CONCEPTUAL DESCRIPTION OF LATVIA'S TRANSPORT SYSTEM DEVELOPMENT OPTIMIZATION AND FORECASTING COMPLEX MODEL

MODEĻA KONCEPTUĀLS APRAKSTS LATVIJAS TRANSPORTA SISTĒMAS ATTĪSTĪBAS PROGNOZĒŠANAI UN OPTIMIZĀCIJAI

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A conceptual description of complex model for Latvia's transport system development forecasting and optimization is represented. As the main criterion of optimization, Latvia's inhabitant 100 km out-of-town communication weighted average time and cost expenses have been taken into consideration. Separate blocks of the model are enumerated (Information, Calculation, Forecasting, Economical evaluation, Optimization). For the main blocks (Calculation, Forecasting and Optimization) basic solved tasks and used mathematical models and algorithms are enumerated, literature sources are given. The analytical description of the inhabitants' allocation on the territory of Latvia (given by A.Kashurin) is used essentially. A nonlinear regression model for a forecasting of passenger flows between various areas of Latvia has been described. The gradient method is used for unknown parameter estimation.Task solution order of priority is described. It is noted that computation procedure is iterative. The iterations are ended when experts accept a suggested variant.

1. Introduction

The aim of our investigation is to work out a complex of mathematical models describing provision of Latvia's population with transportation as well as to work up some recommendations how to raise this level of transportation provision. Here, as the main criterion, Latvia's inhabitant 100 km out-of-town communication weighted average time and cost expenses have been taken into consideration.

The examined complex contains the following blocks:

- Information,
- Calculation,
- Forecasting,
- Economical evaluation,
- Optimization.

Information block includes the necessary information relative to the territory of Latvia:

- Population size distribution density;
- Motor (of various categories) and railway roads network scheme;
- Train and bus operation itineraries and frequencies as well as their capacity,
- Economical indices of different regions development;
- Passenger traffic official statistical data including Latvia's transportation system development performance.

Calculation block carries out the following accounts:

- Finds alternative ways from one to another destination in the territory of Latvia,
- counts corresponding time and cost expenses;
- Evaluates weighted average time and cost expenses of a particular region/town inhabitant related to 100 km out-of-town communication;
- Estimates accepted criteria of transport system efficiency, i.e. weighted average time and cost expenses of Latvia's inhabitant 100 km out-of-town communication.

Forecasting block gives out the following forecasts for the next years of:

- Population size distribution density;
- Economical indices of different regions development;
- Passenger traffic among various destinations;
- Latvia's transport system development performances.

Economical evaluation block carries out economical indices calculations of:

- Costs and revenues for various decision-making variants;
- Capital investments for the reconstruction or making of transportation system elements;
- Accepted global criterion of the economical efficiency.

Optimization block solves tasks of resources assignment for the development of:

- Railroad and bus transport;
- Infrastructure, in particular, motor roads network;
- Network of bus routes and circulation plan of bus.

The complex is based on modern computer, mathematical and software means providing full, quick and qualitative solutions of the above-mentioned tasks.

Computer means ensure storage, processing and outputting of the necessary information as well as performing needed calculations.

Mathematical models and methods allow describing, analyzing and solving the examined tasks.

Software means include both standard program packets (among them for database management) and programs for realizing original mathematical analysis, forecasting and optimization algorithms.

2. Calculation block

The mostly used component of a calculation block is *alternative ways searching* algorithms between two geographical points. These algorithms related to the theory of graphs are quite numerous [1, 5, 7, 8]. Those of them which are the most efficient (by criteria of fast operation and required computer storage space) are used in the complex for the tasks of large dimension. The algorithms which enable to estimate throughput capabilities of the transportation network and its elements and to plan the traffic routing are implemented in this block [7, 8, 12].

Another important task solved in this block is the estimation of Latvia's inhabitant 100 km out-of-town communication *weighted average time* (*T*) *and cost* (*C*) *expenses*. The statistical description of population distribution in the territory of Latvia is used there. Figure 1 shows population's density for another areas of Latvia that has been presented in [10]. Here analytical expression for population's density $f(x, y)$ of Latvia in arbitrary point (x, y) has been suggested as well. We continue a consideration of *T* and C calculation in the section 5.

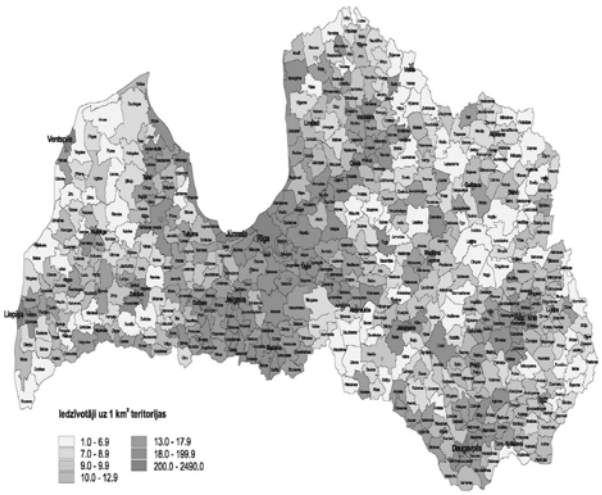

Fig. 1. Population's density in cities and areas

3. Forecasting block

Analysis and forecasting of the different regions development indices and transportation amount is carried our using regression theory method. In this approach, both multivariate regression models are used: classical linear one [3, 17] and nonparametric or semi parametric regression [9]. Application of the latter allows essentially improving the quality of indices forecasting [6, 11, 14].

Highly important is the task of passenger traffic evaluation among regions/towns of Latvia, i.e. working out of the so-called *matrix of correspondence*. In the work [2] the following nonlinear regression model has been considered.

We have *n* corresponding points (towns) with numbers $i = 1, 2, \ldots n$. For the point *i*, one are known inhabitants (citizen) number h_i and *m* numerical characteristics (categorical data) $c_{i,j}$, $j = 1, 2, \ldots, m$, those are known constants. For all pairs of the points (i, l) it is known the distance $d_{i,l}$ between ones as well. Additionally, it is known a size of passenger departure Y_i from point *i* during considered time interval, that is a random variable.

Our aim is to estimate correspondence size $Y_{i,l}$ for all pairs of points (i, l), precisely a size of passenger departure from the point *i* to the point *l*. The matrix of $Y_{i,l}$ is to be said *the correspondence matrix*. Let us denote an estimate of $Y_{i,l}$ by $Y_{i,l}^*$. It is requests that all $Y_{i,l}^*$ are positive ($Y_{i,l}^* > 0$) for $i \neq l$, $Y_{i,i}^* = 0$ and $Y_{i,l}^* = Y_{i,i}^*$. As criterion of the estimation efficiency we use the weighted sum of residual squares

$$R = \sum_{i=1}^{n} w_i \left(Y_i - \sum_{l=1}^{n} Y_{i,l}^* \right)^2 \qquad (1)$$

where w_i is a weight for the point *i*.

It is supposed that the concrete correspondence (i, l) for $i \neq l$ is formed with respect to model

$$Y_{i,l} = \frac{(h_i h_l)^\theta}{(d_{i,l})^\tau} \exp\left[a + \sum_{j=1}^{m} \left(\alpha_j (c_{i,j} + c_{l,j}) + \beta_j (c_{i,j} c_{l,j}) \right) + V_{i,l} \right] \qquad (2)$$

where $a, \{\alpha_j\}$ and $\{\beta_j\}$ are unknown regression coefficients,

τ and θ are unknown form coefficients,

$\{V_{i,l}\}$ are independent identically distributed random variables with zero mean and unknown variance σ^2.

The unknown parameters $a, \{\alpha_j\}, \{\beta_j\}, \tau$ and θ are estimated by the gradient method [13]. Corresponding results for the town of Latvia are presented in [2].

4. Economic evaluation block

The methods of integrated economical index calculus, used for an estimation of transport system development efficiency, have been realized here [16].

5. Optimization block

It represents a set of mathematical methods and software programs for their realization to distribute effectively available resources among transport system elements [15]. Lately developed effective optimization procedures are extensively implemented here as well [13]. Also, some methods of separate transportation system elements optimization are used here.

As we noted earlier, Latvia's inhabitant 100 km out-of-town communication weighted average time T (or cost C) expenses is used as the main criterion of a global optimization. To write down this criterion, let us consider all areas of Latvia. Let i be an area index, $i = 1, 2, \ldots, k$, where k is a number of the considered areas, h_i is number of inhabitants (citizen) for the i-th area. The value of h_i is calculated by the formula

$$h_i = \iint\limits_{(x,y)\in S(i)} f(x,y)\,dxdy, \qquad (3)$$

where $S(i)$ is a square of the i-th area.
Now the time criteria (T), for example, can be written down as

$$T = \frac{100}{\sum\limits_i \sum\limits_{j\neq i} Y_{i,j} \mathrm{d}_{i,j}} \cdot$$

$$\cdot \sum\limits_i \sum\limits_{j\neq i} Y_{i,j} \mathrm{t}(i,j) \omega_i \omega_j \qquad (4)$$

where $d_{i,l}$ is the average geographical distance (km) between the i-th and the j-th areas,

$t(i, j)$ is the average time expenses (hours) connected with a travel between the i-th and the j-th areas,

ω_i is some weighted coefficient for the the i-th area,

$Y_{i,l}$ is calculated with respect to formula (2).

Note that an improving and an optimization of the network elements decreases $t(i, j)$ and T values.

6. Tasks solution order of priority

An iterative program of task solution is perceived to be. Within the framework of iteration, the tasks are being solved in the following order:

- Forecasting of economical indices of Latvia's different regions/towns development.
- Forecasting of demand for passenger carriage among interconnected points (regions and towns).
- Passenger carriage routing and forecasting among the corresponding pints.
- Estimation of a particular region/town and Latvia in whole inhabitant's 100 km out-of-town communication *weighted average time and cost expenses.*
- Economical estimation of costs for separate transport system elements modernization.
- Elaboration of the best variants for resources made available distribution to modernize transport system.
- Expert judgment of the suggested variants to develop transport system.

This sequence in tasks solution is being repeated in the iterative mode as long as the satisfying decision for the experts is achieved.

Conclusions

A problem of an elaboration of complex model for Latvian transport system's forecasting and optimization is considered. The list of corresponding tasks, those content and used mathematical models and methods are described.

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A. Andronovs. Modeļa konceptuāls apraksts Latvijas transporta sistēmas attīstības prognozēšanai un optimizācijai

Ir dots kompleksa modeļa kopīgs apraksts Latvijas transporta sistēmas attīstības prognozēšanai un optimizācijai. Kā galvenais optimizācijas kritērijs, ir pieņemti vidējie laika un maksas patēriņi vienam Latvijas dzīvotājam, lai veikt 100 km garuma ceļojumu. Pārskatīti modeļa atsevišķie bloki (informatīvs, aprēķināts, ekonomisks, prognozēšanas un optimizācijas) un dotas to funkcionālas funkcijas. Pamatblokiem (aprēķinātiem, prognozēšanas un optimizācijas) pārskatīti apskatītie uzdevumi un izmantotas matemātiskie modeli un metodes, doti atbilstošie literatūras avoti. Analītiskais apraksts iedzīvotāju izvietošanai Latvijas teritorijā (kuru deva A.Kašurins) ir izmantots būtiski . Ir piedāvāts nelineārs regresijas modelis, kas ļauj prognozēt pasažieru plūsmu starp Latvijas reģioniem. Gradienta metode ir pielietota lai novērtēt modeļa nezināmus parametrus. Raksta beigās aprakstīta uzdevumu atrisinājuma secība. Ir atzīmēts, ka skaitliskā procedūra ir iteratīva. Iterācijas ir pabeigtas, kad eksperti būs apmierināti ar piedāvājamiem atrisinājumiem.

А. Андронов. Концептуальное описание комплексной модели прогнозирования и оптимизации развития транспортной системы Латвии

Представлено общее описание комплексной модели прогнозирования и оптимизации развития транспортной системы Латвии. В качестве общего критерия оптимальности предложено рассматривать средние взвешенные временные и стоимостные потери одного жителя Латвии, приходящиеся на 100 км пути. Перечислены отдельные блоки модели (информационный, асчётный, прогнозирования, экономический и оптимизационный), дано их функциональное назначение. Для основных блоков (расчётного, прогнозирования и оптимизационного) перечислены основные решаемые задачи, используемые при этом математические модели и алгоритмы, приведены литературные источники. Аналитическое описание распределение жителей по территории Латвии (данное А.Кашуриным) существенно используется. Описана нелинейная регрессионная модель для прогнозирования пассажирских потоков между отдельными районами Латвии. Оценки неизвестных параметров модели находятся с использованием градиентного метода. В заключении статьи указана последовательность решения задач комплекса. Отмечается, что вычислительная процедура является итерационной. Итерации прекращаются, когда эксперты сочтут предлагаемый вариант приемлемым.