Archives of
Transport System
Telematics

Volume 9

Issue 1

February 2016

The management of urban parking LOTS

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ABSTRACT

The continuous development of urban areas significantly affects the life, functioning, moving residents of the urban agglomeration.For that reason, the only way to increase the parking capacity in cities is to construct more multi-story parking lots. Direct correlation of social, environmental and economic factors sets the way of parking lot planning and design basing on sustainable development principle. The article describes the variables that influence the parking lot management model and presents computer methods that can be used to identify the factors affecting it. The measurements of traffic intensity at the entrance and exit of a shopping centre in Wroclaw are also included. The developmental nature of this project requires that certain problems to be analysed more closely. The article includes the impact of the use of telematic tools to manage parking lots.

KEYWORDS: telematic, parking traffic management, telematics systems, genetic algorithms, parking system, reverse logistics, motorization index, traffic intensity

1. Introduction

Reverse logistics, by definition [6], is an integrated system meant to manage the flow of pollution and information about it, as well as to minimize its negative impact on the environment. For that reason, reverse logistics must take into consideration areas such as:

a. technological processes
b. information and organization
c. economic aspects

As such, one could say that during the exploitation phase, the reverse logistics of a parking lot i characterized by the use of engineering, organizational and informative means to maintain balance between environmental and economic aspects. During the planning stage, it is critical to define and correlate social factors with reverse logistics aspects so as to allow efficient management during the exploitation phase.

2. Transportation in a city

Outlining a transportation diagram requires an assumption, that a journey consists of a walking stage (first and last) and public or private transit (Figure1).

Relation between mass transportation and private transportation, as measured by the International Road Transport Union (based on the research conducted in 100 world cities in the year 2000) is outlined in Table 1.

The increasing interest in private transportation, as shown in table 1, usual for wealthy societies is an effect of a “”car phenomenon” [10]. It is mainly characterized by the increase in the number of (registered) passenger cars.

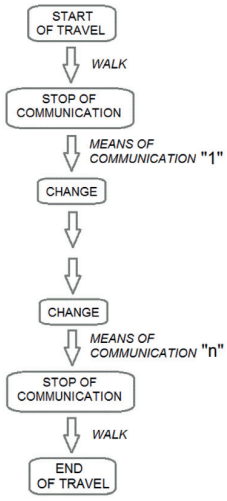

Fig. 1. A city journey diagram [11]

Table 1. The contribution of the public transportation and private transportation in the city travel operation in the world metropolises [11]

Specification	Mass transportation, %	Private transportation, %	Average distance, km
Northern America - Oceania	5	93	11.8
Middle East	14	82	7.3
Western Europe	25	68	7.9
Asia	39	42	7.0
Asian metropolises	42	48	11.0
Africa	42	56	7.5
South America	50	48	10.3
Eastern Europe	60	37	6.6

Data provided by GUS (Central Statistical Office) shows that the number of passenger cars registered in 2012 in Poland (as of 31st of December) was 18,744,000, which is 3,4% more than the year before [12]. As such, the national motorization index reached 484 passenger cars per 1000 inhabitants. The changes in the motorization index in Poland between 2003 and 2012 are outlined in Figure 2.

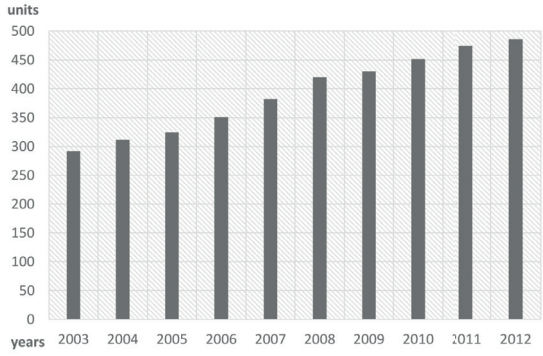

Fig. 2. Passenger cars per 1000 inhabitants [13]

The result is a decrease in the mass transportation share, relative to private transportation. The number of municipal transport passengers between 1986 and 2004 is outlined in Table 2 and Figure 3.

Table 2. Participation of the municipal transport service passengers in Poland in 1986-2004 [6]

Year	Participation In the 1986
1986	100
1992	66.3
1994	65.9
2004	46.2

3. Urban parking

Research shows that passenger cars are stationary for 95% of their use time [4]. As the popularity of private transportation increases (as outlined in the previous chapter), coupled with a limited throughput of urban road system, it is estimated that the ratio may reach even 98%. A typical passenger car journey starts in a garage, goes on to a stop at a parking lot near the target location and then goes back the garage. This process engages not only the inhabitants of a particular city, but also the inhabitants of satellite towns, coming to the city to school, work, shopping centers, administrative institutions, hospitals, etc. Whatever the point of visit, car passengers want to be able to temporarily leave their car in a dedicated parking spot. Depending on the area of the city, parking space index is estimated. They usually amount to around several dozen per 1000 m2. As such, in a city centre, an area required for parking needs is larger than the area available [2]. In the case of modern shopping centers however, which are located outside cities themselves, the area is usually available. As the needs grow, parking lots are planned and built in city centers as well, usually near a developed mass transit node. Because of the limited area available in cities, the only option is to construct multi-story parking lots.

4. Research object characteristics

The analyzed parking area is located in the city centre, outside a shopping centre with 120 retail units and restaurants. The parking area offers (on three levels) 630 car spaces at 90°. The car park entrance is off a quiet enough street.

Opening hours:

- Monday - Friday: 6.00 – 23.00.
- Saturday: 7.30 – 21.30.
- Sunday: 7.30 – 20.30.

The study focused on the users' choice of car spaces in the car park in question every day of the week (Monday - Sunday) over randomly chosen 7 weeks in one year. The selected weeks did not fall on any holiday times (Christmas, Easter, summer break, etc.). The result of the study, which is the number of cars entering the car park on single days of the week is presented in Figure 4.

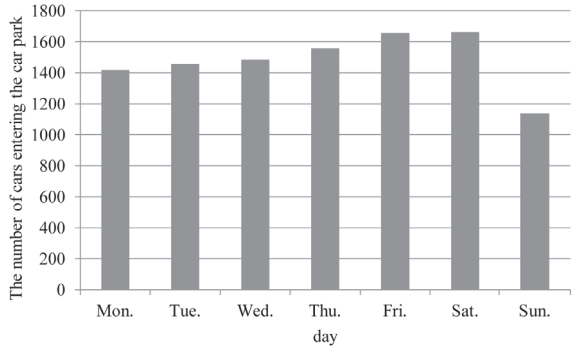

Fig. 3. The number of cars entering the car park on the consecutive days of a randomly chosen week [own study]

The intensity of parking traffic was based on the number of entries and exits. It is described by a percentage share of entries and exits during days in question (Figure 4).

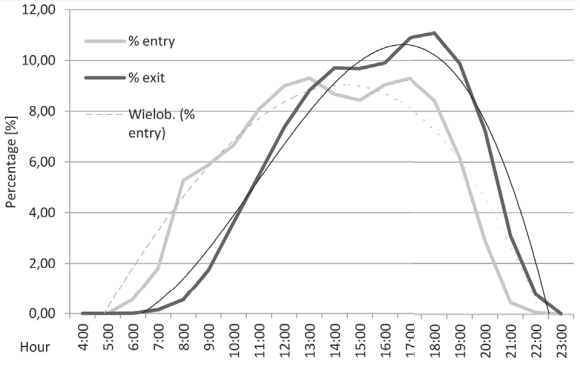

Fig. 4. Average hourly intensity of entries and exits relative to the average daily number of entries and exits [own study]

5. Parking traffic management

As mentioned in the earlier parts of the article, the parking traffic management is based on the analysis of social, economic and environmental factors and efficient organization of tools allowing control over it. A critical social factor is ensuring comfort and safety. Parking space planning is determined by Polish laws, such as Dz. U Nr 75, poz. 690 [9] that defines the minimal dimensions of parking spaces depending on their type (parallel, perpendicular and angle) and the width and type of the approach. Depending on the target group, the type of parking is defined, so that it would allow the comfort of conducting the parking maneuver, while taking the turn radius and the width of the approach into consideration. The comfort and safety factor is also dependent on a number and quality of decisions made, both by the drivers and pedestrians present at the parking lot.

Proper parking traffic management is also based on an environmental factor, which is:

- limiting the intensity of traffic in the parking area
- maintaining the flow and linearity of movement
- ensuring, that the parking maneuver can be done easily

The parking traffic management system is based on providing its users with needed information and directing them, taking the aforementioned factors into consideration. The system should also be able to adapt to current conditions, react to those changes quickly and have a high refresh rate. Expansion of multi-parameter systems of parking traffic management is inherently linked to economic factors, which is why an optimal system should be skillfully balanced and adjusted to project needs.

In parking traffic management, the social aspect of informing and directing the user should be accented. Research has concluded that searching for more than one property (such as both shape and color) causes a relative drop in search efficiency, in terms of response time, accuracy and signal detection [7]. As such, an effective information system should be constructed around the perceptual predispositions of the target user group, taking into account their neurological and psychological traits, impulse control, reflexes- anything that could influence the decision-making process [1, 3, 5].

Based on research described in the literature and the one conducted by the authors of the article, an efficient parking traffic management system should minimize the number of decisions made by drivers. Their parameterization should also be limited to two alternatives. Directional signaling should also be flexible, as mentioned before. Also, due to unequal distribution of traffic, which is particularly visible at 7pm in the direction of the exit. The system should be able to modify its parameters to maintain the flow and adjust it to the aforementioned properties.

Telematic systems and methods of automatic identification may be applied for effective parking management. In the first phase of the research, three factors were focused on:

- automatic payment implementation for the time on a parking lot,
- operating parking systems,
- managing parking places.

Combining these three factors will make it possible to control and supervise traffic on parking lots where users utilize given localizations on a regular basis.

Introduction of tools for automatic identification, as well as using a plate recognition system for that purpose, will enable a faster flow or cars entering and leaving the parking lot.

However, the proposed system must initially meet certain requirements. From the point of view of an administrator, the system must be equipped with a module and devices to identify cars on the basis of registration plates. Another aspect is the necessity to document the identified cars on the drive-in and at entrance gates. As a consequence of the aforementioned factors, the administrator should be in control of the automatic implementation of payment for the factual parking time. In order to implement such parking management, a data base, which shall be an integral part of the whole system, must be created.

In order to aid parking management, a number of methods can be applied to identify vehicles before they approach the entry gate. One of them, a method of radio identification, which, through recognition and radio transmission of the encoded information of moving vehicles equipped with "Tags", identifies and associates them with a database of the vehicles already recorded in it [8]. The RFID system is composed of a permanent scanner (a transceiver

with an antenna and a decoder), a controlling device and a portable transponder – "tag" (transponder), e.g. installed on a vehicle.

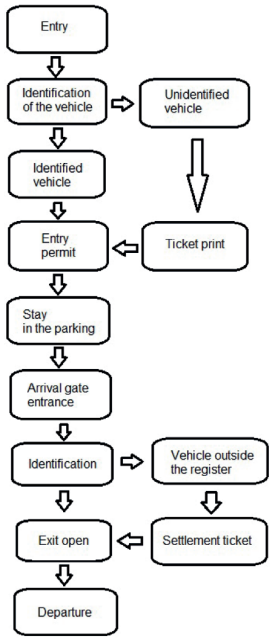

Fig. 5. The diagram of organization of parking management with the use of telematic systems [8]

Application of such a system would enable introduction to the management system of access on the basis of a monthly fee, which would reduce the time of the parking operation and would eliminate any potential errors related to parking management.

In order to additionally aid parking management, the parking places for vehicles are monitored for occupancy. For this purpose, ultrasonic sensors with additional address coders could be installed. The sensors would be controlled by an IT system, and the status of a non-occupied parking lot and the sensor number will be mapped on a variable message board. With such management, after a vehicle with a monthly fee has been recognized, it will be possible to allocate such vehicle directly to a specific parking lot.

6. Optimizing the light signaling system management

The conducted research focused on optimizing a parking management system using an original method derived from the genetic algorithms methodology. Two methods of optimal parking management system are presented. One method is based on traditional genetic algorithms, while the second one uses a blend of genetic algorithms and fuzzy sets. The chief job of any parking system is to help to find free parking spots while optimally utilizing the available resources. An intelligent parking management system is an infrastructure that can lead a vehicle in a direction that takes the least time to find an empty spot. Factors that need to be taken into consideration while determining the correct route are: temporary CO concentration in the air, traffic intensity (P) in the vicinity of parking zones (S) and random variables L. These factors constitute the Z_t vector, where l variable is time. In case of a_i cars located on i route (it can also be a traffic intensity coefficient for a given parking sector, assuming it is scaled), the chromosome rating algorithm is as follows:

$$E(C) = \frac{\sum_{k=1}^{n} \min(Z_t \cdot R_{k,o}) - 0{,}1 * \left|R_{k,o}\right|}{\sum_{k=1}^{d} t_{k,o}} \quad (1)$$

and

$$R_{k,o} = P_{k,o} \cdot Z_t \cdot V \cdot t_{k,o} - \sum_{i \in G_{k,o}} a_{k,i,o} \quad (2)$$

where:

V - vehicle speed coefficient

P_k - cardinality of set Gk (quantity of elements in a given group that follows the same direction)

t_k - time needed to ascertain the ride direction for a given k group of cars

n - quantity of groups

d - quantity of all parking variants

a_i - occurrence coefficient for a given vehicle group

$$a_i = \begin{cases} 1 & for \quad G_k > 0 \\ 0 & for \quad G_k = 0 \end{cases} \quad (3)$$

Assuming a model analyzing traffic on several stories of a parking lot, allowing for interaction between W number of stories, then an optimal route is described by a chromosome rating genetic algorithm. Multi-parking analysis is described by the following equation:

$$\forall W \quad E_W(C) = \sum_{o=1}^{W} \frac{\sum_{k=1}^{n} \min(Z_t \cdot R_{k,o}) - 0{,}1 * \left|R_{k,o}\right|}{\sum_{k=1}^{d} t_{k,o}} \quad (4)$$

As a result of all analyses, a parking variant that maximizes the chromosome rating values is chosen, according to the equation:

$$E(C) = \max\left\{ \int_t \sum_{o=1}^{W} \frac{\sum_{k=1}^{n} \min(Z_t \cdot R_{k,o}) - 0{,}1 * \left|R_{k,o}\right|}{\sum_{k=1}^{d} t_{k,o}} dt \right\} \quad (5)$$

In case of the equation (5) the chromosome rating is done by a modified likelihood function and a center of gravity function, derived from the fuzzy logic theory. Using this method, the best solution for the parking route can be obtained. It should be noted, that in the case of linking dependent parking lots, a sequential system is created. It can be successfully described by a model that links fuzzy logic with the Dempster-Shafer evidence theory [12].

Here is a different parking algorithm method using fuzzy logic. Fuzzy sets [12] can be applied to obtain a fuzzy chromosome rating.

$$E_k(C) = \sup_{R_{k,o}} \{\mu(Z_t \cdot R_{k,o})\} \cdot \max_{1<k<M} \mu(Z_t \cdot R_{k,o}) \quad (6)$$

Eventually, the cycle that maximizes the chromosome rating value using combination rule from Dempster-Shafer Theory [12] is chosen. The result is:

$$E(C) = \max[E_1(C) \oplus E_2(C) \oplus ... \oplus E_k(C)] \quad (7)$$

Implementation of chromosome rating genetic algorithmgiven by equation (6) depends on the parking type. There are no definite premises that would allow a logical choice. Implementing two methods or a simulation testing of solutions is preferable when trying to choose a superior one.

7. Conclusion

Urban areas transform natural environments and create artificial ones. The increasing motorization index creates new challenger for the urban infrastructure in terms of parking planning and organization. Computer methods enhancing the management are based on genetic algorithms and fuzzy sets. They have a practical application in intelligent control over complex parking systems. The advantage of fuzzy sets in such systems is that they can work with imprecise and uncertain data.

Parking traffic management is based on analysis of social, environmental and economic parameters. A set of tools that allows control and directing is a significant help in management process. IT systems allow accurate description of traffic and an effective management system should adjust itself to changing conditions.

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