# THE ROLE OF ACCESS DISTANCE TO HIGHER CATEGORY TRAFFIC NETWORK (BYPASS) ON IMPACT OF ITS USE

Norbert MONDEK

*University of Pardubice, Jan Perner Transport Faculty, Pardubice, Czech Republic, EU,*
*norbert.mondek@student.upce.cz*

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**Abstract**

Road bypasses of cities are built primarily for the purpose of detouring transit traffic from cities to their periphery. Urban roads are then released and used primarily by traffic flows with origin or destination in the city and inner-city individual and public transport. The use of urban roads depends, among other features, on the usability of the bypass in context of achievability of the surrounding municipalities. Several factors influence the demand for bypass, such as the distance of the bypass from the city, the access options from bypass to the destination. The aim of the article is to find and evaluate these factors using the possibilities of transport modelling. This analysis will be carried out for several categories of cities depending on their size and regional importance. Individual (road) transport will be monitored.

**Keywords:** Bypass; roads; surrounding municipalities; factors; transport model

## 1. INTRODUCTION

The use of new and original road infrastructure is influenced by several factors. For the purposes of this paper, the term 'original road network' means lower category infrastructure, on the contrary, the new infrastructure is understood as a higher category road network, i.e., bypasses. As part of scientific activities, the author deals with the issue of replacing lower-category communication with higher category roads. This article uses an analysis using the transport model. Transport modelling provides several tools enabling the analysis of traffic flows. The aim of this article is to evaluate the effect of some factors in the context of bypasses, precisely using the transport model. It is an examination of the factors relating to the attractiveness of the bypass in relation to its location and parameters, on the one hand, and the location of the centres of interest, on the other.

## 2. FACTORS AFFECTING ROAD TRANSPORT IN THE CONTEXT OF BYPASSES

The use of higher category traffic network, in this case bypasses, depends on local circumstances. Their use is generally influenced by several factors, such as the intensity of traffic flows, the attractiveness of the city, etc. Some of these factors have already been the subject of author's research [1, 2]. In the context of this paper, the subject is to examine the effects related to the demand for bypass in relation to its location towards municipalities. The following factors should be considered in this case:

- The attractiveness of the bypass for journeys within the city - In fact, it is a situation where it can be effective to use a bypass to move between local parts within a single city (or agglomerations), especially if such a transfer is faster, shorter, more comfortable, etc.
- The comfort of driving on the bypass and bypassed route - This is partly a subjective assessment, because above all the driving comfort is a more difficult to measure quantity, which is due to the individual perception of everyone.

- Location of attractive objects in the city - This factor is related to the fact that there are objects that create quite large volumes of traffic, which can generally affect the choice of route.
- Journey extensions in case of use of bypass - This factor partly results from the previous one, but the actual extension of the route is already quantifiable and thus it is possible to compare or assume the use of specific road sections, especially from a time point of view.

In order to evaluate the above factors, it is necessary to select the appropriate quantities to be monitored on the road traffic. The first such quantity is the volume of traffic by which it is possible to track absolute changes (additions or losses) of vehicles on the infrastructure under examination. Another indicator examined may be the distribution of traffic flows after the opening of the city bypass. With this indicator, the ratio between the use of urban roads and the road bypass can be appropriately interpreted, including, for example, depending on some socio-economic factors [3]. Similarly, the year-on-year increase in traffic can be interpreted, both on bypass and urban roads, but also globally for a certain traffic flow monitored. The volume of transport itself also has a major impact on the sustainability of the urban environment system, as the number of emissions is generated precisely from transport [4].

In the context of the subject under examination, it is essential to distinguish between the types of bypasses that can be encountered in practice. These bypasses are closely related to the road category [5]. In the first case, therefore, these are motorway bypasses, the social benefits of which are, above all, significant for transit traffic flows. A specific category around motorway bypasses is those, currently built in half profile (with possible future extension to a fully-fledged motorway). These types of bypasses arise either as a temporary condition during construction or, in certain cases, for a longer period, which can be explained by the acute need to divert transit traffic from the city to the road, which will be part of the motorway link in the future.

## 3. LITERATURE REVIEW AND METHODOLOGY

In this chapter, the first part produces an overview of the literature in relation to the use of bypasses. The second part of the chapter presents literature on the issue of transport modelling and the based methodology of the paper.

### 3.1. Use of the bypass

When examining the issue of bypasses, it is possible to take inspiration from Article [6], which is a simplified model of traffic intensity on the planned bypass. When creating this model, one of the input requirements was that the data entering the calculation could be obtained easily. This achieves a fast and undemanding way of estimating the traffic load on the proposed transport infrastructure. By entering the model, statistical methods calculate the average daily intensities on roads of the lower and higher categories, while data from the feasibility study of eight sites in Bosnia and Herzegovina have been used as a calibration tool. In addition to daily intensities, the characteristics of the original road and bypass, such as their length, number of connections and the time spent driving on the original and replaced infrastructure, enter the calculation. The resulting model can be interpreted as the ratio of traffic density on the planned and existing roads, with regression analysis detecting deviations of predicted future traffic intensities from the simulated values.

The issue of network congestion of inner-city roads is addressed in a publication [7], which confirms, inter alia, the announced fact that the planning of new road infrastructure in cities, be it individual or network roads, requires verification by an efficient and high-quality transport model. Such a model should be able to provide an overview of mobility as it stands, as well as to predict the future behavior of the population after the construction of new infrastructure replacing the original one. The design of a sufficiently high-quality transport model provides information on the behavior of residents with the various alternatives considered (route guidance options) and thus facilitates the decision on the final choice of route, which should divert as many vehicles as possible and save travel time. In the context of the article cited above, a practical example is the conduct of a case study for the Spanish city of Badajoz, in which different variants of the routing and connection of the bypass to the city itself are compared.

### 3.2. Transport Modeling

The field of transport modelling and forecasting is an important part of transport planning, as it makes it possible to examine the various planned scenarios in the area of transport infrastructure without the need for their physical existence. This field of science is based on the very definition of the model, which is defined as an idealized imitation of the real world, enabling relevant information on the system under examination to be obtained in order to design and verify solutions [8]. The four-stage model is one of the basic methods of transport modelling, showing the movement of traffic flows over the transport network. It consists of parts of Trip Generation, Trip Distribution, Modal Split and Traffic Assignment.

An important one for this paper is the last stage of the four-stage transport model, i.e. the allocation of traffic flows to sections of the transport network (traffic assignment). At this stage, a specific route is assigned for each trip. As with modal split, the most advantageous route for a particular user is chosen in this case, not only in terms of time or distance, but also based on a number of other, often individual factors. At this stage, weightings of criteria are often used, which enter the evaluation of individual parts of the transport network (roads, lines). It is within the level of traffic assignment that it is also possible to assess the factor of the existence of bypasses due to the dispersion of traffic flows in the monitored area. The quite used All-or-Nothing (AON) method often works with this algorithm, which forms the basic and simplest method in the traffic assignment phase. This method assumes that all users of the transport system will choose the shortest possible route for their journey by the mode of transport in question, while not allowing any alternative routes.

It is well known that a traffic pattern satisfying the equilibrium conditions (Wardrop clause) in a transportation network can be obtained by solving a convex programming problem with linear constraints, provided the travel cost in each link is dependent only on the flow on that link [9]. The convex combination algorithm was originally suggested by Frank and Wolfe in 1956 as a procedure for solving quadratic programming problems with linear constraints and is known also as the Frank-Wolfe (FW) method. In the traffic application, the linear program decomposes into a set of shortest path problems [10]. The Frank-Wolfe method is one of the most widely used algorithms for solving routing problems in the telecom and traffic areas [11]. Its popularity is attributed to its modest memory requirements and simplicity. The marked advantage of the FW algorithm allows the traffic assignment problem to be solved without the need to store paths, which is a significant benefit for planners working with large-scale networks. [12]. The use of FW algorithm is diverse. In general, it is typical for him that the issue addressed is often high-dimensional and thus [13]. In addition to transport this algorithm is applicable in solute specific models that can be practically applied as groundwater quality management tools [14].

There are several modifications to the Frank-Wolfe transport algorithm that are adapted to the specific conditions detected by solvers in the past [15]. For example, a modification designed for calculation in a Microsoft Excel environment that is written in Visual Basic and also uses CAD-based software [10] The traffic assignment in this study took into account only travel time and capacity of the network. The values of Beta and Alpha were assumed. For best results it would be great to analyze more factors such as velocity, preloads, stops, etc. and use values of alpha and beta calibrated from the network. The purpose of this paper was to introduce solve the traffic assignment in a real network but also in order to get a better model of traffic assignment in any network. The work with the FW algorithm is also devoted to an article [12] in which the so-called ODBFW algorithm is presented. This one-OD-at-a-time flow update speeds up the convergence by using the path-flow information. In the study presented in the article, the authors concluded that the ODBFW algorithm is at least three times faster than the standard FW algorithm for reasonable congestion levels somewhat competitive even for unrealistic congestion levels and an order of magnitude faster than the modified FW with path storing. Another important advantage of this algorithm is that it significantly reduces the path storage requirements, if both link and path flow solutions are required from a link-flow based algorithm.

## 4. SOLUTE OF TRAFFIC ASSIGNMENT PROBLEM ON PARTICULAR EXAMPLE

A link between Chrudim and Pardubice (CZ) was chosen as a sample example for detecting bypass effects. These are towns located in the Eastern Bohemian region, with Pardubice having approximately 90 000 and Chrudim having approximately 23 000 inhabitants. Depending on the route, the distance of these two places is approximately 12 km. These cities are connected by the first-, second-, and third-category roads (ranked according to regional importance), and the first-category road forms in this case a bypass of both cities. Therefore, in this case, it is interesting to see whether the existence of the bypass in some way changes the way the transport between these cities, or how strongly and on which shows. The **Figure 1** shows the road network between Pardubice and Chrudim consisting of the first- (red), second- (orange) and third-category (yellow) roads. The effects studied within the selected case include the following outcome:

- How far is it to the bypass, and at the same time
- How far is it to your destination (what is the share of the bypass on this route), and
- What are the other options.

Aimsun Next modeling software has been selected for bypass research. Within this software, a transport network important for journeys between Chrudim and Pardubice was created. All important intersections, road category, number of lanes and associated capacity were entered. In order to investigate specific factors related to the bypass, one part of the four-stage transport model, namely traffic assignment, was used. In particular, several methods of assigning traffic loads to the transport network are available under Aimsun, the implicit choice being the Franke and Wolfe method, with the possibility of selecting the Conjugate Frank and Wolfe methods, which, however, makes no difference to the chosen example. By comparison, the All-or-Nothing method was also used, since it is its simplicity that highlights some of the essential features of the bypass.

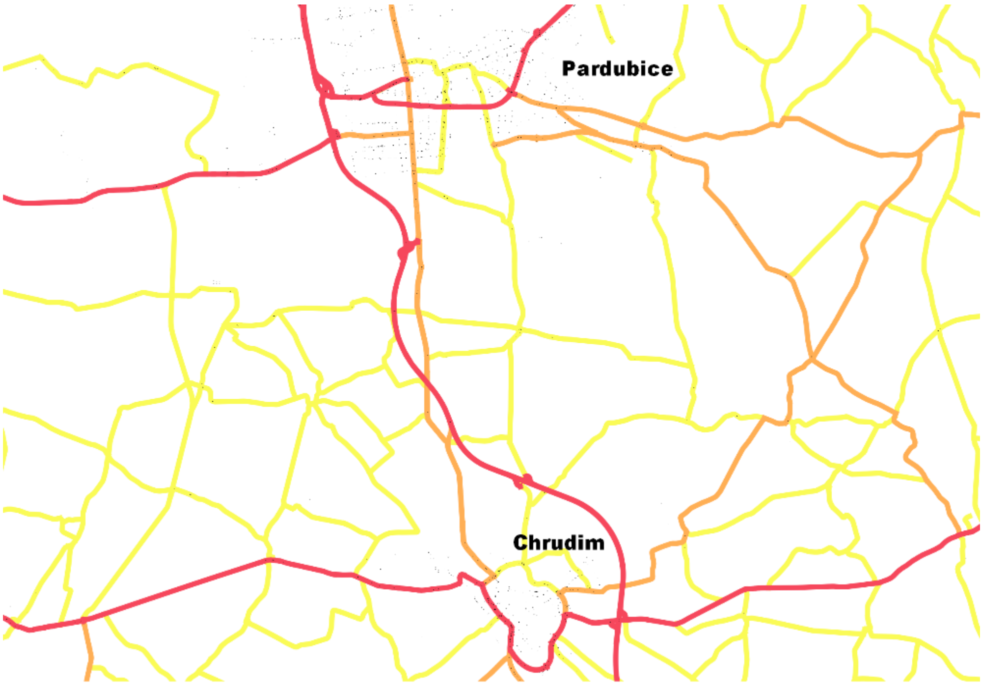


**Figure 1** The road network between Pardubice and Chrudim

The initial step was to create that part of the transport network in the model that forms the main connections of Chrudim and Pardubice. This represent a first category road I/37, a second category road II/324 and a third category road III/34026. Multi-level junctions and substantial intersections have also been created. Average speeds and capacity were determined for individual road sections based on the parameters of the roads. After the creation of the road network, it was necessary to create centroids that concentrate potential origins and destinations of journeys in one center location. Since it is a closely focused macroscopic model designed specifically for the purposes of this research, the number of centroids and their origin and destination loads corresponds to research needs. The town of Chrudim is represented a total of two centroids, one of which is located near the city center (Masarykovo náměstí). Up to four centroids have been created in Pardubice, and the one also representing the city center (Masarykovo náměstí) is essential for the article.

To verify the effects, it was necessary to create an OD matrix that represents the number of vehicles between each centroid. For the purposes of this article, a model load of 100 vehicles from each to each centroid has been chosen (in one hour). This number has been chosen from a practical point of view, as it is thus possible to easily determine the relative distribution of the traffic load between centroids (100 vehicles correspond to 100 %). Once the required inputs had been completed, the Traffic Assignment process could be started. This process was started using two described FW and AON algorithms. Both algorithms achieve different results, but they essentially describe the situation that occurs between the two cities. A comparison of the results of both methods is shown in **Figure 2** and **Figure 3**, and the differences are not so pronounced.

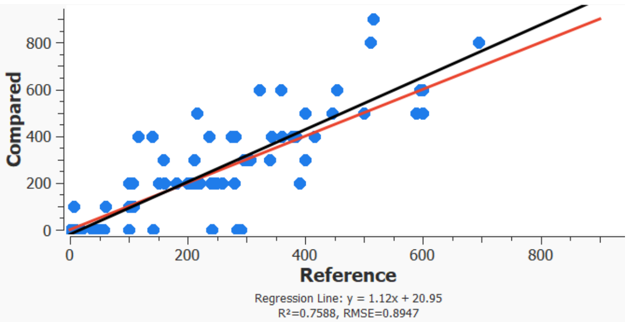


**Figure 2** Differences between Compared (AON) and Reference (FW) traffic assignment in each section

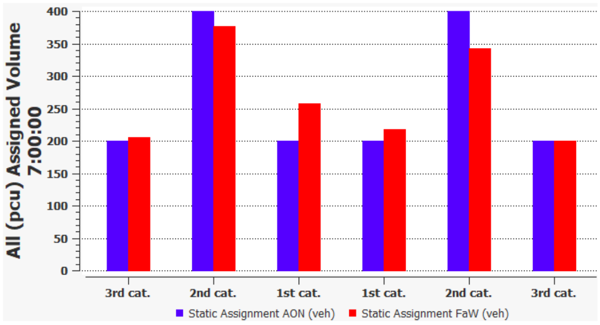


**Figure 3** Distribution of assigned volume by AON (blue) and FW (red) algorithm

For further analysis, the output from the FW algorithm is used, because it generates more real data for the load on the transport network (individual drivers do not decide the same way, but differently). The static simulation carried out shows that the bypass does not bring virtually any benefits for the journeys to the city center. In this case, the bypass connected to the city center is quite eccentric, so the use of another descent would be counterproductive. The parameters of the bypass are also comparatively important, because it is not a motorway with a higher maximum speed limit, and at the same time on the eastern edge of the city the traffic on the bypass is slowed down due to the existence of a intersection (roundabout). Part of the passengers choose between Chrudim and Pardubice for the use of the bypass, but from a time point of view there will be no savings, but an important factor may be, e.g., driving comfort, which is higher on the road of the higher category in this case. However, using a second-class path appears to be the best alternative (**Figure 4**).

A similar situation occurs in the case of Chrudim, where the use of a road other than the marked road (**Figure 5**) does not make sense for journeys to the city center. Unlike in the previous case, there are different options for connecting the bypass and the roads of the lower category depending on the direction of travel. For the direction Chrudim - Pardubice, there is basically only one route available when travelling between city centres, and therefore the choice is quite clear. The situation is different in the direction of Pardubice - Chrudim, where there is an alternative to the exit from the bypass closer to the city (due to the progress of the construction in the past), which in the overall view affects the use of the bypass in its entire route between the cities studied. This is an important finding as it turns out that the frequency and location of intersections on the bypass has a significant impact on the use of all roads in the region.

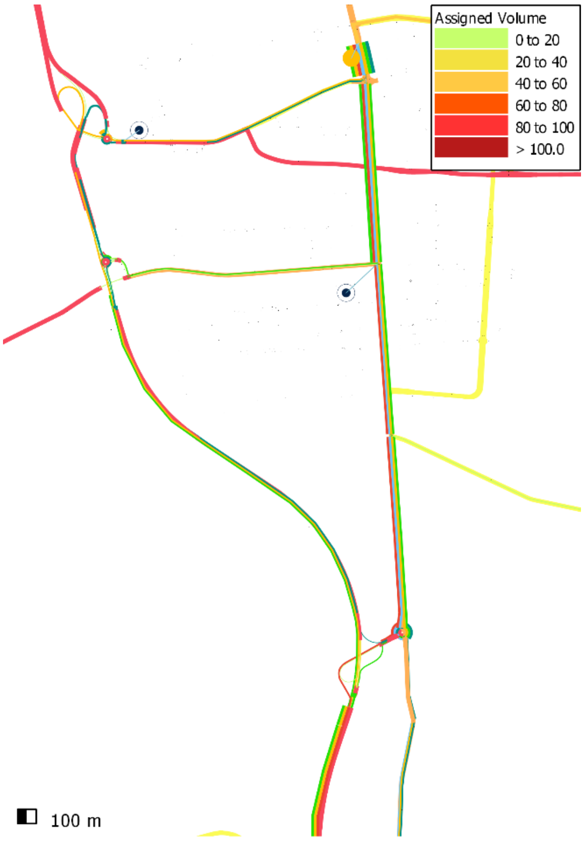


**Figure 4** Usability of bypass to journeys to/from city centre (Pardubice)


**Figure 5** Usability of bypass to journeys to/from city centre (Chrudim)

For other journeys between Pardubice and Chrudim, traffic assignment distribution is spread across all available roads. These roads are subject to the same conditions as those found in the model example of the interconnection of the centres of Pardubice and Chrudim. The location of journeys origins/destinations towards the bypass is therefore important. Therefore, for other parts of the city, the bypass is either unusable at all (eastern part) or very beneficial (western part). The example chosen showed that the way in which the two nearby places are connected to the bypass has a major role in its use, but depending on the parameters of the roads. It is important to look at the problem under examination comprehensively and also to take into account the available alternatives to the bypass, of which there are enough in the present case.

## 5. DISCUSSION AND CONLUSION

As explained and shown in the specific example of Pardubice and Chrudim (CZ), the use of bypasses is influenced by several factors. The role of access distance to the bypass is very important, depending on the location of the resources and destinations of the roads. Furthermore, it is mainly about the number, length and parameters of the connection of the bypass and the city. The effects observed in this paper were the use of the bypass and other roads nearby, depending on the specific conditions. A transport model created specifically for the purpose of researching the problem was used, while at the same time the algorithms AON and FW were compared. Model data shows that the AON algorithm is suitable for a quick assessment of the suitability of roads for individual journeys, but the FW algorithm is more sophisticated and provides multiple options more suited to people's decision-making. Model data was used in this model, but after updating it with real data, it would be possible to assess the problem more comprehensively in the context of a wider area and using other transport modelling functions (e.g. BPR function). It would also be possible to model the findings in question on the example of other places with a similar or different road structure. In addition to individual transport, it is also possible to monitor public transport, or to create a multimodal model evaluating the territory comprehensively across all modes of transport. These topics may be the subject of further research in the further work of the author, or possibly also of other researchers dealing with this issue.

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