Impact Factor: 9.9
ISSN-L: 2544-980X

MODELING THE MATRIX OF INTERDISTRICT CORRESPONDENCE

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Abstract: The modeling the matrix of interdistrict correspondence transport system explores the development and optimization of transportation systems between different districts or regions. The term "interdistrict correspondence" refers to the movement of people or goods between various districts. This article focuses on the modeling aspect, which involves creating a cohesive and efficient matrix that facilitates smooth and seamless transportation.

Keywords: Transport demand, interdistrict correspondence, correspondence matrix, transport modeling, travel behavior, gravity model, aggregated models, disaggregated models, Wardrop principles, user optimization, system optimization, pre-network modeling, network modeling, transport infrastructure, urban planning, transport network, mobility analysis, travel cost, transport equilibrium, flow distribution, induced demand, transportation planning.

Introduction

Concept of transport demand

Transport demand is the quantitatively determined need for transportation and additional transport services.

Can be measured in the number of vehicles, passengers, or cargo per unit of time. The demand for the services of a particular type of transport is determined, in particular, by the development of various types of transport in the region, the degree of their integration, the level of transport tariffs, and the quality of service provided to consumers by various types of transport enterprises and organizations. The demand for freight transportation is largely determined by two factors: the dynamics and structure of changes in production volumes, as well as the solvency of enterprises and organizations in all sectors of the economy.

As in a market situation, in the field of transport services, there is a so-called market equilibrium (equilibrium of supply and demand). Flow distribution in the transport network is an analog of a market equilibrium situation in which traffic participants create demand for the use of elements of the transport system, the capabilities of these elements act as supply, and the price is the costs (time, cost, level of comfort) of traffic participants arising from the use of these elements. When demand exceeds supply, traffic conditions deteriorate, leading to an increase in such costs. The total increase in such costs can be used as one of the indicators of the overall overload of the transport system. For individual sections of the network, such growth can serve as an indicator of their insufficient throughput (carrying) capacity. In addition, it is known that improving traffic conditions provokes an increase in traffic - the so-called induced demand manifests itself.

It should be noted that in recent years, in the practice of urban planning, transport demand has often begun to be considered not as a predetermined value that determines the structure of flow distribution, but as a tool for managing the city's transport system. In particular, over the past

Impact Factor: 9.9 ISSN-L: 2544-980X

decades, experience has been gained in using a whole range of regulatory measures aimed at reducing the demand for the use of individual transport, especially in dense urban areas.

General approaches to correspondence modeling

Modeling the matrix of interdistrict correspondence is the main stage in calculating the parameters of transport demand. The problem of distributing movements (correspondences) between pairs of transport areas with known values of “departures” and “arrivals” determined at the stage of trip generation has an infinite number of solutions. In Fig. Figure 1 shows a tabular form of the correspondence matrix, each element of which represents the number of movements between pairs of transport areas - from area i to area j.

<table>
<tr><td></td><td colspan="4">Arrivals</td><td></td></tr>
<tr><td>Departures</td><td>1</td><td>2</td><td>…</td><td>n</td><td>Sum</td></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td><td>P1</td></tr>
<tr><td>2</td><td></td><td colspan="2" rowspan="2">?</td><td></td><td>P2</td></tr>
<tr><td>…</td><td></td><td></td><td>…</td></tr>
<tr><td>m</td><td></td><td></td><td></td><td></td><td>Pm</td></tr>
<tr><td>Sum</td><td>Q1</td><td>Q2</td><td>…</td><td>Qn</td><td></td></tr>
</table>

Figure 1. Tabular form of the correspondence matrix.

The values of the correspondence matrix cannot be directly measured, therefore, various indirect approaches are used to determine them, for example, sociological studies or a method for restoring matrix values based on known flow distribution parameters. This tutorial discusses models based on the study of individual preferences of city residents; It is these models that are widely used as part of many well-known software packages for transport and urban planning modeling.

Models for calculating interdistrict correspondence are divided into two large groups: aggregated and disaggregated. Aggregated models are built on average values of variables that determine the travel demand. The number of movements determined by such models is calculated in proportion to the size of the area generating demand, and demand is estimated in proportion to the population living in the transport area. The number of movements attracted to a particular transport area is calculated in proportion to the number of sources of attraction located in the territory under consideration.

However, inter-district correspondence is the cumulative result of individual movements of city residents. Therefore, it is logical to use disaggregated models as a tool that is sensitive to the individual transport behavior of respondents. Disaggregated models describe the transport behavior of an individual, taking into account the influence of socio-economic and urban planning factors on it.

Behavioral principles are associated with two possible situations.

1) network users independently choose routes that correspond to their minimum transportation costs (time, money);

2) network users choose routes based on minimizing the total transport costs in the network.

These behavioral principles are called the first and second principles of Wardrop, respectively. In the first case, everyone strives to reach the final destination of their trip as profitably as possible for themselves and, from the available possible travel options, chooses the route along which they will incur minimal costs (time, financial, moral, etc.) for travel. Therefore, this principle is also called user optimization.

Wardrop's second principle involves centralized control of traffic in the network. The corresponding distribution of traffic flows is called the system optimum, and the principle itself is

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called system optimization. An example of users moving according to the second principle is drivers of route transport [9].

In the classical (network) scheme for calculating demand, correspondents select areas of arrival based on the capabilities of the transport network, i.e., the time spent traveling between areas is calculated taking into account possible travel speeds. When developing projects for the future, even when we are talking about established cities, this approach is not always acceptable. For example, closely located areas, separated by a water barrier and therefore practically inaccessible to each other via the network at present, may well be mutually attractive to residents during the construction of a bridge crossing.

When calculating the correspondence matrix in a network model, it turns out that the costs of such movement are high, and, as a consequence, the number of correspondents between these areas will be small, from which it can be concluded that it is inappropriate to build crossings connecting these areas. Speaking about the 20-30-year perspective, for which many projects are being developed, one cannot focus on the network configuration, since its construction is one of the main goals of developing such projects. Thus, there is a need to develop pre-network models for the formation of inter-district correspondence that would take into account the general level of transport services and network speed parameters but would be less susceptible to the influence of geometric features and network limitations. Such models will make it possible to more adequately identify the potential demand for inter-district movements.

The determining factor when modeling the distribution of correspondence at the pre-network level is the relative location of settlement areas and areas of labor employment, that is, such factors as the configuration parameters of the urban area, the density of population and labor employment, as well as the relative location of functional zones come to the fore. (Table 1). Pre-network models provide the designer with information about the directions of development of the transport network under the conditions of a given location of functional zones. Modeling the distribution of correspondence at the pre-network level allows us to calculate the situation of the most complete disclosure of the territory's potential by proposing a rational structure of gravity that can be supported by network solutions.

Table 1

Comparison of approaches to calculating matrices

Method for calculating inter-district movement matrices	Network method (network layer model)	Pre-network method (pre-network layer model)
An approach to determining the time spent between departure and arrival points	Taking into account the speed parameters of transport network elements	Based on average level of transport service
Method for calculating interdistrict movement matrices	Network method (network layer model)	Pre-network method (pre-network layer model)
Factors influencing the distribution of correspondence	❖ The relative position of flow-forming and flow-absorbing centers ❖ Configuration and parameters of the transport network ❖ Behavioral factors (gravity function)	❖ The relative position of flow-forming and flow-absorbing centers ❖ Behavioral factors (gravity function)

Gravity model

The gravity model is based on the following proposition: correspondence from area I to area j is proportional to the total volume of departures from center i, the total volume of arrivals to center j,

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and some function depending on the transport distance between centers i and j. Transport distance reflects the degree of proximity of areas, taking into account the speed and convenience of movement provided by the transport network. The method for determining this value may vary in different versions of the model.

In essence, the gravitational model is based on the analogy between the mutual attraction of two masses and the attraction of those leaving area i to their arrival points in area [11] j, i.e. it is assumed that

$$xij = kPiQi \,/\, c^2ij\ , \qquad (1)$$

where x_{ij} is volume of correspondence between regions i and j, thousand people;

P_i is volume of departures from region i, thousand people;

Q_j is the volume of arrivals to region j, thousand people;

c_{ij} is the generalized cost of travel between regions i and j (analogous to distance);

k is some constant.

On x_{ij} natural restrictions are imposed: $\sum ixij, \sum Pi\ ,\ \sum Pi\ , \sum xij\ \ \sum Qj$.

Conclusion

The use of computer simulations and data analytics helps in predicting future travel patterns, understanding factors that influence transportation demand, and identifying areas where infrastructure improvements are required. This modeling approach allows planners to optimize routes, allocate resources effectively, and make evidence-based decisions regarding the development of interdistrict correspondence transportation systems.

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