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BASIC APPROACHES TO THE FORMATION OF THE TRANSPORT MODEL OF THE CITY

The pace of development in modern cities and the continuous increase in motorization lead to the aggravation of various issues, such as the creation of rational traffic management, the allocation of parking spaces, the quality assurance of road surfaces, and the protection of the environment. Solving these problems requires «correct» systematic management, effective organization of traffic flows, and optimal planning of transportation infrastructure.

To manage the transport system and make optimal decisions in transport planning, specific systematic knowledge about the current transport situation and possible scenarios of its development are needed.

The lack of a quantitative description of the transport situation significantly complicates an already challenging selection among options for the development of the urban transport system. Bridging the gap between the desired and actual outcomes can be achieved through modern planning tools and impact assessments of decisions, particularly through a unified city transport model.

As experience shows, a city transport model used to support decision-making in strategic transport planning is the optimal tool for quantitative assessment of proposed options for transport network development, their subsequent comparison, and well-founded conclusions regarding the feasibility of investments in transport infrastructure projects.

Transport models based on modern information technology represent powerful computational software systems that, based on the functional and spatial characteristics of the city combined with all available data on transport demand and supply, calculate the most probable distribution of traffic and passenger flows across the street network. These calculations then form the basis for forecasting city development and provide the necessary analytical foundation for decision-making in the development of urban transport infrastructure.

«Correct» strategic management of the city's transport system, among other things, directly affects the quality of transport services for the population and road safety.

The main advantage of transport models is that they allow experimentation not with people, but only with a computer representation of their daily behavior.

Keywords: transportation model, transport demand, transport supply, transport zone, demand layer.

INTRODUCTION

Transportation models based on the principles of computer modeling of traffic flow distribution were first created in 1960. One of the first programs to implement a four-step procedure for forecasting the loading of transportation networks was the EMME program (Equilibre Multimodal, «Multimodal Equilibrium»), developed and applied in the city of Montreal, Canada.

The rapid development of computational power in modern computers has, over recent years, accelerated key computational procedures by multiples, significantly refining and detailing models of urban transportation networks, and incorporating a much larger number of factors influencing the behavior of modern road users into the calculations.

Today, there are dozens of software products for macro-modeling of traffic flows worldwide, such as Tmodel2, Cube, Emme/4, Transcad, Transnet, and Visum.

These software packages have been used to build transportation models for cities like New York, Los Angeles, London, Paris, Milan, and others. A model of the transportation network covering almost all of Europe has also been constructed.

The most detailed transportation model in the world (with the largest number of elements) is Germany's transportation model, created in PTV Vision VISUM. In addition, a transportation model for Switzerland has been developed, which also includes neighboring European countries as external zones.

In recent years, several Russian cities and two Ukrainian cities have developed transportation models using PTV Vision VISUM software, which they are now successfully operating.

LITERATURE REVIEW AND PROBLEM STATEMENT

A transportation model is essentially a software complex comprising informational and computational blocks.

The informational blocks form a unified database designed for storing and processing information necessary for calculating traffic flows. The computational blocks implement algorithms for solving mathematical programming tasks focused on calculating the demand for movements and traffic flows.

Based on this, the creation of the model's foundation and the input of its initial data can be divided into two independent stages: the creation of transport supply and the creation (calculation) of transport demand (Fig.1).

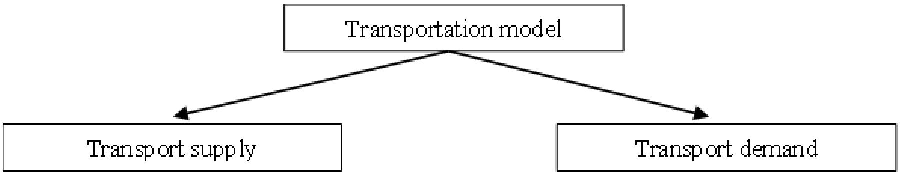

Fig.1. Stages of creating a transportation model

Transport supply consists of elements through which the city's transport system satisfies existing transport demand. Transport demand quantitatively and qualitatively determines the residents' need for movement.

Transport supply:

–Cartographic information (digital city plan, topographic map);

–The network of roadways for different types of transport, their properties, and traffic conditions, including technical means for organizing road traffic;

–Types of streets and roads, average daily intensity, capacity of sections and intersections, etc.

Transport demand:

–Statistical data: information about the population, working population, jobs, jobs in the service sector, number of students, and educational institutions;

–Statistical data on the distribution of trips by purpose;

–Data on the overall distribution of traffic flows by types of transport in the studied area [1].

PURPOSE AND OBJECTIVES OF THE STUDY

The transport supply model includes models for both individual and public transport.

The transport supply of individual transport consists of intersections (nodes) and segments (road sections between intersections).

Nodes are points of intersection of transport communications (main roads, tram lines), intended to model the representation of intersections (Fig.1). Each segment corresponds uniquely to a pair of nodes. Accordingly, the attributes of each node include identifiers for the segments associated with that node, as well as binary variables indicating whether the node is the start or end of the segment.

For each node, relevant attributes are specified (number, type, name, capacity, regulation at the node, additional values).

Segments connect nodes and reflect the geometry of the transport network. For each segment, corresponding attributes are specified (number, name, type, capacity, number of lanes, speed, permitted transport systems). Statistical data for nodes and segments are obtained from various information sources. The characteristics of segments in the forward and reverse directions of traffic are defined separately.

The transport supply of urban passenger transport (UPT) consists of stopping points, routes, and schedules (intervals) of movement. UPT routes traverse existing segments and nodes through specified stopping points.

Information about stopping points, routes, and schedules of urban passenger transport (UPT) (Fig.2) is obtained from various information sources and entered into the software complex.

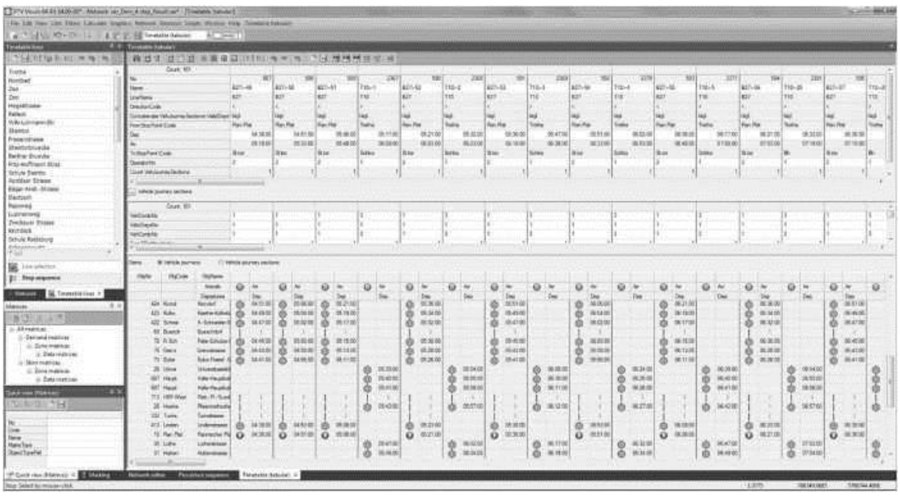

Fig.2. Schedule of movement in the software complex

Transport demand model

The construction of the transport demand model is possible through the formalization of the studied area. The entire studied area is divided into a certain number of regions, referred to as transport zones.

The zones represent conditionally isolated territorial entities selected based on comparative identity in terms of social and economic indicators within these zones (Fig.3). Each transport zone contains statistical information about the population, working population, jobs, jobs in the service sector, number of students, number of educational institutions, etc. (table.1). Transport zones interact with the road network based on junctions (Fig.4).

№ транспортного району	Назва адміністративного району	Назва транспортного району	Населення транспортного району	Працездатне населення	Робочі місця	Робочі місця в сфері послуг	Місця в дитячих дошкільних установах	Дошкільнята	Навчальні місця в школах	Школярі	Навчальні місця в ВУЗах	Студенти	Види діяльності																
													Сільське господарство, мисливство, лісництво (a);	Рибальство (b);	Прничодобувна промисловість і розробка (c);	Обробна промисловість (d);	Електроенергія, газ і водопостачання (e);	Будівництво (f);	Оптова та роздрібна торгівля (g);	Готелі та ресторани (h);	Транспорт, складське господарство та зв'язок (i);	Фінансова діяльність (j);	Діяльність з нерухомим майном та орендою (k);	Державне управління та оборона (l);	Освіта (m);	Охорона здоров'я та соціальні послуги (n);	Діяльність по наданню комунальних, соціальних і персональних послуг (o);	Діяльність по веденню приватних домогосподарств з найманим обслуговуванням	Діяльність екстериторіальних організацій і органів
	Солом'янський район	43	44483	26245	26133	19976	739	1243	1132	1132	19502	17018	344	5	0	3896	875	1037	2951	528	2661	1772	4085	2260	2593	1870	1256	0	0

Table 1. Example of statistical data for a transport zone

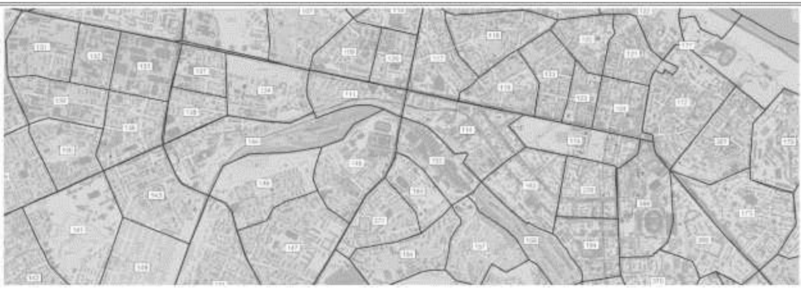

Fig.3. Fragment of the transport zoning of Rivne city

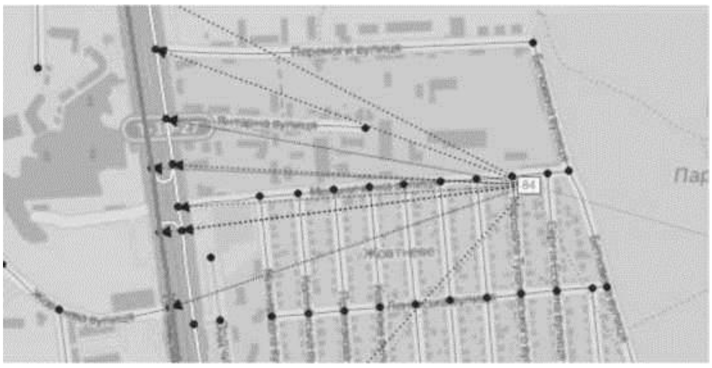

Fig.4. Fragment of junctions of transport zones to the road network of the city.

RESEARCH RESULTS

To calculate transport demand, data on the mobility of the population is required. Data collection is based on a survey of respondents distributed across the city according to the principles of quota sampling, reflecting the spatial distribution of the population and its gender-age structure. The survey is conducted using a specially designed questionnaire [8].

During the survey, residents should provide answers to the following questions:

-Who is making the trip?

-For what purpose?

-Where is the trip starting and ending?

-When does the trip begin and end?

-What modes of transport were used?

Based on the survey, a movement chain of the respondent for a day is formed. An example of a tyFigal movement chain or a change in human activity throughout the day is a sequence of activities such as H-W-S-H (Home - Work - Store - Home), from which homogeneous movements are formed: H-W (Home - Work), W-S (Work - Store), S-H (Store - Home), which can, in turn, serve as both the beginning and end of this movement, i.e., the source and destination of the movement.

In the city, there are numerous types of activities that generate a corresponding volume of movements and have a source and a destination. Therefore, to simplify the calculation of transport demand (which does not affect the accuracy of the results), such connections and, accordingly, types of activities are generalized. For the city's transport model, 10 of the most characteristic types of activities (demand layers) have been formed: Home - Work, Home - Education, Home - Other, Education - Home, Work - Home, Work - Work, Work - Other, Other - Home, Other - Work, Other - Other, and the identified sources and destinations of trips (table 2).

Table 2. Sources and destinations of trips by demand layers

Demand Layers	**Trip Origin ($RO_{u_{tv}}$)**	**Trip Destination (ROdest.)**
Home - Work	Working Population	Places of Employment
Work - Home	Places of Employment	Working Population
Home - Other	Working Population	Places of Employment in the Service Sector
Other - Home	Places of Employment in the Service Sector	Working Population
Work - Other	Places of Employment	Places of Employment in the Service Sector
Other - Work	Places of Employment in the Service Sector	Places of Employment
Work - Work	Places of Employment	Places of Employment
Other - Other	Places of Employment in the Service Sector	Places of Employment in the Service Sector
Home - Education	Students	Educational Institutions
Education - Home	Educational Institutions	Students
Education - Other	Educational Institutions	Places of Employment in the Service Sector
Other - Education	Places of Employment in the Service Sector	Educational Institutions

Based on surveys of the population, the number of trips by demand layers is determined.

Calculation of transport demand

In the software complexes, three alternative demand calculation models are presented:

1.Four-step model.

2.EVA model.

3.VISEM model.

For calculating demand in urban transport models, the classical four-step model is most often used. The operation of this model can be divided into four stages (Fig.5):

1. Demand generation; 2. Demand distribution; 3. Mode choice; 4. Redistribution.

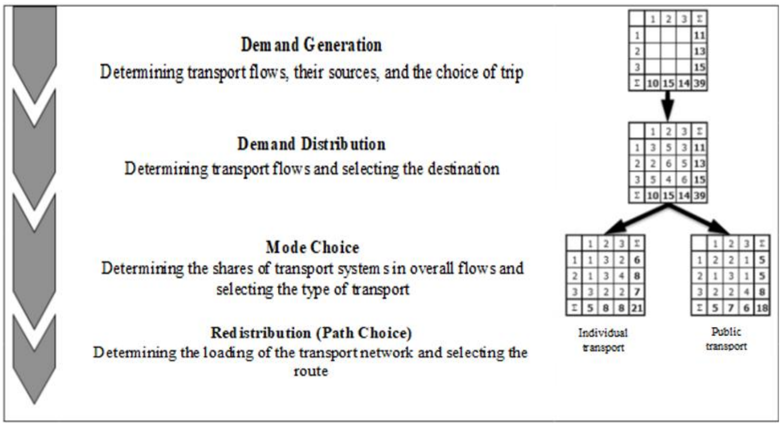

Fig.5. Stages of transport demand calculation

1. Demand generation
2. Distribution of transport demand

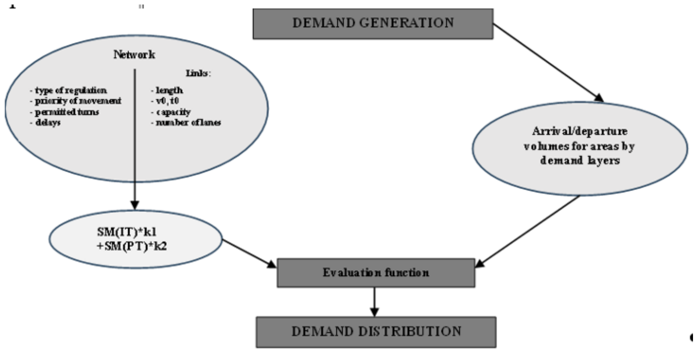

Fig.6. Scheme of transport demand distribution

Based on the transport supply, the costs of correspondence implementation are calculated, meaning cost matrices are determined. Using the volumes of generated demand and the cost matrices, the demand distribution occurs, which involves calculating correspondence matrices for each demand layer corresponding to the respective transport district.

The distribution of demand layers occurs based on the evaluation function (the probability assessment of movement from the district *i* in district */)*. The evaluation function is determined for each demand layer based on surveys of the city's population regarding the distance (probability) and average travel time (Fig.6).

In urban transport models, the following main evaluation functions are used at the demand distribution stage: Logit, Kirchhoff, Box-Cox, and Combined types:

$$f(U_{ij}) = e^{(c \cdot U_{ij})}$$ - Logit function;

$$f(U_{ij}) = U_{ij}^{c}$$ - Kirchoff;

$$f(U_{ij}) = e^{\left(c \cdot \frac{U_{ij}^{b}-1}{b}\right)}$$ - Combined;

$$f(U_{ij}) = a \cdot U_{ij}^{b} \cdot e^{(c \cdot U_{ij})}$$ -Box-Cox;

$$f(U_{ij}) = \frac{1}{U_{ij}^{b} + c \cdot U_{ij}^{a}}$$ - function TModel.

when *f (U)*- probability of correspondence with costs *V;*

Uij- the costs of correspondence from the district *i* in district *]*, min.;

a, Ь, c - coefficients.

The «Combined» type evaluation function is shown in Fig.7. The horizontal axis represents the time spent on carrying out the transport correspondence, while the vertical axis indicates the probability of such correspondence being carried out.

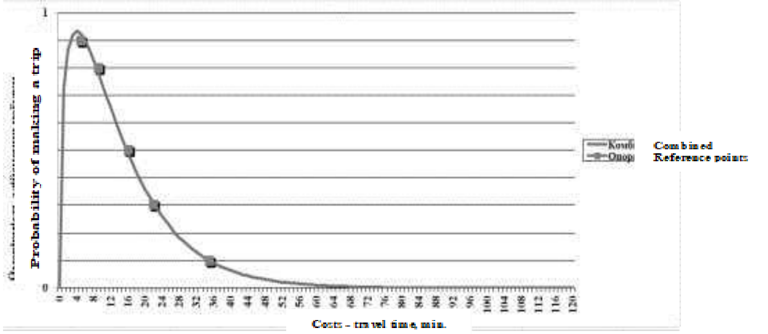

Fig.7. Graph of the combined assessment function

The model of people's transport behavior, based on the assessment function, has independent parameters the coefficients of the function *(a, b, c)*. The values of the coefficients are obtained from the results of population surveys (Fig.8).

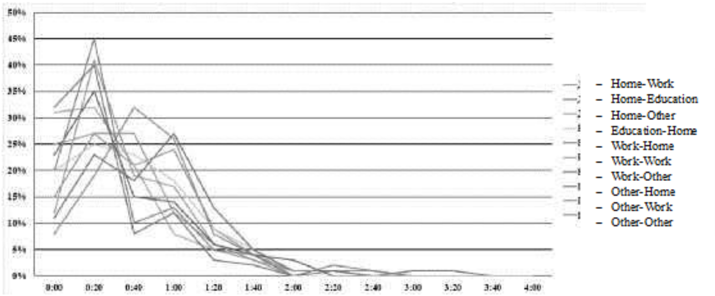

Fig.8. Graph of the distribution of demand layers by distance and average travel time (based on the survey)

As a result of the calculation of the distribution procedure, correspondence matrices are computed for all demand layers.

3. Mode Choice

After calculating the correspondence matrices for the demand layers, it is necessary to separate these matrices by modes of transport. The mode of transport will determine how the correspondence is realized—either by individual transport (IT) or by public transport (PT).

The distribution of demand layers by modes of transport occurs based on the evaluation function: Logit, Kirchhoff, Box-Cox, or Combined. This evaluation function is determined from a survey of the city's population regarding the distance and average travel time for a specific mode of transport (individual or public).

As a result of the calculations, correspondence matrices for all modes of transport are obtained.

4. Redistribution of transport demand

After obtaining the correspondence matrices for the demand layers and dividing them by the types of transport that will be used for implementation, it is necessary to redistribute the obtained correspondence matrices according to the transport supply to select the appropriate route for realizing these correspondences.

As a result of the redistribution, a cartogram of passenger flows for public transport routes (Fig.9) and a cartogram of transport flow intensity on the city's street and road network are constructed [3].

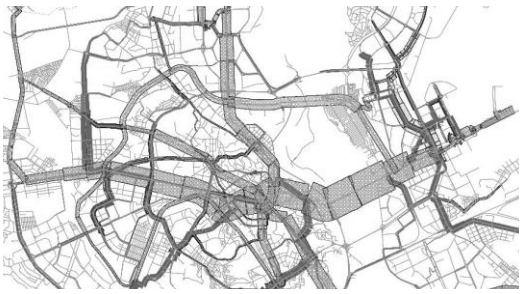

Fig.9. Cartogram of passenger flows for public transport routes

DISCUSSION OF RESEARCH RESULTS

The final stage of developing transport models involves refining and adapting the key defining relationships that characterize the patterns of redistribution of transport demand, taking into account the existing transport supply in relation to local conditions. This stage is referred to as model calibration.

CONCLUSIONS

The calibration process is one of the most crucial stages in the creation of a transport model. During calibration, it is necessary to achieve the closest possible alignment between the results obtained through modeling and the data collected from surveys of passenger flows and transport flow intensity.

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***Пашкевич С. М., Никончук В.М., Колодюк О. П.*, Базові підходи до формування транспортної моделі міста**

Швидкість розвитку сучасних міст та постійне зростання моторизації призводять до загострення різноманітних проблем, таких як створення раціонального управління дорожнім рухом, виділення місць для паркування, забезпечення якості дорожнього покриття та охорона навколишнього середовища. Вирішення цих проблем вимагає «правильного» системного управління, ефективної організації транспортних потоків та оптимального планування транспортної інфраструктури.

Для управління транспортною системою та прийняття оптимальних рішень у транспортному плануванні необхідні специфічні системні знання про поточну транспортну ситуацію та можливі сценарії її розвитку. Відсутність кількісного опису транспортної ситуації значно ускладнює вже й так складний вибір серед варіантів розвитку міської транспортної системи. Подолати розрив між бажаними та фактичними результатами можна за допомогою сучасних інструментів планування та оцінки впливу рішень, зокрема, через єдину міську транспортну модель.

Як показує досвід, міська транспортна модель, яка використовується для підтримки прийняття рішень у стратегічному транспортному плануванні, є оптимальним інструментом для кількісної оцінки запропонованих варіантів розвитку транспортної мережі, їх подальшого порівняння та обґрунтованих висновків щодо доцільності інвестицій у проекти транспортної інфраструктури.

Транспортні моделі, засновані на сучасних інформаційних технологіях, представляють собою потужні обчислювальні програмні системи, які, спираючись на функціональні та просторові характеристики міста, в поєднанні з усіма доступними даними про транспортний попит і пропозицію, розраховують найімовірніший розподіл транспортних і пасажирських потоків по вуличній мережі. Ці розрахунки стають основою для прогнозування розвитку міста та надають необхідну аналітичну основу для прийняття рішень у розвитку міської транспортної інфраструктури.

«Правильне» стратегічне управління транспортною системою міста, серед іншого, безпосередньо впливає на якість транспортних послуг для населення та безпеку дорожнього руху.

Основною перевагою транспортних моделей є те, що вони дозволяють експериментувати не з людьми, а лише з комп'ютерним представленням їхньої щоденної поведінки.

Ключові слова: транспортна модель, транспортний попит, транспортна пропозиція, транспортна зона,.

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