Balance Model of Conversation of Passengers Flows in Residential Part of City

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Abstract: The aim of this work is to investigate of flows of passengers who needs to use urban public transport from a place of residence to urban stops. Arguments are based on the determination of the movement time through discrete residential part of a city, comparisons of values of destination points, reflections of the flow. The model in form of conservation passenger’s flows equation intended for use in problems of modeling and optimization of movement of public transport. Overview of possible criteria for the quality of urban public transport for different target groups permits to make different optimal solves of the task.

Key words: Urban public transport • Passengers flow • Modeling • Identification

INTRODUCTION

A management of urban public transport (UPT) is relevant and practically important task for municipalities and transportation companies. A satisfactory of public immediate needs, such as administrative, utilities, energy and transport services is an important factor of the trust to the local government. The organization of public transport is the area where a reasonable mix of symbiosis analytical, expert, model and administrative components could cause an increase of public loyalty [1].

An effectiveness of UPT can be described from different points of view: local administration, carriers and passengers as consumers of the service [2]. Usually the task of UPT optimization includes some features of the existing system such as the presence of the stopping points established routes, limited mobile and personnel of the service movement etc. The time of UPT schedule calculating has a great social importance. Traditional settlement-graphic way to compose a schedule mainly focused only on the execution of a known amount of transportations of passengers on each route. The main limitation is a number of rolling stock. But settlement-graphic methods are hardly useful to algorithmization and programming. Developers of optimizing software (for example VISUM/VISSIM [3, 4]) do neither show nor the algorithmic side of scheduling, nor even the criteria of schedule quality. An unclarity in this matter is exist despite the efforts of researchers (for example, [5-7]). Some years ago we had preliminary negotiations with vendors of such system regarding the optimization of the network of UPT in city with population about 150000. As a result they offered only one optimum (from some point of view) schedule. An subsequent adaptation and changes of the schedule are inevitable due to changes in city conditions but very difficult.

Probabilistic models like [8, 9] are complex in equipping and require large amounts of data to define and clarify the statistical distributions of threads. The idea [10] about the integration of threads from discrete cells is interesting, however only the cells along the highways are described in this paper. Distribution of this approach in discrete residential zone of the city can clarify passenger flows. As a result we can change a stops network and schedule according to some criterion.

It is obvious that the criterion from the point of view of carriers and consumers are contradictory. For example the minimizing of waiting time causes increase of rolling stock and consequently decreases of its load and income. On the other hand, an excessive desire to increase profitability of transportation causes the population to refuse from the carrier and to the emergence of competing transport organizations. Therefore, assessment of efficiency should be based on:
Achievement of guaranteed minimum economic result for carriers and local government within the satisfactory rate of profit;

Achievement of the required result for passengers in the sense of satisfying their claims. The probability of the last must be not less than some threshold value, otherwise passengers will refuse to use UPT.

We have to describe several processes for the complete solution of the problem of modeling UPT:

- The emergence of potential passengers (PP) in residential buildings and various objects (workplaces, trades, social objects etc.). “Potential passenger” is a person who needs to move, and one of the ways is UPT.
- The choice of ways to move by potential passenger. If PP choose UPT then he have to select the stop and the way to the stop.
- The dynamics of passengers at the stop. Somebody from passengers will not use UPT because of long waiting time but will prefer other kind of transport or refuse from transportation.
- The decrease of passengers amount at the stop because using of UPT.

Further, if we have the criterion of quality management system, we can change the various settings of the system for improving the work of UPT with different points of view by:

- Changing stops.
- Changing routes.
- Changing schedules on existing routes (includes an amount of vehicles in it) etc.

We solve these tasks consistently using public information about housing stock (the coordinates of the house and the amount of apartments in it), about network of city streets (including the possibility of use of segments between crossroads for the movement of a certain type UPT), the location of objects which create inflow or outflow of passengers in specific periods of time. We suppose the information about the amount of people living in the household is unspecified because none of the governmental documents in Russia give a precise answer to this question.

We make a discretization of the subject area so that each element includes no more than one stop of UPT. But each element can include several houses. We make equal steps of discretization by X and Y to obtain square or rectangular elements for simplicity (Fig. 1). Denote by “A” existing stops. Also streets where UPT can move presented in Fig. 1. We introduced coordinate axes, and we indexed elements of size \( \Delta x \), \( \Delta y \) as \( i \) and \( j \) respectively. Denote by \( x_i, x_2, \ldots, y_1, y_2 \) etc. coordinates of centers, then any elements have a size \( S_{ij} = S \Delta x \cdot \Delta y \) and there exists borders at \( x_i \pm \frac{\Delta x}{2} \) and \( y_j \pm \frac{\Delta y}{2} \) (Fig. 2).

Suppose different “consumer values” for all social and workplace objects; then each element has a worth. The worth characterizes an ultimate amount of passengers from all UPT stops to the element \( \zeta(x_i, y_j, t) = \zeta_{ij}(t) \). For example if any element includes only 1 enterprise with 1000 workers then we can suppose that all of them will arrive to job in short time interval (20-40 min.). Therefore

![Fig. 1: An example of discretization of the subject area](image-url)
where \( h \) – duration of a day, \( k_i \) – the proportion of workers in the job.

It follows that the amount of passengers in all the city arrived by UPT to all stops is

\[
I_1 = \int h \int \xi(x,y,t)dx\,dy\,dt = \Delta t \sum_i \sum_j \xi_{ij}(t) \tag{1}
\]

It is a first part of an equation of "conservation of passengers". We construct all equation later by similar way together with solving the tasks above.

Let us consider the creation of passenger flow from residential buildings. This flow is primary because all other (from shops, from theatres, from workshops etc.) are reflections and re-reflections of primary. We suppose that passengers flow from houses is smaller than a total amount \( M_i \) of citizens living there except population who never use UPT. Therefore the need to move for citizens in the element \( ij \) is \( \Psi^{*}(t) \), where \( \Psi^{*}(t) \) – a specific need to move.

Let people of different "kinds" (workers, students, pensioners etc.) settled in the city uniformly; \( \Psi^{*}_{ij}(i) = \Psi^{*}(t) \forall i, j \) then where \( \Psi^{*}(t) \) – average value of the needs to move. Else if one district is significantly differs from another in a large city ("sleeping", "shopping", "office" etc.) then we have to determine average values for each area. So a citywide passenger flow generated for \( \Delta t \) is

\[
I_2 = \Psi^{*}(t) \cdot \Delta t \sum_i \sum_j M_{ij} \Psi^{*}(t) \cdot \Delta t \cdot M \tag{2}
\]

where \( M = \sum_i \sum_j M_{ij} \) is a total amount of passengers in the city. We add to the equation (2) first reflections of the original flow (returning from a work, a shopping, a theater), and additionally generated flows (for example from a station):

\[
\Psi_{ij}(t) = \Psi^{*}(t) \cdot M_{ij} + \Psi_{ij}(t) \tag{3}
\]

and

\[
I_2 = \left[ \Psi^{*}(t) \cdot M + \sum_i \sum_j \Psi_{ij}(t) \right] \cdot \Delta t \tag{4}
\]
Let $r_{ij}^{km}$ be a passenger travel time from element $ij$ to $km$, with a time required from $ij$ to stop of departure and from stop of arrival to $km$. Then the complete equation of conservation of passengers is

$$\Psi^*(t) \cdot M_{ij} + \Psi_{ij}(t) = \zeta_{km} \left( t + T_{ij}^{km} \right)$$

(5)

for each pair of elements $ij$ and $km$. For the whole city

$$\sum_i \sum_j \left( \Psi^*(t) \cdot M_{ij} + \Psi_{ij}(t) \right) = \sum_k \sum_m \zeta_{km} \left( t + T_{ij}^{km} \right)$$

(6)

We have to determine travel times $r_{ij}^{km}$ depending on stops network, rolling stock and schedule for practical application (6). The main advantage of (6) is that it provides the opportunity to solve the schedule optimization problem with any criterion (for example, how the populations assess the balance between the need to move and satisfaction of this requirement using UPT).

REFERENCES

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