is clear that intelligent parking of trucks is an integral part of the European telematics platform and its implementation is related to the distribution of multi-modal transport data and increase the road safety.

## 2 Architecture of the telematics system

Architecture of the telematics system for predicting the occupancy of parking spaces on highways and expressways in the Czech Republic connects the database, prediction model and distribution channels for the providing information to end users.

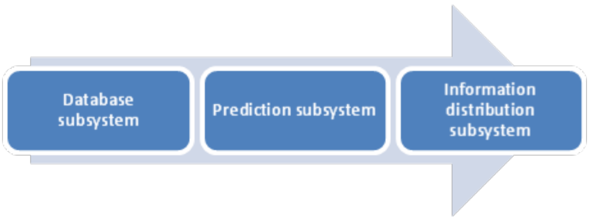


Fig. 1 Architecture of the telematics system

Architecture of the telematics system consists of three basic subsystems:

- database subsystem - data primarily consists of transactional data from electronic toll collection system, which are provided on-line (or at intervals close to on-line transmission) to prediction subsystem;
- prediction subsystem – the core of this subsystem consists of a predictive model that calculates by defined algorithms the probable occupancy of parking spaces on the highway network based on the data
- Information distribution subsystem – this subsystem uses the results of prediction model that processes and distributes intelligible information to end users.

### 2.1 Database subsystem

Subsystem of database combines data from data sources, both historical data and current data. This data are stored in the operational database in which the data are preprocessed so those with them are able to run a prediction model to predict the occupancy of parking lots on the highway network in the Czech Republic. Especially it is the calculation of driving time each detected vehicle and calculates intensity in each toll section.

Data base draws data from the following sources.

- the primary source are transactional data from electronic toll collection system, namely: a) historical data, which are recorded to operational database one-off; b) actual data, which are sent to the production database on-line c) telematics data (speed and composition of traffic flow), which are sent to the production database in batches;
- secondary sources are a) data from detection sensors located at the entrance and exit of the selected parking lot, used to calibrate the prediction model, these data are sent to the production database on-line as an individual transactions and batch for a defined time intervals, b) data from manual vehicle census at selected parking lots serving the calibration and validation of the prediction model; c) data from automatic vehicle census at selected parking lots from mobile surveillance vehicle of toll collection system; d) other traffic data, e.g. data from traffic sensors on highways etc.

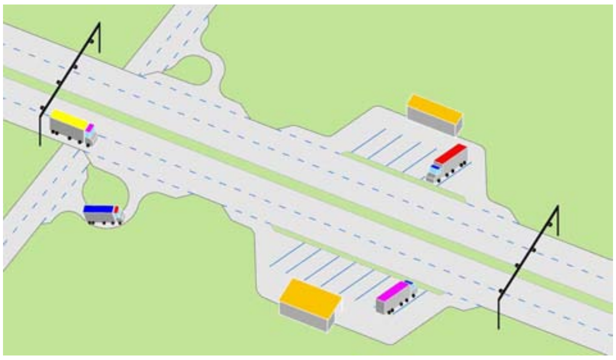

Fig. 2 Simplified diagram of the highway network with the location of parking areas, toll gates, entrance and exit ramps

### 2.2 Prediction subsystem

The prediction subsystem is the core of the entire system. It is connected to the subsystem of database over which implements the defined prediction algorithms.

The predictions are calculated in systems derived on the basis of fully formalized statistical methodology. At the core of the whole approach is the fact that value which is needed to predict, i.e. the number of free parking spaces, is directly unobservable. The prediction of this value should be constructed on the basis of correct algorithms derived from models for time series of observable variables. Basically, it is an estimate of the status-type model, which we deal with in a few steps. First, we construct the proxy variable for the latent number of vehicles parked on the parking lot at a time from the observed data on the passage of vehicles through toll gates. For the proxy variable we build a statistical model completely describing its dynamic and probabilistic behavior. Unknown parameters of the model of a particular class we estimate from the historical data from a passage through the toll gates. After more statistically demanding estimate the unknown parameters of the data (identification), the model has been fixed and used for routine, already simply available, predictions with parameters fixed at estimated values. With extended operation will be appropriate in the context of the entire system service (e.g. annually) to "re-learn" model, i.e. to re-estimate the parameters, or modify (or choose an entirely new) class model. According to our previous tests the stability of the estimated parameters using several months of data is significant and re-learning is not a critical requirement. From the estimated model we derive using the theory of Markov chains (Resnick, 1992 Klebaner, 2005) method for calculating the prediction of the number of vehicles parked on the parking lot for a set of necessary horizons. For fast and efficient implementation of predictive calculations in real traffic, we use a method based on Monte Carlo simulations. Prediction of the number of free parking spaces is obtained as the difference between extended parking capacity and prediction of parked vehicles, and for each of the required horizons. Prediction of the number of free parking spaces is using the subsystem distribution information transmitted to end users. Solution of the prediction system has been described in [1], [2] and [3].

The prediction subsystem is implemented in the first version of the telematics system as a script in the statistical software "R". This script implements algorithms for the minimum and maximum prediction horizons from 5 minutes to 150 minutes with a time step of 5 minutes.

Prediction process is performed at regular intervals and the results of the process are recorded in the table in the operational database where they are available to end users through distribution channels.

For each parking lot is available the information about the GPS position, the maximum capacity, detail of gas station or other information. This information is static and changes only when the layout changes such as reconstruction. For each parking lot are regularly at 10 minute intervals calculated prediction of the state of occupancy in several prediction horizon. In the functional sample we predict for the four parking lots on the highway D5. The prediction subsystem additionally maintains the entire history of the calculations of predicted occupancy for the all monitored parking lots. Historical data are another source of verification and validation of the prediction model.

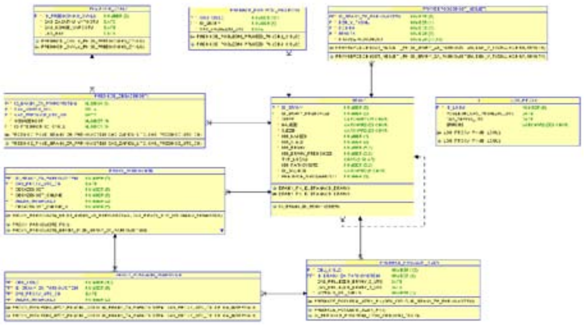

Fig. 3 Relational schema of the production database

Table of occupancy prediction for the parking lot contains the following parameters:

- ID of parking lot
- date and time of update
- prediction horizons – from a computational reasons the prediction is calculated for several horizons (windows), not continuously for each time point. The maximum prediction horizon is 150 minutes. Horizons are divided in 5 minutes and counting since the last update time,
- predicted occupancy status – for each forecast horizon is on the basis of the developed model calculated the predicted occupancy. Aggregate channel then assign a specified color according to the following table (Tab.1) to predicted occupancy.

| Occupancy [%] | color |
|---|---|
| <0,60) | green |
| <60,80) | yellow |
| <80,+∞) | red |

Table1Occupancy intervals and their color for drivers

## 2.3 Information distribution subsystem

Subsystem of distribution of information is from the end user perspective crucial component of the entire system. Distribution channels are the only interface between the telematics system and end-user, i.e. truck drivers. Selecting the appropriate information channel therefore fundamentally affects the efficiency of the entire system and the acceptability of the system by the drivers. Nowadays there are more and more options to display and distribute information.

For intelligent parking system is necessary to resolve the distribution of information channels that are suitable for this type of system. Distribution channel must be selected properly to be effective for distributing information and also for end users, truck drivers, acceptable.

### 2.3.1 Description of the data in the user interface

The user interface subsystem is represented by a channel of distribution of information to the end users (truck drivers).

To end users will be display information about the occupancy of parking lots on the highway in the direction of travel of the vehicle. The driver receives information about whether the parking lot in his driving direction is open or closed. If they are open, the information will refer to the availability of data to predict the state of occupancy for a given parking lot, resp. calculated predicted occupancy for the given parking lot. In case that parking lot is open and data of predict the states of occupancy are available, the system will provide information about the status of occupancy at the time of expected arrival on a parking lot. This situation is shown in the following figure.

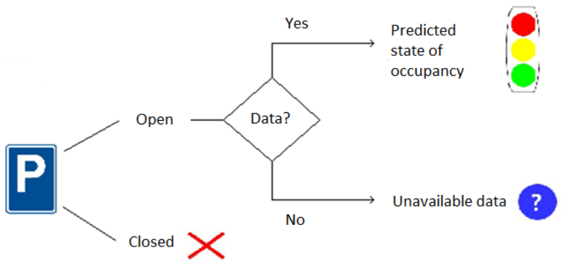


Fig. 4 Parts of a distributed information system for truck drivers

In case that parking lot is closed or no data of the predict the state of occupancy are available, truck driver will receive information in the form of simple signs (question mark in a blue circle or red cross) reflecting the situation.

For the open parking lot for which the data of predict occupancy are available, are distributed the following information:

- predicted occupancy - for drivers will be distributed only predicted information for the time of their expected arrival to the parking lot. Information about the current occupancy is only informative; it cannot affect driving behavior as well as using information about the predicted state. The model developed in this project counts only predicted states.
- Display Time - the time of display the information for truck drivers during his journey (on-trip). With the information we will be able to influence behavior of the driver, respectively choice of parking lot for his rest. If the driver receives information such as that the parking lot, which he is approaching, is probably overcrowded and the other is empty, he decides to stop at the next parking lot. This decision is unable to make if you are planning a trip, for example, one day in advance (pre-trip), because this information is not available and also relevant.
- Number of parking areas about which the information is displayed - distributed information shows the predicted state of occupancy at parking lots, for which are available the data about predicted occupancy (calculated time of arrival at parking lot is not higher than the maximum prediction horizon) and which the driver wishes to display the information.
- The information content - the content of transmitted information has a multiple values, namely the three-state value, which is parallel to the traffic light. The colors of traffic light of functional sample reflect the state of the predicted occupancy at the time of the driver arrival to the car park:
  - o green – free (up to 60 % of predicted occupancy),
  - o yellow – almost full (from 60 % to 80% of predicted occupancy),
  - o red – full (from 80% of predicted occupancy).

We have selected the distribution of information using colors for several reasons. This type of information is:

- clear - the driver does not need to think long that he will be be able to park or not,

- independent of the language - the colors of a traffic light are used to manage traffic in all states, meaning of colors is therefore clear,
- simple - the information shall not be complex, the driver must take the information as quickly as possible and on that basis then decide..

### 2.3.2 A prototype of a mobile application
The developed prototype of mobile application communicates with the communication layer of prediction system and shows the acquired prediction of the parking lots in the driving direction, as shown in the following figure.
The application is adjusted so that it can be tested without the presence on the D5 highway, thanks to manually input the current position on the highway D5 and average vehicle speeds, which are input parameters for prediction of occupancy parking lots along the route.

Fig. 5 An example of the mobile application in the vehicle

### 2.3.3 Model example
In our model example in Figure 6 the driver of the red truck wants to see the status of occupancy at the time of his arrival to the nearest parking lot in his direction. Driver queries the prediction system and transmits his GPS coordinates from the driver's mobile device, proposes highway (the driver can manually override the proposed highway) and the driver enters the direction of their movement on the highway. Communication layer after successful authentication and authorization of users determines the distance to the parking lot in a driving direction based on a fixed average speed calculates the time of arrival. To each arrival times to the parking lots then assigns the forecast horizon, which corresponds to the predicted occupancy status and then sends the predicted occupancy to the mobile client.

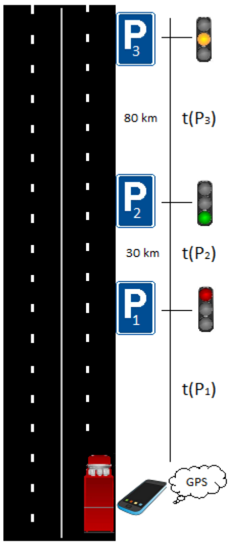


Fig. 6 Model example of the system

The driver receives information in the form of color (see figure), which interprets the statement: "The closest parking lot will be full when you get there, the second parking lot will be free, when you get there and the third will be almost full, so you may not parked there."

## 3 Conclusion
The paper presents the proposed telematics system, which provides information for drivers of trucks over 3.5t about the predicted occupancy for the nearest parking. Providing this information to drivers will optimize the usage of existing parking areas on the highway network and to drivers to facilitate decisions about the appropriate place for parking, which will contribute to the fluency and safety of traffic as a whole.

*References:*

[1] Directive 2010/40/EU of the European Parliament and of the Council of 7 July 2010 on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport Text with EEA relevance, OJ L 207, 06/08/2010, p. 1–13 (BG, ES, CS, DA, DE, ET, EL, EN, FR, IT, LV, LT, HU, MT, NL, PL, PT, RO, SK, SL, FI, SV)

[2] M. Brabec, O. Konar, I. Kasanicky, E. Pelikan, M. Maly, Z. Lokaj, T. Zelinka: *Forecasting system for truck parking based on statistical modeling of indirect, easily available data*, Proceedings of the 11th European Transport Congress. Faculty of Transportation, Czech

Technical University in Prague, Praha, pp. 26-28, 2013, ISBN 978-80-01-05416-1

[3] M. Brabec: *Statistical metodology for truck parking modeling and prediction*. TRANSBALTICA 2013, Vilnius, Lihuania, 2013, ISBN 978-609-457-470-2, ISSN 2029-2384

[4] M. Brabec, O. Konar, I. Kasanicky, E. Pelikan, M. Maly: *Statistical modeling of truck parking lots occupancy*, MOSATT 2013, Zlatá Idka, Slovakia

[5] Jirovsky, V., Novak, M., Svitek, M., Votruba, Z., Zelinka, T.,: *Transport Telematics – Systemic View*. Edited by Tomas Zelinka. WSEAS press, World Scientific and Engineering Academy and Society, Athens 2013, ISBN: 978-1-61804-144-9

[6] V. Fabera,Transformations of Pairs of FSMs, *LATEST TRENDS in INFORMATION TECHNOLOGY, 1st WSEAS International Conference on Information Technology and Computer Networks*, WSEAS, ISBN 978-1-61804-134-0, 2012, pp. 403-408.

[7] T. Brandejsky, M. Ruzek, Model of homeostatic artificial neuron, *Recent advances in Neural Networks, Fuzzy Systems & Evolutionary Computing, 11th WSEAS International Conference on Neural Networks*, WSEAS, ISBN 978-960-474-195-3, 2010, pp. 145-148.