Study on transport infrastructure as mechanism of long-term urban planning strategies

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Abstract. In this article, the authors carry out the research of the transport infrastructure. The authors have developed an algorithm for quality assessment of transport networks and connectivity of urban development areas. The results of the research are presented on the example of several central city quarters of Arkhangelsk city. The analysis was carried out by clustering objects (separate quarters of the Arkhangelsk city) using of SOM in comparable groups with a high level of similarity of characteristics inside each group. The result of clustering was 5 clusters with different levels of transport infrastructure. The novelty of the study is to justification for advantages of applying structural analysis for qualitative ranking of areas. The advantage of the proposed methodology is that it gives the opportunity both to compare the transport infrastructure quality of different city quarters and to determine the strategy for its development with a list of specific activities.

1. Introduction

Issues of complex long-term urban planning strategies are considered in a great number of scientific researches [1-3]. Of particular importance in the urban development is the role played by its transportation infrastructure. One of the most significant factors limiting the efficiency of transport infrastructure reproduction management is the lack of its monitoring support.

This research is aimed at solving the problem of the neural network modeling adaptation for building an intelligent monitoring system, dispatching and effective organizational and technical management of the urban transport infrastructure.

2. Methods

Within the framework of the research, the authors solve the problem of designing an intelligent operational management system and urban transport networks monitoring based on structural analysis.

This research covers the analysis of urban transport networks and connectivity characteristics. transport infrastructure cannot be characterized by one particular parameter. It is represented as a complex hierarchical system of parameters (characteristics) and can be described with varying degrees of detailing. The city’s areas have different qualitative and quantitative indexes for each characteristic. In this research a quarter is taken for the territorial unit of urban development. An aggregate assessment of all characteristic indexes generates an overall assessment of the unit’s quality (quarter).

Structural analysis of urban transport infrastructure multidimensional characteristics is performed by
clustering the objects under study (city quarters) in comparable groups with a high level of similarity of characteristics inside each group. The clustering mechanism is based on the use of neural networks of T. Kohonen’s self-organizing maps (Self-Organizing Map - SOM). Self-organizing map (SOM) is an effective neural network modeling software tool for synthesizing multidimensional data [4,5].

The proposed method of mathematical modeling enables:
- to structure information based on material and intangible urban transport infrastructure parameters;
- to obtain integrated quality indexes of areas (city quarters).

The obtained data is used to plan the complex reproduction of urban transport infrastructure development by forming typical management programs for objects referred to a particular group [6].

3. Results
Research results are represented on the example of separate central city quarters of the Arkhangelsk city. The methodology of the research included following stages:
1. Forming the databases of transport networks and connectivity of urban development areas characteristics. The list of chosen characteristics describing each sector is presented in the table 1. It should be noted that such method makes it possible to change freely the detailing degree of characteristics in their description, i.e. to vary the amount of characteristics describing the system in accordance with the objectives of a particular research.

| Characteristics                     | Kinds of indicators | Formula                                                                 | Describes the characteristics |
|-------------------------------------|---------------------|-------------------------------------------------------------------------|--------------------------------|
| city quarters area                  | quantity            | \( \hat{l} \times \hat{b}, \quad \hat{l} - \text{average length}, \ \hat{b} - \text{average width} \) | -                             |
| city quarters form                  | quantity            | \( F = \frac{l_1 + l_2}{b_1 + b_2}, \quad l_1, l_2 - \text{length}, \ b_1, b_2 - \text{width} \) | \( F \geq 1 \) |
| status of traffic on highways and streets | qualitative | \( T = \frac{l_1 \times i_1 + l_2 \times i_2 + b_1 \times i_1 + b_2 \times i_2}{l_1 + l_2 + b_1 + b_2}, \quad l_1, l_2 - \text{average traffic for city quarters} \) | 1 – low traffic; 2 – medium traffic; 3 – high traffic. |
| road surfaces                       | qualitative         | \( I = \frac{l_1 \times i_1 + l_2 \times i_2 + b_1 \times i_1 + b_2 \times i_2}{l_1 + l_2 + b_1 + b_2}, \quad l_1, l_2 - \text{average indicator of road surfaces for city quarters} \) | 1 – poor-quality, requires major repair; 2 – satisfactory quality, requires maintenance; 3 – high-quality, does not demand repair. |
| type of traffic                     | qualitative         | \( P = \frac{l_1 \times p_1 + l_2 \times p_2 + b_1 \times p_1 + b_2 \times p_2}{l_1 + l_2 + b_1 + b_2}, \quad l_1, l_2 - \text{type of traffic for city quarters} \) | 1 – unidirectional traffic, 2 lanes; 2 – bi-directional traffic, 2 lanes; 3 – bi-directional traffic, 4 lanes. |
| public transport                    | qualitative         | \( A = \frac{l_1 \times a_1 + l_2 \times a_2 + b_1 \times a_1 + b_2 \times a_2}{l_1 + l_2 + b_1 + b_2}, \quad l_1, l_2 - \text{public transport lines for city quarters} \) | 1 – none of lines of public transport; 2 – not more than 2 lines of public transport; 3 – more than 2 lines of public transport |
More than 90 central city quarters of Arkhangelsk city were examined. Six of the described characteristics above are graphically shown in Fig. 1. There is a selection only of 10 city quarters (10% of the whole data) since the diagram of 644 columns (92 city quarters * 7 attributes) would be absolutely unclear. The example illustrates the problem of clustering of high dimension data set: it is impossible to classify a transport infrastructure with a diagram which reflects the whole range of objects and characteristics.

![Figure 1. Graphic presentation of the transport infrastructure characteristics](image)

2. Structural analysis of transport networks and connectivity of urban development areas (city quarters). The analysis was carried out by clustering objects (separate quarters of the Arkhangelsk city) using of SOM in comparable groups with a high level of similarity of characteristics inside each group [6]. The result of clustering was 5 clusters with different levels of transport infrastructure. The results of the structural analysis are presented in the table 2 and in Figure 2 and 3.

![Figure 2. Self-Organizing Map (clusters)](image)
Table 2. Clusters characteristics of transport infrastructure in Arkhangelsk

| Group of quarters | Description |
|-------------------|-------------|
| 0                 | Good        | maximum traffic with medium and low level of traffic jam; good road conditions around city quarters with a shape close to square and with a large and medium-sized area; more than 2 lines of public transport, bi-directional traffic, 2 lanes. |
| 1                 | Satisfactory| maximum traffic with high level of traffic jam; good and satisfactory road conditions around city quarters of rectangular shape and with a medium-sized and small area; more than 2 lines of public transport, unidirectional and bi-directional traffic, 2 lanes. |
| 2                 | Satisfactory| quarters a square shape and with an average area, more than 2 lines of public transport, unidirectional and bi-directional traffic, 2 lanes. |
| 3                 | Poor        | medium traffic with medium level of traffic jam; satisfactory condition of roads around quarters a rectangular, strongly elongated shape and a large area; more than 2 lines of public transport, unidirectional and bi-directional traffic, 2 lanes. |
| 4                 | Poor        | minimal traffic with low level of traffic jam; unsatisfactory condition of roads around quarters with a form close to a square and with an average area; not more than 2 lines of public transport; unidirectional and bi-directional traffic, 2 lanes. |

3. The urban transport infrastructure monitoring is carried out through periodic. For transport infrastructure, the periodicity of the survey should be annual, which is determined by the dynamics of road’s surface deterioration and the annual repair plans. Thus, if the overall assessment of the area quality within all transport infrastructure parameters changes, then a quarter can get from one cluster (group) into another. At the same time the transition to a better one demonstrates the effectiveness of ongoing activities while transition to a worse quality cluster shows the lack of activities or their inefficiency and the need to take measures to improve the quality of transport infrastructure.

4. Discussion
This article provides an algorithm for quality assessment of urban transport infrastructure. The results of the research are presented on the example of several central quarters of Arkhangelsk city. On the basis of 7 characteristics of transport networks and connectivity of urban areas (city quarters) the authors have obtained 5 groups of quarters with a high level of characteristics similarity within each group.

The advantage of the proposed methodology is that it gives the opportunity to compare the transport infrastructure quality of territories. The universality of such system and its "fast" processing allows one to assess the state of any urban massifs. Systematic monitoring enables us to track the direction and development dynamics of areas. It makes it possible to respond quickly to the changes that occur.

The main objective of the research is to improve the efficiency of the organizational and technical management of urban development areas. Application of the proposed methods will enable one:
- to form a long-term transport infrastructure development strategy for the urban area taking into account the complex comparative assessment of the individual quarters’ quality
  - to accelerate the planning process and make adjustments to urban development programs in real time.
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