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RESEARCH ARTICLE

Investigation of Cordon Pricing in Budakeszi

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Abstract

This paper is about a theoretical investigation of a Congestion pricing system in the municipality of Budakeszi. Due to its special geographical background the city is heavily affected by congestion problems, produced by the high number of commuters passing through. This paper illustrates the usage of transport planning models as the Four Step Model to picture this situation and how this model can be used in the simulation of a theoretical congestion pricing system. Finally the utilities of different systems are investigated for the Budakeszi area.

Keywords

congestion pricing, cordon pricing, area pricing, Budakeszi, Four Step Model

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1 Introduction

Regarding the daily life of world's urban population, traffic congestion is a well-known problem all over the world. Under scientific perspective congestion "*...is a situation in which demand for road space exceeds supply*"(OECD, 2007). Another definition was formulated in an ECMT Round Table report in 1999 "*... Congestion is the impedance vehicles impose on each other, due to speed overflow relationships, in conditions where the use of a transport system approaches its capacity*" (OECD, 2007). The problems and external effects of congestion are widely known and are not topic of this paper. However traffic planners have several instruments to solve congestion issues. One solution is Congestion Pricing stated by Sabounchi et al. (2014). In our paper authors have investigated the situation of Budakeszi in Hungary in terms of traffic flows and possibility of congestion pricing.

Budakeszi is in the Budapest metropolitan area, located 12 km west of city centre. It has a population of approximately 13 500 persons. However Budakeszi is affected by widely traffic congestion problems as the main street Főutca (Fig. 1) in the town is used by many commuters every day to reach the city centre of Budapest.

Fig. 1 Fő utca (Source: Own picture, recorded on the 30th of October 2013)

Due to the geographical background of the area, the Fő utca is the only passage in the area of Jánoshegy to reach Budapest (Fig. 2).

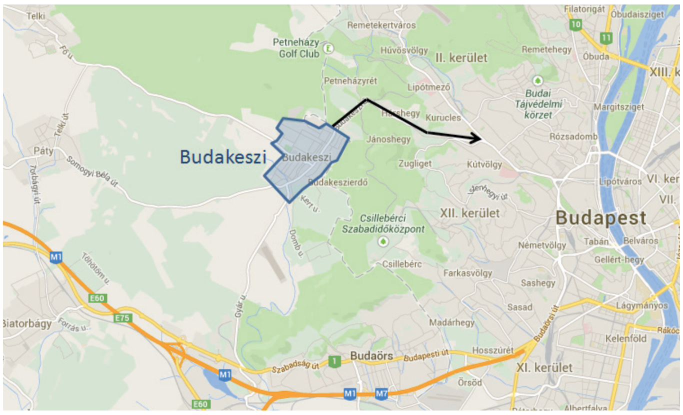

Fig. 2 Budakeszi area (*Source: Google Maps*)

First of all this paper will introduce the Four Step Model recently described by *Tavasszy* et. al. (2011) in detail, which is able to create a simulation of the travel network and travel demand of the Budakeszi area. Afterwards the paper will introduce a cordon pricing system in the town of Budakeszi. This cordon will only affect commuters from the western cities which are driving through the municipality of Budakeszi to reach Budapest, whereas the inhabitants themselves and public transportation are not affected at all. The outcome of this Budakeszi trial will be an analysis at which price level some car commuters are changing to public transport system and how this development can enhance the travel situation in similar cases.

2 Methodology

2.1 Introduction of the Four Step Model

Thinking about urban transport planning the use of models is an obligation. Usually the reality is too big and complex to investigate and solve all practical assignments. With the help of these models we can calculate the effect of several variables and use the outcome to increase transport systems easily. (Péter and Fazekas, 2014)

A useful model should be able to simulate a travel network based on the practical travel demand of the average population of one region or area (Reimann, 2007). The Four Step Model (FSM) is fulfilling these criteria well. "...The history of demand modeling for person travel has been dominated by [this FSM]" and it is still the foundation for urban transport planning systems today (McNally, 2007). As the FSM is so important, this paper takes a closer look on it. The foundation of the model consists of two main points:

- An abstract of the travel system. It transfers the transport connection of the real world into a network of nodes and links. These network is divided into several Travel Analysis Zones - TAZ (Grzymski, 2008)
- Socioeconomic data of the affected area which indicate factors such as the number of trips, e.g. , usually broken down into various categories

With the help of this background the FSM use these data in four different steps, illustrated by Fig. 3. Afterwards the steps are explained in more detail and become connected to the practical trial.

Fig. 3 The Four Step Model

2.2 First step: Trip Generation

In the beginning the socioeconomic data is used to create an estimation of the number of person trips produced and attracted between every TAZ (Reimann, 2007). This trip generation uses the purpose of the travel. These reasons can be education/work, shopping, medical appointments as well as leisure activities (Dlr/Infas, 2010). These activities are usually categorized into several groups: (Levine, 2010)

- Home based work trips (HBW)
- Home based non-work trips (HBN)
- Non-home trips (NH - neither the origin nor the destination is the residence location)

Using the TAZ-zones *"...each trip purposes are collections of trips from each origin zone to each destination zone. Thus every zone produces a certain number of HBW, HBN and NH and each zone attracts a certain number of HBW, HBN and NH"* (Levine, 2010).

Using categories (e.g. level of household income, level of vehicle ownership, level of population density) the mean number of trips can be estimated.

2.3 Second step: Trip Distribution

The concept of activity based approach has evolved from human geography and social science, where it focused on interaction between land use and individual's activity-travel patterns. Transportation researchers carried this approach into the transportation field correlating activities and travel behavior with a number of assumptions (Malayath and Vermaa, 2013).

Continuing the first step the trip distribution is a model "*... of the number of trips that occur between each origin zone and each destination zone*"(Levine, 2010). The different travel purposes mentioned above (HBW, HBN and HN) are used for this step. The model "*...uses the predicted number of trips originating in each zone [as HBW and HBN start in the zone of the residence location] and the predicted number of trips ending in each destination zone. Thus, trip distribution is a model between travel zones – trips or links*" (Levine, 2010). This is exemplary illustrated by Fig. 4.

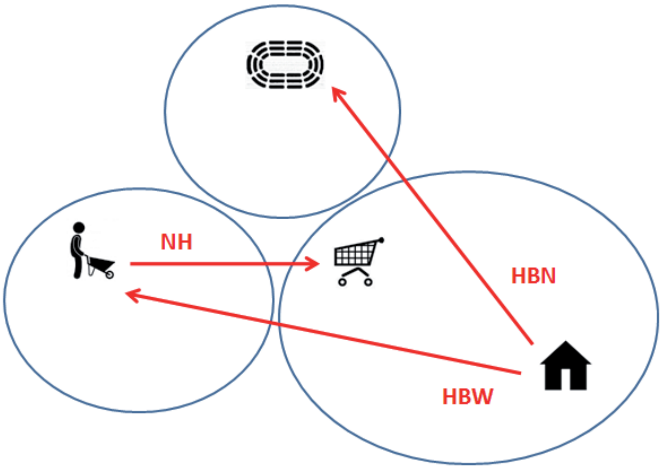

Fig. 4 Trips categories (*Source: Own figure*)

To calculate the destinations, the trip distribution uses the “gravity model” borrowed from Newton’s law of gravity which indicates: “*...The attractive of force between two bodies is directly related to their size and inversely related to the distance between them*”(Grzymski, 2008).

This relationship can be described mathematically as:

$$F_{12} = G * \frac{m_1 * m_2}{d^2} \tag{1}$$

where, G refers to the constant of gravitation, whereas m_1 and m_2 are the mass of the two different objects. The d refers to the distance between the balance points of these objects.

This gravity model has been applied to social interactions since the 19th century successfully (Tsekeris and Stathopoulos, 2006; Levine, 2010). Using this physical model in the urban transport planning the number of trips between different TAZ is directly related to the level of land development and the distances between them. Adopted to transport issues the formula can look like this:

$$F_{ij} = c * \frac{P_i * P_j}{r_{ij}} \tag{2}$$

Instead of the mass the model uses the potential P of the compared locations “i” and “j”. The c refers to constant and r refers to the resistance function, which is explained in more detail in the next chapter.

The potential is influenced by the number of inhabitants, jobs and leisure opportunities (Knoflacher, 2007). Regarding the Budakeszi issue the potential of the centre of Budapest is higher as the other cities, as it is not only the centre of the metropolitan area but the capital of Hungary also. Visible in Fig. 3 this effect is illustrate droughly. The townswest of Budakeszi are circled by small red circles, respectively Budapest by a larger one.To illustrate the importance of the different cities take a look to Table 1.

Table 1 Inhabitans of Budakeszi area (Pethő, 2013)

City/District	Inhabitants
Budajenő	1,687
Budaörs	26,757
Budapest II. District	87,744
Budapest XII. District	57,709
Budapest	1,735,711
Páty	7,009
Perbál	2,046
Telki	3,661
Tök	1,341
Törökbálint	12,841
Zsámbék	5,174

Using this gravity model, nearly all commuters of the western towns will commute to Budapest ignoring the other places.

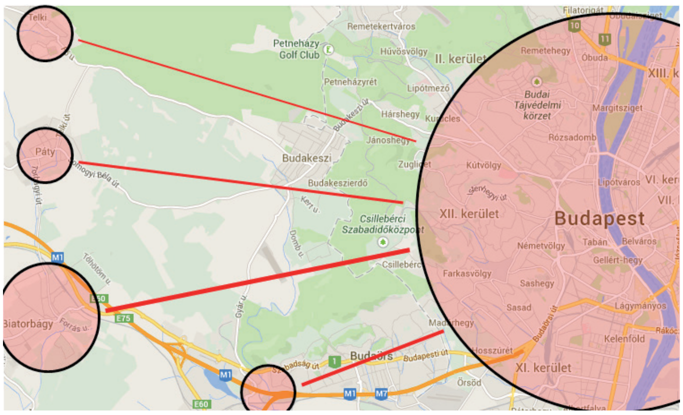

Fig. 5 Trip distribution in the Budakeszi area *(Source: Google Maps)*

2.4 Third step: Mode choice

After using the gravity model in the trip distribution the demand for travelling is segmented into different modes of transport. This depends on factors as the geographical data of the trip, the trip maker as well as the purpose of the trip taken from the socioeconomic data. To solve this problem, all the models use a concept based on a “utility function”. In this case the utility “*...can be used to compare completely different alternatives. [... There] is a method, of combining the various features of all the attributes including their price, to give one measure of utility which is consistent across the alternatives within the set of choices*” (Davidson, 2007).

For example the utility function of Koppelman and Bhat (2006) uses the total travel time, in-vehicle travel time as well as out-of-vehicle travel time, travel costs, numbers of transfers, walk distance and the reliability of on time arrival to compare the completely different modes of transport. Other authors as Davidson are expanding this utility function by some factors as the waiting time or the personal opinion about the different modes of transport (Davidson, 2007).However the utility function has to fulfill its requirements. Si, Zhong and Gao (2008) elaborated a utility function for using the FSM especially in

China as the normal approaches cannot illustrated all aspects properly. Following the paper of Tánczos and Török (2007) the utility function could also depends just on two attributes, like costs as well as the total travel time.

Regarding these utility functions there are various choice models based on it. The most popular models are based on logit and probit regression. The systems are using a different mathematical approach by using a different link function. However the results are similar (Viton, 2013). „*...The most common form is the logit model. [...] The logit model has a theoretic pedigree from random utility theory, has been found to fit mode choice behavior quite well and is computationally tractable*"(Davidson, 2007). Due to this quote this paper focuses on the logit model. Anyway the logit model can be distinguished into the nominal and nested logit model, depending on the different approaches of dealing with more than two alternatives (Fig. 6).

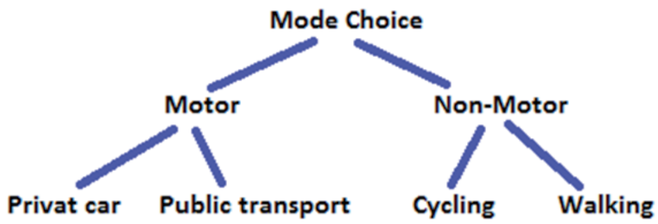

Fig. 6 Mode Choice, Nested Logit Model

With the help of the e-function the logit model creates a formula which gives us the proportion of the travellers for each mode. Due to several reasons the Mode Choice will not be regarded in the first run of the Budakeszi trial test. As it is written above, the trial test wants to affect car users passing through the municipality. There is a public bus connection from Budakeszi to Budapest (BKV bus lines 22 and 222). As there are not so many Park & Ride opportunities these bus lines are usually not used by the commuters from the western towns and villages. Due to this, these bus lines are mainly used by the inhabitants of Budakeszi, which will not be affected by the Budakeszi congestion charging. Anyway there are some other possible bus connections with interchanges. To keep the model easy, these connections will not be regarded as well, as they are not used by a large amount of travelers yet. Due to the high traffic and the geographical background other modes of transport like walking or cycling do not need to be regarded in the trial as well.

2.5 Fourth step: Trip assignment

At the end these trips and mode of transport decisions are allocated to the network, consisting the links and nodes of the real world. This involves the assignment of predicted trips to particular routes. "*...The predicted trips are those that are either predicted from the trip distribution stage or from the mode split stage*" (Levine, 2010). This step is necessary, because in the former cases all trips are assigned to one travel route which is not distinguished by the different mode of transport. However the route using public transport depends on the public transport network, whereas car drivers can also choose different routes of the same trip. In the Budapest trial test the situation is clearly arranged. On the one hand the mode choice is not regarded in the first run of the test, on the other hand the possible routes for the trip Assignment by car is limited by one. This situation can be regarded in Fig. 7:

Fig. 7 Trip assignment in the Budakeszi area (*Source: Google Maps*)

Using the data of a traffic investigation arranged by (Pethő, 2013) in the Budakeszi area in 2009 we can estimate the real contribution in the Budakeszi street network. Following the projection for 2014 has been made (Fig. 8):

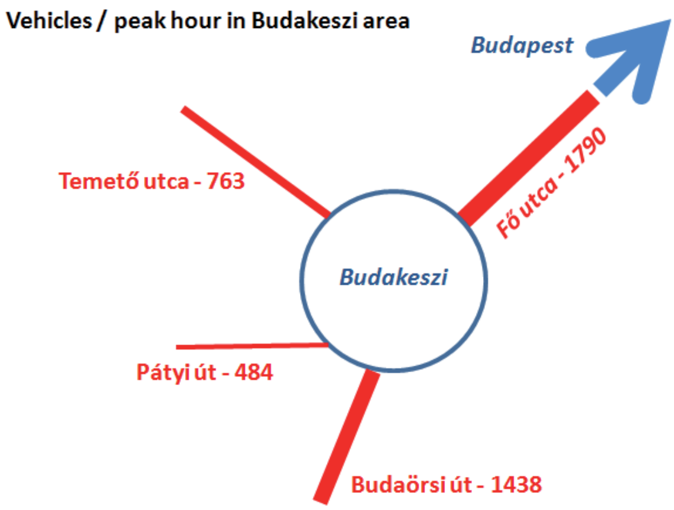

Fig. 8 Traffic investigation in Budakeszi area in 2009 (Source: Pethő, 2013)

3 Cordon Pricing

Regarding the subject of Congestion Charging, we find different approaches for this issue. As the best solution marginal cost pricing is not realisable due to practical restrictions this paper focus on Cordon and Area Pricing. These systems have been adopted in the practice successfully. On the one hand Area Pricing is used in Singapore, on the other hand the Cordon Pricing systems in London and Stockholm are well known as well. To understand the differences between these two systems, take a look to Table 2:

Table 2 Comparison of Area and Cordon Pricing

Area Pricing	Cordon Pricing
Area Pricing charges vehicles driving in a defined area. The charge is directly connected to the amount of driven distance inside the defined area.	An area is enclosed by a charging cordon. Drivers need to pay by crossing the cordon boundaries either in one or both directions.

Due to its economical and political background London was early affected by congestion problems. The London congestion charging was introduced in 2003 and was able to decrease the overall traffic flow entering the zone by 16 %. Another example for Cordon pricing systems is the city of Stockholm. Established in 2006, the capacity and quality of public transport was increased immensely at the same time. The congestion, covering the inner-city centre of Stockholm, is collected electronically through an onboard unit. The Stockholm system uses different charges, distinguished between peak and off-peak hours. "*...the forecast for the traffic effect made during the system design process actually pointed at [...] a decrease, around 20-25 %. As the trial turned out, traffic flows across the cordon decreased almost exactly as predicted by the model*" (Mondiale De La Route, 2008).

Regarding the two different pricing models, Cordon pricing and Area Pricing, Cordon Pricing is the proper solution for the Budakeszi trial as well. As mentioned above, the Budakeszi trial seeks to affect commuters driving through the municipality of Budakeszi, whereas driving in the city should be unconcerned. This purpose can be reached by the Cordon pricing system properly.

This cordon can be easily developed. Due to the geographical and infrastructural backgrounds there are only four passages for crossing the cordon (As already declared in Fig. 7 and 8). Therefore the introduction and operation can be solved easily. Using the Four Step Model we can calculate the traffic assignment affected by the Budakeszi Cordon pricing. Whereas the personal costs increase due to the Cordon pricing, the social costs for the whole society decrease, as the transport infrastructure can be used more efficient. However some negative environmental and social effects need to be considered as well (Oregon Department of Transportation, 2009). The social cost curve needs to be specified, versus the individual cost curve before and after cordon pricing. Using the experiences of existing Cordon pricing, it has broadly neutral economic impacts on local businesses. However businesses in the charging zone can outperform those outside as it happened in London. Due to the minor importance of local business in Budakeszi no negative impact is expected (US Department of Transportation, 2008). Cordon Pricing reduces the use of facilities, allowing faster trips for the paying commuters. As there are no geographical alternatives for most of the commuters they need to pay the cordon fee or may change the mode of transport. As already investigated in the paper the public transport is not used by many commuters yet. With the help of the resistance function we could investigate a proper price level of the Cordon pricing system. At this price level, a large amount of car drivers change the mode of transport. On the one hand the traffic congestion problems would decrease. On the other hand the earnings could be used to increase the whole public transport system in Budakeszi area.

4 Conclusion

The theoretical investigation of Budakeszi Cordon pricing system refers to a problem concerning many cities and suburban municipalities in the whole world. On the one hand Budakeszi is heavily affected by traffic congestion, due to the high number of commuters passing through the city. On the other hand this problem cannot be solved by the usual tools of urban traffic planning, as the geographical and infrastructural background do not allow an upgrade of the local transport infrastructure.

This paper elaborated how traffic models as the Four Step Model can simulate and reproduce the traffic properly in these difficult situations as well. Using this model we can calculate the effects of the congestion charging system. Regarding the Budakeszi trial Cordon pricing is the proper solution.

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