MUNICIPALITY BYPASSES AS A TOOL FOR REDUCING THE NUMBER OF PLACES WITH REDUCED SPEED: A TRANSPORT MODELLING APPROACH

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Abstract

This paper addresses places with reduced speed in road transport, such as railway crossings, signalized junctions, roundabouts, and pedestrian crossings, and the importance of their number in deciding on municipality bypasses. Based on an assessment of 10 existing bypasses in the central part of the Czech Republic, bypasses have been divided into 3 groups depending on the importance and size of municipalities. The importance of the proposed indicator – the number of places with reduced speed divided into groups – is explained here. Possible use is illustrated on a case study of a planned bypass of Ústí nad Orlicí validated by a four-tier transport model.

Keywords: Municipality, road bypass, speed, transport model

1. INTRODUCTION

The need to eliminate places with reduced speed has been identified as a way to increase the quality of railway logistic processes [1]. This mainly involves the elimination of railway crossings on regional railway lines and, by extension, the introduction of grade separation structures on TEN-T lines. The aim of this paper is to test a similar approach on road bypasses of municipalities. The idea behind it is the fact that even though bypasses are sometimes longer, they offer a shorter travel time and greater driving comfort.

Using server [2], 5 existing bypasses have been analysed in the wider conurbation of Hradec Králové and Pardubice (Chrudim+Slatiňany, Třebechovice pod Orebem, Holice, Hořice, Vamberk). The greatest route extension was by 23.1 % (Vamberk). By contrast, the Hořice route was shortened to 71.1 % of the original length. However, in all cases, the travel time was reduced – to a maximum of 33.3 % (Hořice), and to a minimum of 75.0 % (Vamberk) of the original duration.

For comparison, 5 more bypasses have been analysed (Nymburk, Kolín, Čáslav, Golčův Jeníkov, Habry) on road No. I/38 not far to the south-west of the conurbation in question. Here, the maximum route extension is by 9.3 % (Čáslav), and the greatest route reduction is to 92.6 % of the original length (Kolín). As for travel time, the greatest reduction (to 40 % of the original value) was in Kolín, and by contrast, in Nymburk the travel time is comparable to the original one.

It follows that a bypass can reduce the travel distance if there are favourable space and terrain conditions. In other cases, for a bypass to be attractive, it needs to bring greater driving comfort. In addition to a higher speed limit, what contributes to this attractiveness is the elimination of places with reduced speed. Places with expected speed reduction include railway crossings, signalized junctions, roundabouts, and pedestrian crossings.

Analysing the current state of art, it is obvious that road bypasses have been dealt with by several authors. For instance, the author of article [3] even makes a structural assessment of the Wellington Inner City Bypass (Wellington, New Zealand) in relation to a possible impact of an earthquake. Article [4] deals with the relationship of a bypass and possible pollution reduction in Vilnius (Lithuania). Specifically relying on a case study of Badajoz (Spain), article [5] focuses on modelling the impact of bypasses of small and medium cities without congestions. This article also states that for bypasses, it is appropriate to consider high-capacity roads allowing for a reduction of travel time. Paper [6] represents an economic perspective, featuring a cost-benefit analysis of the bypass of Prešov (Slovakia). This brief analysis of the current state of art shows that the authors of the individual papers often take quite different, and often partial points of view on bypasses. A positive role of transport models has been mentioned as well (for instance in [5]). Our approach focusing on a specific aspect – the elimination of places with reduced speed using modelling – is in line with this.

In the case study part, this paper deals with transport modelling in Ústí nad Orlicí and its immediate surroundings, taking into account the planned realignment of road No. I/14 (city bypass). The transport model is based on an analysis of the current state of roads in Ústí nad Orlicí and transport on these roads. The motivation for these proposals lies in the expected problems connected with the construction of the city bypass (costs, land grabs, popular resistance). The aim of this paper is to create a transport model of Ústí nad Orlicí and to assess the changes in road transport after the planned city bypass has been constructed.

In methodological terms, the subject of this paper is the comparison of a LOGIT model applied within traffic assignment for route selection with the possibility to express driving comfort using the number of places with reduced speed. This is illustrated on a situation analysis of 5 existing bypasses in the conurbation of Hradec Králové and Pardubice or in its close surroundings; and of 5 adjacent bypasses on I/38 next to this conurbation; and, based on the above-mentioned model study, of a bypass yet to be built on I/14 in Ústí nad Orlicí.

2. GENERALIZATION OF MOTIVATIONS FOR THE USE OF BYPASSES

Discussed in the introduction, the relationship between travel distance, travel time, and driving comfort can be generally expressed by equation (1), calculating the travel times on the individual route variants $i \in I$.

$$T_i = \frac{60 \cdot L_i}{V_i} + \sum_{j \in J_i} t_j \quad \forall i \in I \qquad (1)$$

where:

T_i – travel time on travel route $i \in I$ (min)

L_i - length of travel route $i \in I$ (km)

V_i - average travel speed on route $i \in I$ (km·h^{-1})

t_j - extra time related to time loss at a place with reduced speed of $j \in J_i$ (min)

J_i - set of places with reduced speed at the route of $i \in I$

Considering that not all drivers select a route (on the bypass, through the city centre) with a shorter travel time, a LOGIT model can be applied. Based on equation (2), this method allows for dividing the traffic flow into non-identical parts, taking into account the travel times on all route variants and the parameter expressing willingness to selection of more expensive variants (Φ).

$$P_i = \frac{e^{-\varphi T_i}}{\sum_{j \in I} e^{-\varphi T_j}} \quad \forall i \in I \qquad (2)$$

where:

P_i - probability that the travel route $i \in I$ will be selected by an individual driver (-)

T_i - travel time on travel route $i \in I$ (min)

T_j - travel time on travel route $j \in I$ (min)

Φ - parameter expressing willingness to selection of more expensive variants (-)

3. CHARACTERISTICS OF SELECTED CASES (BYPASSES)

As already mentioned in Section 1, 10 existing bypasses in the central part of the Czech Republic have been analysed as a basis for a proposed solution. This sample includes different small and medium-sized municipalities from 1.3 thousand (Habry) to 31.5 thousand (Kolín) inhabitants and bypasses with a length from 2.4 km (Habry) to 11.4 km (Chrudim).

The analysed set of bypasses can be divided by municipality size – or importance, for that matter – into 3 groups (**Table 1**). They can be divided into bypasses of a) small municipalities, b) medium-sized municipalities, and c) local centres.

Table 1 Subsets of road bypasses Source: Authors.

Municipality type (group)	Original route accessibility for transit	Share of transport on the original route (%)	Parameter Φ of the LOGIT model (-)
a) small	No	0–10	-
b) medium-sized	Yes	10–45	0.29–0.39
c) local centre	Obligatorily	> 45	-

Even though it is not possible to justify the division into groups by mathematical statistics (low range of data), from a technological point of view, the share of transport on the original route can be described in a way provided for in **Table 1**.

Materials [7] only include absolute values of traffic flow intensities. Unfortunately, there is no division into source (target) and transit transport, which would allow for a correct interpretation of using the LOGIT model in modelling the route selection. However, it is possible to take an approach of lower granularity, to extend the perspective and apply the LOGIT model on the total values of traffic flow intensities regardless of the journey types. The conclusion is that this approach is indeed possible, but its accuracy is limited, as expected.

In some cases, especially for the small municipalities in a), there is not enough source data for the application of this method (no available intensities established in the built-up areas of these municipalities). This leads to a further deepening of ambiguity. For local centres, the traffic volume on the original route sometimes even approaches the volume of transit transport on the bypass or is even greater. This renders the use of the LOGIT model irrelevant, and as such, the values of Φ have not been calculated for a) and c) in **Table 1**.

Table 2 Counts of places with reduced speed on original route / on bypass (-). Source: Authors based on [2]

Municipality	Railway crossings	Roundabouts	Signalized junctions	Pedestrian crossings
Chrudim+Slatiňany	2/0	4/0	6/0	12/0
Holice	1/0	1/0	0/0	7/0
Třebechovice p. O.	2/0	0/0	0/0	9/0
Vamberk	1/0	0/2	0/0	4/0
Hořice	1/0	0/0	0/0	1/0
Nymburk	0/0	4/1	1/0	16/0
Kolín	1/0	2/0	4/0	9/0
Čáslav	2/0	2/0	2/0	14/0
Golčův Jeníkov	1/0	1/0	0/0	9/0
Habry	0/0	0/0	0/0	2/0

On the given level of granularity, it might be more efficient to characterize the different places with reduced speed and assess the overall attractiveness of the bypass based on their number (**Table 2**). Once again, there is one more simplification slightly reducing the informative capability of the results, but simplifying the data collection and bringing greater objectivity, to a certain extent. This simplification lies in replacing the time loss at a place with reduced speed t_j by the number of these places.

As for **Table 2**, it is to be noted that the bypasses mentioned there were built at different times, and the number of places with reduced speed was identified based on the status quo (using [2]). This can be the reason for the relatively low number of places with reduced speed for instance in Habry, a city with a bypass which has been long in operation. In some cases, new places with reduced speed can appear on bypasses as well. However as can be seen from Table 2, there is only very few of these and in the set of bypasses examined, these are roundabouts connecting the original and new infrastructure.

4. ÚSTÍ NAD ORLICÍ CASE STUDY – APPLICATION ON A PLANNED BYPASS

Having 15.3 thousand inhabitants and being a local centre, Ústí nad Orlicí is located about 150 km to the east from Prague.

I/14 runs through the city, and there is no road bypass so far; however, one is planned in the north-south direction. The city lies in hilly terrain and as such, there aren't many options as to possible bypass route variants. Ústí nad Orlicí can be assigned to group c) with an expected significant share of target and source transport and quite prominent use of the original route (today's route of I/14) in the future as well.

The expected bypass route will be 4.9 km long, with a travel time of 4 minutes. The current route is 5.2 km long, and the travel time is 7 minutes. Running through the wider city centre, the route is a through road including several lanes in some sections. There is a total of 5 signalized junctions and 4 uncontrolled pedestrian crossings. In the Czech context, it is quite remarkable that there is no roundabout on this route. There aren't any railway crossings, either.

For validation, a transport model can be used that was created at the authors' department and with their participation as part of thesis [8], outside of the PositTrans project, though. This model includes a very good OD matrix of routing of traffic flows with emphasis on transit on I/14 in the north-south or south-north directions. This OD matrix contains nearly 6,900 journeys (vehicles).

However, attention was paid to other transport directions as well, including the sources and targets of traffic flow journeys starting or ending in the city (city centre, hospital, shopping centres, employers, housing estates). As such, it is an ideal instrument for the validation of the proposed approach connected with the number of places with reduced speed. [9,10]

As can be seen from **Figure 1**, transit transport and target transport (or source transport, for that matter) will probably be separated. Traffic intensity on the original route of I/14 will decrease (marked in green in **Figure 1**). However, considering the relatively low number of places with reduced speed (compared to other cities, such as for instance Chrudim+Slatiňany, Kolín, Čáslav) – especially of uncontrolled pedestrian crossings – together with the relatively insignificant shortening of the route through the bypass brings with it the risk that drivers will still be willing to use the through road.

In a specific example, a section of the Královéhradecká street (part of the present I/14 route) was analysed in detail between the streets of M. R. Štefánika and Zahradní close to the city's historical heart in the wider city centre. In the model, traffic flows have been examined in a total of 342 transport relations. 58 of them were running through the section mentioned above without the bypass, i.e., nearly 17 %. With the introduction of the bypass, this number dropped to 50, i.e., less than 15% of the relations. On the other hand, the modelled traffic burden on this section dropped by nearly 41% with the proposed bypass; specifically, from 2,192 to 1,294 vehicles, i.e. by 898 vehicles per 2 hours of the modelled peak time.

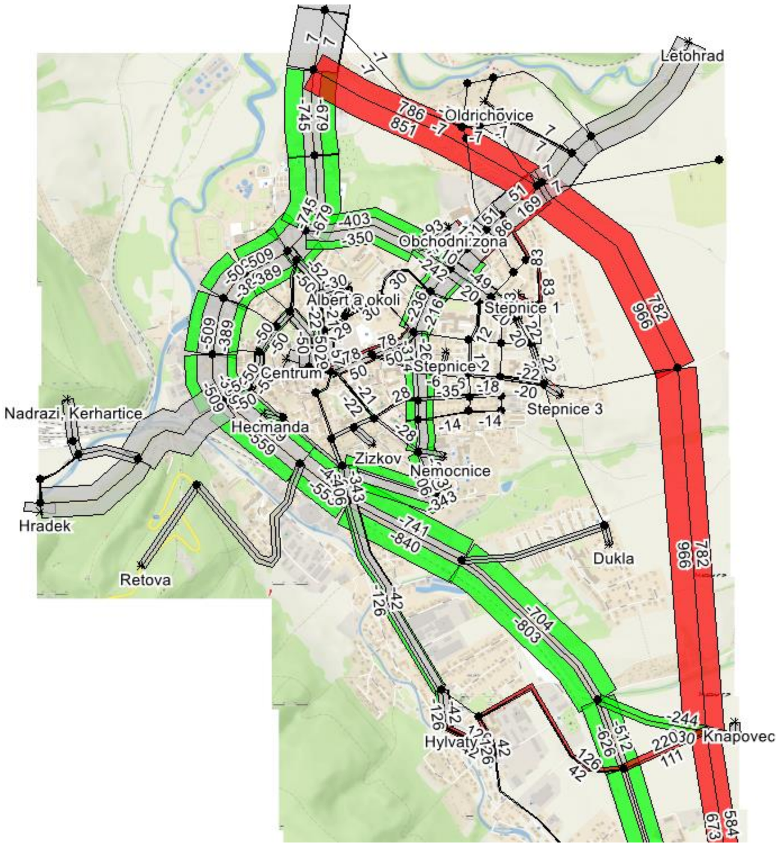

Figure 1 Modelled change of traffic flows related to bypass in Ústí nad Orlicí (cars/2 hrs). Source: [8]

The above-mentioned data is completely in line with the findings presented in the paper. According to the model, 59 % of traffic intensity will remain on the original route even though the bypass offers a reduction of the travel time by nearly 43 % (from 7 minutes to 4 minutes). The LOGIT model parameter takes a value of Φ = -0,12, which again confirms the ambiguity of its application on bypasses in group c) local centres. The negative value is due to the fact that the route offering a shorter travel time (the parameter considered) attracted less than 50 % of the demand.

On the other hand, the relatively low number of places with reduced speed brings a potential risk that the bypass will not be as attractive for drivers (will not sufficiently increase the driving comfort) as might be expected. This can manifest itself indirectly as well, with drivers not willing to move activities they could potentially perform in other cities as well and still going to Ústí nad Orlicí during transit, even if it is not strictly necessary.

5. CONCLUSIONS

This paper has shown that defining places with reduced speed and determining their number (by type) on the original route (through a municipality) can serve as a meaningful indicator justifying the need of a bypass and the related theory of managing traffic flows in conurbations.

The number of places with reduced speed can for instance be used for setting priorities as to the order of implementation of bypasses of different municipalities. It is clear that compared to four-tier modelling and the above-mentioned LOGIT model, this approach has a lower granularity. However, this is offset by a lower range of necessary data and their higher objectivity.

The proposed bypass groups by municipality size (**Table 1**) have only been defined in outline. It is to be noted that for statistical validation, the range of necessary data would need to be much greater. From the points of view of traffic and technology, the proposed approach does indeed provide some insight into the issue (see **Table 2** or Section 4).

What can also be mentioned in the discussion is the fact that the number of places with reduced speed can support decision-making in regard to the future use of the original route through the city built-up area. Where the number of places with reduced speed is low, their increase can be considered (e.g., adding new pedestrian crossings, roundabouts, etc.), partly with the aim to increase the attractiveness of the bypass. Nevertheless, mostly the results of the Section 4 model, but also the intensities established in Kolín and Nymburk show that such roads will not remain completely unused. Therefore, when considering the future configuration of original roads, it is necessary to look for a balance between securing the attractiveness of the bypass, the quality of servicing of other transport relations (including the source and target transport) using the original network – with excessive calming of traffic on these roads potentially leading to undesirable transfer of this traffic burden to other sections – and, last but not least, the comfort of movement of pedestrians and cyclists.

The desired objective has been met and it can be assumed that places with reduced speed certainly are an important factor for both railway and road transport.

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