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Generalized Trip Cost: One of the Estimation Approaches

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***Abstract* — The solution of modern transport planning problems, aimed at improving the quality of transport service for all the users of the city's transport infrastructure, requires application of modeling tools to describe components of urban areas, transport infrastructure and transport behavior. The IrNITU NI Transport Laboratory proposed several approaches for estimating the generalized trip cost, taking into account the time spent on searching for a parking place and parking fees for off-street parking. The proposed approaches for estimating the components of the generalized private vehicles trip cost can be applied to plan paid parking lots and tariff policies, as well as to plan a system of commuter parking lots (Park and Ride).**

Keywords* — *generalized trip cost, traffic flows distribution, travel demand estimation, search for a place in the parking lot, parking fee, time equivalent of parking fee.

I. INTRODUCTION

Designing a sustainable city transport system involves an increase in attractiveness of public transport and other non-motorized ways of movement (pedestrian and bicycle infrastructure). As a result of increase in public transport attractiveness, there is a change in transport behavior of the population, and the total share of not using private transport means is growing, i.e. the distribution of total volumes of trips by means of transport is changing (modal split).

The solution of modern transport planning problems aimed at improving the quality of transport service for all the users of the city's transport infrastructure requires application of modeling tools to describe components of urban areas, transport infrastructure and transport behavior. Thus one of the most important parameters is the calculated generalized trip cost and its time equivalent on the basis of which trips are distributed by modes of transport (the selection of mode of transportation made by transport infrastructure users is simulated).

In simplified form, the public transport (OT) trip cost can be represented as:

$$C_{PuT} = (t_{ped_{or}} + t_{wait} + t_{tr} + t_{int} + t_{ped_{dest}}) \cdot \frac{C_{man\_h}}{60} + C_{tr}, \qquad (1)$$

where C_{PuT} is generalized public transport trip cost, RUB; $t_{ped_{or}}$ is time spent to walk from a departure point to a public transport stop, min; t_{wait} is time spent to wait for a public transport mean, min; t_{tr} is time spent on a public transport trip, min; t_{int} is time spent to change a public transport route, min; $t_{ped_{dest}}$ is time spent to walk from a public transport stop to a destination point, min; C_{man_h} is man-hour cost, RUB; C_{tr} is public transport fare, RUB.

Professional foreign literature [1–3, 5–7, 12–15, 19–21] presents recommendations how to model the city transportation system and how to adjust the formula (1), for example, regarding the time spent on pedestrian approaches and waiting, the value of which should be doubled compared to the time spent on a public transport trip [14]. The objective to determine man-hour cost is considered complicated if to take into account the fact that transport system users are representatives of different population social strata, characterized by different income levels, estimating time losses in a different way. If there is no high-quality baseline data, the man-hour cost can be determined by average hourly wages level.

At the same time, a more detailed system to estimate this indicator is required to simulate transport behavior; it should take into account the peculiarities of transport behavior of people depending on the purpose and time of travel in a flexible way.

Forecasting transport demand on the basis of its modelling is focused on estimation of transport flows distribution between competing travel modes, including walking and cycling. Modern concepts of sustainable development and comfortable urban environment imply the formation of a multimodal urban space, where the interests of all its users are taken into account. In connection with it, the concept of multimodal means of communication has been developed (multimodal streets, boulevards, shared space streets, etc.), which are a fundamentally new type of transport infrastructure. At the same time, it is obvious that the objective to redistribute street space among all its users in the most relevant way requires, in its turn, the solution of problems of managing transport demand and traffic flows, which includes search for the appropriate location of objects of travelling by private vehicles visitors' attraction, introducing restrictions on parking, the development of off-street parking systems and parking restrictions (in the form of a fee or a duration limit). Therefore, special attention should be paid to methods to estimate the generalized private transport trip cost, on the basis of which modal split is determined. The generalized private transport trip cost C_{PrT} (RUB) in its simplified form can be represented as follows:

$$C_{PrT} = (t_{or_p} + t_{tr} + t_{search} + t_{dest_p}) \cdot \frac{C_{man\_h}}{60} + C_p + l \cdot C_{km}, \quad (2)$$

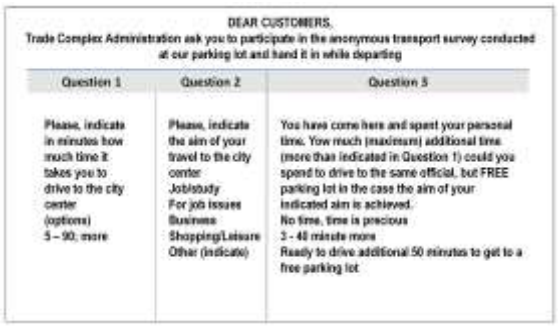
where t_{or_p} is time spent on approaching from the point of departure to the place of storage of vehicles, min; t_{tr} is time spent on a trip in vehicles, min; t_{search} is time spent on searching for parking and free space on it, min; t_{dest_p} is time spent on approaching from the parking (storage) to the point of destination, min; C_{man_h} is man-hour cost, RUB; C_p is cost of parking fee, RUB; l is length of the trip by car, km; C_{km} is average cost of car maintenance and fuel, RUB/km.

Taking in consideration that the indicator of total trip time is used to estimate the transport flows distribution applying transport simulation tools in most of the cases, all costs that are expressed in monetary terms must be converted to time values using corresponding time equivalents. The presence of such indicators as time equivalent of certain monetary expenditures allows to take into account additional restrictions imposed on private vehicles users (parking, entrance or passage to a particular section fees, such as a high-speed road), and, therefore, plan activities to manage transport demand.

One of the main ways to estimate the time equivalent of monetary expenditure used to simulate a transport proposal is to study the subjective assessment of time costs in monetary terms, which is carried out by interviewing users of a particular segment of transport infrastructure.

II. PARKING FEE COMPONENT FOR GENERALIZED TRIP COST ESTIMATION

In the framework of research aimed at studying, updating and refining the parameters of transport demand and traffic simulation [4, 8–11, 16–18], IRNTU NI Transport Laboratory proposed approaches to estimate the generalized trip cost taking into account time spent on searching for a parking space and parking fees in the case of off-street parking lots.



DEAR CUSTOMERS,
Trade Complex Administration ask you to participate in the anonymous transport survey conducted at our parking lot and hand it in while departing

Question 1	Question 2	Question 3
Please, indicate in minutes how much time it takes you to drive to the city center (options) 5 – 90; more	Please, indicate the aim of your travel to the city center Job/study For job issues Business Shopping/Leisure Other (indicate)	You have come here and spent your personal time. How much (maximum) additional time (more than indicated in Question 1) could you spend to drive to the same official, but FREE parking lot in the case the aim of your indicated aim is achieved. No time, time is precious 3 - 40 minute more Ready to drive additional 50 minutes to get to a free parking lot

Fig. 1. Survey questionnaire for visitors of paid parking lot to find out their subjective assessment of parking fees in time equivalent

The time spent to search for a place in the parking lot was determined as a dependency of the amount of doubled time spent to walk from the parking place to the entrance of the visited object (taking into account the average speed of a pedestrian) and time spent to search for a vacant place at the parking lot depending on parking lot load.

Figure 2.a presents an example of the results of measuring the time spent to search for a place in the parking lot of one of Irkutsk large shopping centers. The results of observations at ten off-street parking lots allowed us to develop an algorithm to determine the time spent to search for a parking place depending on the load and other parameters (capacity, area, share of driveways, driveway configuration) of a parking lot.

To determine the time equivalent of parking fees, a questionnaire survey of users of a paid parking lot was conducted in accordance with the developed questionnaire (Fig. 1). For each visitor, a set of characteristics was collected: time spent in the parking lot, the trip to the parking lot time, the actual payment for parking, acceptable additional time expenditure instead of parking fees.

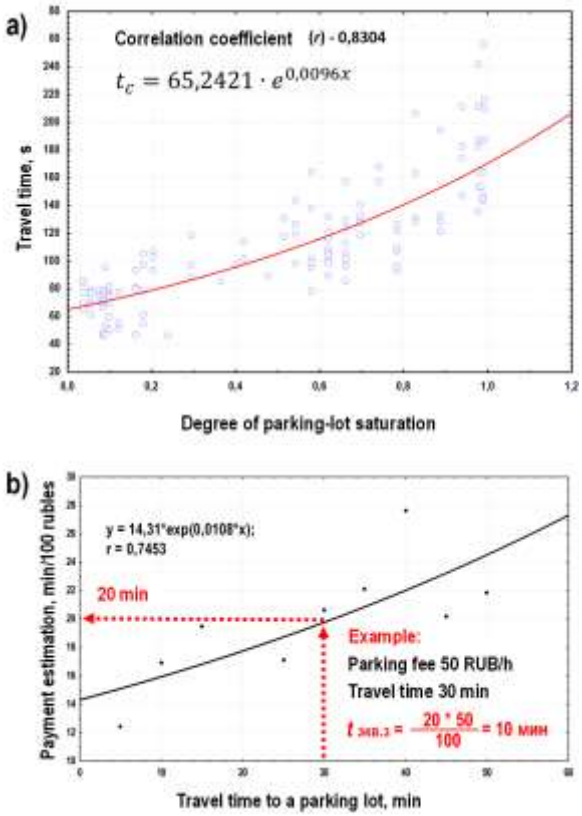


Fig. 2. Dependencies of additional time spent when travelling by car: a) on the parking lot level of saturation; b) on the time spent on a trip to a parking lot

As a result of the analysis of the obtained statistical data, it was found out that the time equivalent of parking fees depends on the time spent to drive to a parking lot, the value of the time equivalent increases simultaneously with the growth of time expenditure; consequently, the amount of additional costs to drive to a free parking lot decreases.

III. RESULTS OF THE MODELLING

Fig. 3 presents the parameters of the test model within the boundaries of Irkutsk with artificial calculation areas. The number of leaving the area vehicles within an hour and the number of parking places in areas with mass service facilities were used as the main characteristics of the areas. At the same time, the city center parking lot is supposed to introduce a parking fee. Fig. 4 and 5 present the travel time spent at the

network segments and the sequence of calculation of the generalized time expenditures on driving a car, taking into account the parking fee of 50 rubles per hour. As a result, the redistribution of transport flows occurs (Fig. 6, 7).

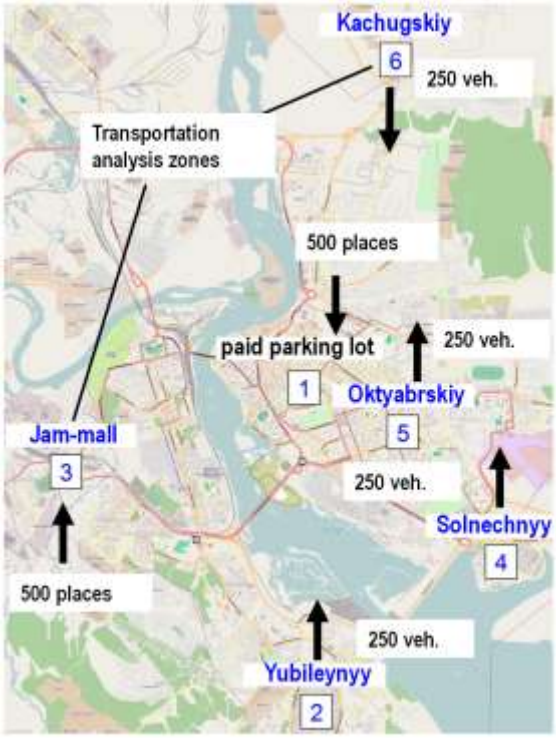


Fig. 3. Test model parameters indicating the location of the estimated transport areas (1–6), including the area with a paid parking lot (1), the number of parking places at parking lots in areas with objects of attraction and leaving vehicles number

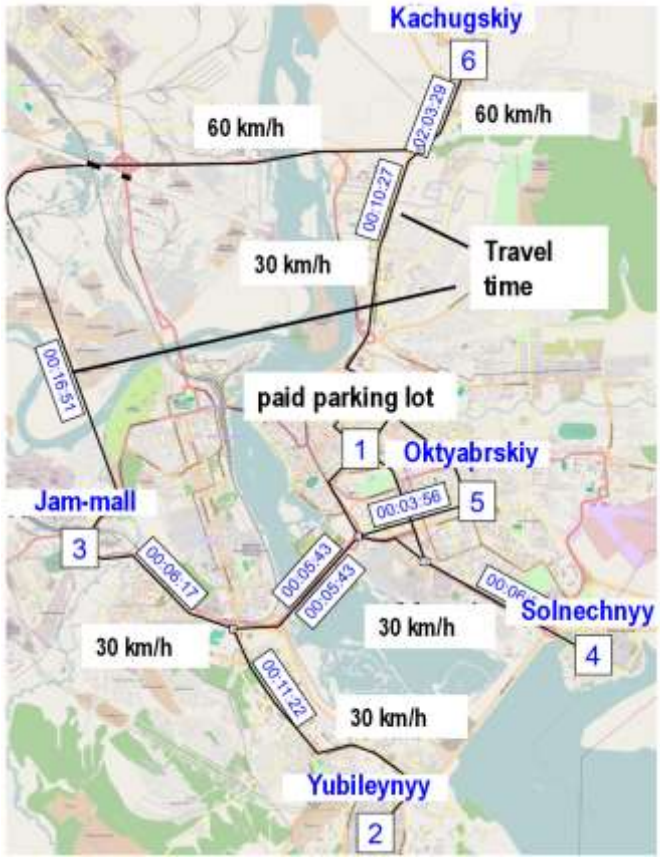


Fig. 4. Test model parameters indicating travel time spent at the network segments

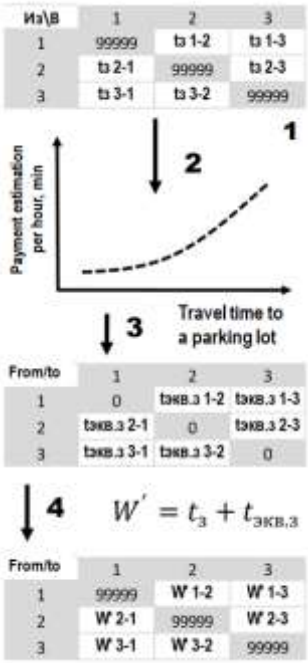


Fig. 5. Sequence of determining the total trip cost W' in the form of the sum of the trip time cost $t_з$ and the time equivalent of the parking charge $t_{экв.з}$ (down: payment estimation for an hour/min; across: trip to the parking lot time, min)

Fig. 6. Initial traffic flows distribution test without considering a paid parking lot

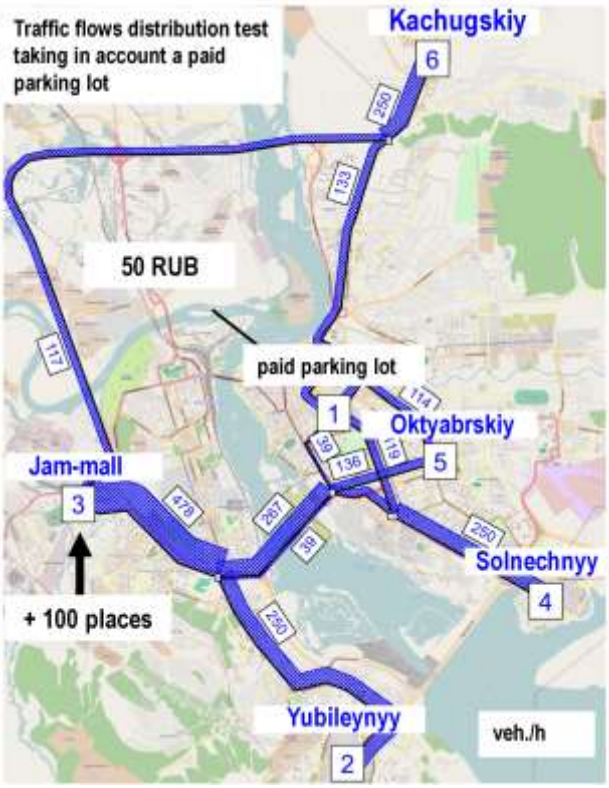


Fig. 7. Results of estimation of the traffic flows distribution test taking in account a paid parking lot

IV. Conclusions

In the example under consideration, the imposed restrictions on parking in the city center, combined with the introduction of additional parking spaces in the shopping center, located on the periphery of the city, reduced transport loads in the city center by an average of 25 %.

The proposed approaches to estimation of the components of the generalized private vehicle trip time can be used in the planning of paid parking and tariff policy, as well as in planning the system of commuter parking lots (Park and Ride).

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