Research Article

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The issue of addressing the lack of parking spaces for road freight transport in cities - a case study

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Abstract: Static traffic (parking of vehicles) is one of the most problematic areas of transport in urban areas. In particular, parking areas for heavy freight vehicles in city areas cause problems connected, for example, with insufficient capacity or inadequate equipment. In the Czech Republic the regional concepts for the location of parking lots for trucks have not been developed - rest areas are built mainly on highways. Drivers are forced into other roads to search for alternative parking spaces and thus jeopardize the safety of the cargo to be transported. Because of the lack of such parking areas, drivers are forced to violate the European Agreement Concerning the Work of Crews of Vehicles Engaged in International Road Transport (AETR) or, due to this agreement, to park the truck before the driver's work shift ends, thereby reducing the efficiency of full driver usage. The paper deals with the issue of rest areas location for road freight vehicles in the selected area. The first part of the paper characterizes variant solutions of parking areas in a particular selected area, which were evaluated on the basis of an analysis of the current conditions. The second part of the paper introduces the evaluation of individual variants using the TOPSIS method, which was chosen as the most appropriate method of multicriteria decision making process.

Keywords: road freight transport, freight transport parking areas, TOPSIS, multicriteria analysis

1 Introduction

The liberalization of markets has caused an extreme increase in transport performance, which is linked to an increase in static traffic in cities as well [1, 2]. In particular, parking areas for heavy freight vehicles in city areas cause problems connected, for example, with insufficient capacity or inadequate equipment. In the Czech Republic the regional concepts for the location of parking lots for trucks have not been developed - rest areas are built mainly on highways. Drivers are forced into other roads to search for alternative parking spaces and thus jeopardize the safety of the cargo to be transported. Because of the lack of such parking areas, drivers are forced to violate the European Agreement Concerning the Work of Crews of Vehicles Engaged in International Road Transport (AETR) or, due to this agreement, to park the truck before the driver's work shift ends, thereby reducing the efficiency of full driver usage [3].

2 Literature review

Several authors deal with the issue of static traffic in road freight transport area. An interesting study on the capacity of parking spaces is provided in [4]. This paper assesses the parking needs of freight and service related commercial activities and identifies the role of demand management in mitigating these needs. To provide a context for the analyses, the authors selected two small commercial areas of about the same number of commercial establishments-one in Troy, NY, and the other in New York City-and applied freight and service trip generation models to estimate the total freight and service traffic generated at these sites. Then, using different assumptions of the amount of time these vehicles spend at a parking location, the authors estimated the number of parking spaces required by time of day under different assumptions of demand management. The initial analysis revealed the importance of parking duration as it was shown to be proportional to parking needs; the longer the duration the higher

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the need for parking. The delivery simulation further bolstered this finding by showing that the optimal case occurs (*i.e.* minimizing parking duration) the closer the parking location is to the establishment.

Another interesting study is presented in [5]. The paper provides an insight into a comparison of the parking practices and problems of freight-vehicle drivers in Gothenburg, Sweden, and Delhi, India. The purpose of this study is to understand how parking problems are related to relevant characteristics of the study zones, *e.g.*, geographical location, transport mode used for last-mile deliveries, and type of industry sectors attracting freight traffic. The study also examines the possible impacts of imbalance between parking demand and supply. The methodology involves the estimation of freight-parking demand using establishment-based surveys and cordon counts; parking practices and problems are captured through freight-vehicle drivers' semi-structured interviews, and parking space supply is obtained from a parking inventory.

In article [6] the authors focus on the issue of static freight traffic from the point of view of transport safety. Obviously the rest period must be planned according to the standards and regulations, as well as at a safe parking area. Choosing a safe parking lot often reduces the risk of robbery, theft, thereby the threat of the driver and cargo. International studies indicate that 42% of all road cargo thefts take place on unsecured and unmonitored parking lots. The article points to secure parking areas in the world as a major element to prevent the risk of the goods transport.

Findings on safe parking of trucks in Italy are given in reference [7]. This paper focuses on the problem of lack of safe, secure and comfortable HGVs parking areas in Lazio Region, Italy. Within the study a detailed survey was conducted in order to underline the critical aspects and the complexity of the problem. Results underline data concerning haulage companies and truck drivers behaviours, number and main characteristics of several parking areas, as well as quantitative elements concerning occupancy rate and satisfaction level of users.

Other interesting findings in the field of static freight traffic and the issue of parking spaces for road freight vehicles are also cited by sources [8–10].

The authors of this paper focus on the issue of lack of parking spaces in a particular selected location and point out one of the ways of increasing these capacities. The authors use some exact mathematical methods when choosing a suitable option.

3 Analysis of the current state of parking capacities

The Czech Republic has a theoretical advantage in its geographic location in the centre of Europe. At present, the major priority is the completion of Europe-wide highway networks. Within Europe, freight transport growth is projected to increase by as much as 50% by 2020 [11, 12]. This of course raises concerns about network congestion on European highways. Analyses show that a large number of traffic accidents in freight transport are due to non-compliance with mandatory breaks for drivers on long journeys.

3.1 General characteristics of parking capacities within the EU

One of the main reasons why this offense is perpetrated by drivers is a lack of parking spaces. There is no clear answer to the question whether the number of parking spaces for trucks is sufficient. Statistically, we can say that during the working days within a week the number of parking spaces is sufficient, though reserve is not too large. The problem arises when truck drivers have to stop due to mandatory breaks, state or public holidays. Drivers on long journeys are forced to plan their journey so that they do not violate the law in the country they are passing. In most cases, however, they have no means to reach that goal, and planning a new journey is a mere estimate. Because of driver's bad decisions or traffic congestion, drivers are placed in a situation where they have to decide whether to break the law on driving time or to park the vehicle outside the area specified [13].

The problem with parking areas for trucks is not only in the Czech Republic, but most of the EU countries are also dealing with the issue, especially after the opening of national markets and the enlargement of the European Union. Building new parking areas or expanding the capacities of existing parking areas seems to be the solution. An important factor is the correct use of information technology. This is closely related to the availability and quality of the information provided [14, 15].

3.2 Parking capacity in the given area

The authors chose to apply the methodology to the city of Jindrichuv Hradec, because there was a survey of static

traffic for international road freight transport, which is used as a basis for proposals and solutions.

There is no parking area for trucks in Jindrichuv Hradec, except the parking spaces for light lorries, which would comply with the Czech technical standards CSN 73 6056. Parking spaces for trucks are usually sought after by drivers who have a permanent residence in Jindrichuv Hradec. Others who search for parking spaces are drivers of vehicles that have their loading or unloading directly in Jindrichuv Hradec and have to park near the city and wait for the next day for load/unload in a specific day period. In this city there are several companies that accept trucks every day.

The analysis in [16] provides information on parking areas such as petrol stations or other areas that allow safe parking for trucks and have negative influence on other road traffic. It has been found that from all the surveyed petrol stations in the city only one offers parking space for the semi-trailer or trailer combination. Other petrol stations allow the trucks to be parked at places not intended to this purpose and at driver own responsibility. With this step, petrol stations are often overloaded with freight vehicles, increasing the risk of accidents (for example due to poor visibility) and damage to property. There is no social background at any petrol station.

In addition, [16] highlights where trucks are parked in more frequent and regular frequencies. It has been found that trucks are parked on roadsides, roads intended for supply, former car parks for passenger cars, old military roads, urban public transport end stops, and the like.

The main objective of this analysis was to point out that in Jindrichuv Hradec there is no parking lot for trucks that would meet all parameters and requirements for safe parking. Trucks are parked in any place, no matter what consequences this bad parking could have. An example is the fact that vehicle owners are not familiar with the situation that, in the event of theft of a vehicle or cargo (if the vehicle or cargo is insured), the insurance company does not have to pay any compensation for the damage caused due to inappropriate parking in such places. Another example may be the absence of safety seals or locks at the door of trailers, or theft of fuel from fuel tanks.

4 Variant solution proposal of parking lots

Nationwide traffic census in 2010 [16] showed that in terms of freight traffic volume vehicles with semitrailers (on average 127 vehicles/hr.) prevail, the other in the statistics are heavy trucks of over 10 tones without a trailer (average 54 cars/hr.) and with a trailer (average 27 cars/hr.). These results illustrate the fact that the parking area must have a predominance of parking spaces for semi-trailer or trailer combination of vehicles. We therefore designate these vehicle combinations as determinant vehicles.

By field survey in Jindrichuv Hradec it was found that 19 trucks were parked on a usual working day, 33 trucks were parked at a weekend day and 35 trucks were parked on state holiday. Based on this point, two parking areas are proposed.

4.1 Design of parking area

Based on the required number of parking spaces, 2 proposals were created [16]. Due to the fact that there is a parking lot for light trucks in Jindrichuv Hradec, the proposals will be created only for trucks with trailers trucks or semitrailers, but the parameters of the parking area will be suitable for heavy freight vehicles over 10 tons as well.

The parking area A has an area of 7030 m^2 and the proposed number of parking spaces is 27. This calculation was determined as the lowest measured value of parking spaces and half the difference between the largest and smallest measured parameters parked vehicles. Due to the full capacity utilization of parking area, the number of parking spaces was increased to 27. Parking spaces are designed at 60° angle and the length of one parking space is 60 m. The advantage of a space length of 60 m is that up to three trucks with trailers can stand behind each other. One parking space is divided into three fields, each field having a length of 20 m. According to standard CSN 73 6056, the minimum parking space length is specified to 18.5 m (at 60° arrangement) when the distance between the truck and the door of the semi-trailer must be at least 0.5 m. The width of the parking space is 4 m (average width of the truck is 2.5 m), where the gap between trucks must be at least 1 m. The distance between the edge of the property (fence) and parking space is 11.05 meters, which is sufficient space for handling a long set of vehicles.

The parking area B has an area of 7770 m^2 and the proposed number of parking spaces is 36. This number is derived [16] from a traffic survey when, on public holidays, an average of 35 trucks are parked in the whole city. For full use of the area, capacity is increased to 36 parking spaces. Parking spaces are designed at 60° and 90° angles. The length of the parking space at an angle of 60° is 22 m. Although CSN 73 6056 specifies a minimum length of 18.5 m, the length of 22 m is due to parking the longest possible tandem vehicle set used on Czech roads. The width of the

Table 1: Evaluation of parking areas

Parking areas comparison	Parking area A	Parking area B
Size of area	7030 m^2	7770 m^2
Number of parking places	27	36
Parking system	Difficult	Simple
Security measures	Security + surveillance cameras	Security + surveillance cameras
Parking meter	yes	no
Restaurant	yes	yes
Sanitary facilities	yes	yes
Number of employees	3	3

Source: authors

parking space is 4 m (average width of the truck is 2.5 m), where the gap between trucks must be at least 1 m. The length of the parking space at an angle of 90° is 20 m. This type of parking space complies with the conditions stated in CSN 73 6056. The width of the parking space is 3.5 m (average width of the truck is 2.5 m), where the gap between trucks must be at least 1 m. The parking lots are located on the longest sides of the property opposite each other and the distance between them is 35.9 m, which is enough space for handling the vehicles.

4.2 Evaluation and selection of the parking area

The evaluation of both parking areas proposals according to various aspects is shown in Table 1.

Both parking areas designs are very similar. The difference is between the size of area, the number of parking spaces and the parking system. The size of the parking areas differs by only 740 m^2, which will have no big effect on the price of the land. To increase safety on adjacent road I/34, a roundabout could be created instead of a crossroad, but this would increase costs. The price of a roundabout can increase the project costs by about five million CZK [17–19].

5 Variant solution selection using TOPSIS method

Verification of results will be achieved using the TOPSIS method, which is one of the multi-criteria decision-making methods [20–24]. This method selects the option closest to the ideal variation and farthest from the basal variation (the variant with the worst rating) assuming that all criteria have maximizing character. If not, it is necessary to convert all of the criteria [25–28].

The g_{ij} elements are normalized according to the formula [29, 30]:

$$r_{ij} = \frac{g_{ij}}{\sum_{i=1}^{m} g_i^2} \tag{1}$$

where:
r_{ij} – normalized matrix elements,
g_{ij} – evaluation criteria.

1. Determining matrix with elements w_{ij}:

$$w = v_j * r_{ij} \tag{2}$$

where:
w – Elements of the weighted normalized decision matrix,
v_j – criteria weights.

2. Determination of the ideal and basal variant [31].
3. Determining the distance from the ideal variant d^+:

$$d_i^+ = \sqrt{\sum_{d=1}^{m} (w_{ij} - H_j)^2} \tag{3}$$

where:
d^+ – ideal solution,
H_j – elements of ideal solution.

4. Determining the distance from the basal variant d^-:

$$d_i^- = \sqrt{\sum_{d=1}^{m} (w_{ij} - D_j)^2} \tag{4}$$

where:
d^- – basal solution,
D_j – elements of basal solution.

5. Determination of relative closeness to basal variation c_i:

$$c_i = \frac{d_i^-}{d_i^+ + d_i^-} \tag{5}$$

Table 2: Evaluation of parking areas

TOPSIS	Parking system	Charging station	Parking meter	Number of parking spaces	Safety
Proposal B	5	5	1	5	5
Proposal A	3	1	5	3	4
Significance	**0,4**	**0,15**	**0,05**	**0,1**	**0,3**

Source: authors

where:
c_i – relative closeness of alternatives to the basal solution.

6. Variants are sorted by decreasing values c_i.

According to this procedure, parking area designs are evaluated in Table 2.

Each criterion was rated from 1 (worst) to 5 (best). The significance and the evaluation of the individual criteria were determined in an objective manner [32–34]. The complete calculation is the following.

Step 1: $\frac{5}{\sqrt{5^2+3^2}} = 0,857$; $\frac{5}{\sqrt{5^2+1^2}} = 0,980$; $\frac{1}{\sqrt{1^2+5^2}} = 0,196$; $\frac{5}{\sqrt{5^2+3^2}} = 0,857$; $\frac{5}{\sqrt{5^2+4^2}} = 0,781$

Step 2: $\frac{1}{\sqrt{5^2+3^2}} = 0,514$; $\frac{1}{\sqrt{5^2+1^2}} = 0,196$; $\frac{5}{\sqrt{1^2+5^2}} = 0,980$; $\frac{3}{\sqrt{5^2+3^2}} = 0,514$; $\frac{4}{\sqrt{5^2+4^2}} = 0,624$

$$\begin{pmatrix} 0,857; 0,980; 0,196; 0,857; 0,781 \\ 0,514; 0,196; 0,980; 0,514; 0,624 \end{pmatrix}$$

Step 3:

$$\begin{pmatrix} 0,4*0,857; 0,15*0,980; 0,05*0,196; 0,1*0,857; 0,3*0,781 \\ 0,4*0,514; 0,15*0,196; 0,05*0,980; 0,1*0,514; 0,3*0,624 \end{pmatrix} \Rightarrow$$

$$\begin{pmatrix} 0,3428; 0,147; 0,0001; 0,0857; 0,2343 \\ 0,2056; 0,0294; 0,049; 0,0514; 0,1872 \end{pmatrix} \Rightarrow$$

$H = \{0,3428; 0,147; 0,049; 0,0857; 0,2343\}$;

$D = \{0,2056; 0,0294; 0,0001; 0,0514; 0,1872\}$

Step 4:

$$d_1^+ = \sqrt{A} = 0,0489$$
$$d_2^+ = \sqrt{B} = 0,1899$$
$$d_1^- = \sqrt{C} = 0,1899$$
$$d_2^- = \sqrt{D} = 0,0489$$

where:
$A = (0,3428-0,3428)^2 + (0,147-0,147)^2 + (0,0001-0,049)^2 + (0,0857-0,0857)^2 + (0,2343-0,2343)^2$
$B = (0,2056-0,3428)^2 + (0,0294-0,147)^2 + (0,049-0,049)^2 + (0,0514-0,0857)^2 + (0,1872-0,2343)^2$
$C = (0,3428-0,2056)^2 + (0,147-0,0294)^2 + (0,0001-0,0001)^2 + (0,0857-0,0514)^2 + (0,2343-0,1872)^2$
$D = (0,2056-0,2056)^2 + (0,0294-0,0294)^2 + (0,049-0,0001)^2 + (0,0514-0,0514)^2 + (0,1872-0,1872)^2$

Step 5:

$$c_1 = \frac{0,1898}{0,0489+0,1898} = 0,795 \Rightarrow \text{Proposal B}$$
$$c_2 = \frac{0,0489}{0,0489+0,1898} = 0,205 \Rightarrow \text{Proposal A}$$

6 Discussion

The main task of the research was to design a complex parking area, which is safe, with catering facilities and social facilities for drivers of trucks with semi-trailers and trailers, and provide conditions for driver regeneration [35–37]. After analysing all the positive and negative criteria of the proposals and their evaluation using the TOPSIS method, proposal B will be chosen for realizing in the town of Jindrichuv Hradec. The most important factor in the decision was the criterion of the parking system. The value in proposal B was chosen to be significant because parking is simple here and it is not necessary to be organized by a person or a computer. In proposal A, the parking system is not tested in practice. Another important criterion was the safety - the values differing by just one point value due to parking in the middle of the proposed parking lot at proposal A. The last criterion was the presence of charging station for refrigeration units. This is a novelty that is being tested in Germany and is widely used to reduce the need for diesel as the primary source of the aggregate [38–40]. According to surveys conducted in Germany, these charging stations can save several thousand euros a year for the owners of refrigeration semi-trailers.

7 Conclusion

Parking area proposal B offers drivers comprehensive services such as restaurant, hygiene, secure parking or a supermarket. The parking area is conveniently located on the second most frequented road in Jindrichuv Hradec (significant transport route within CZ), which has already a suitable entrance, which should not create undesirable congestion. In the case of the construction of this complex, it will be necessary to intervene in the form of a decree, where the parking of trucks outside the marked places in the town will be prohibited, thus increasing the demand for parking areas. This restriction information should be placed on telematics devices on every road that heads to the town of Jindrichuv Hradec. If the municipality was considering financing this project, its implementation would be possible with the aid of European subsidies. European subsidies for the 2014-2020 programming period are aimed at linking the Czech Republic regions to strategic transport infrastructure, TEN-T infrastructure development, using intelligent logistics or transport management systems (Galileo system), constructing the transport facilities that are key to infrastructure. The most effective financing of this project would be through a private investor where financial resources are more affordable than public resources. To solve a nationwide problem, the best would be the entry of a large investors such as MaxiAutohöfe in Germany (or 24, SVG, EURO RAST-PARK, VEDA) who would be able to create a network of rest places throughout the Czech Republic.

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