Optimization of pedestrian traffic in residential areas of large cities

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Abstract. Currently, there is a high activity in the construction of multi-storey residential buildings in large cities. This causes an increase in pedestrian flows and traffic intensity in various areas of cities, but most streets and roads are not designed for a given number of pedestrians and vehicles. In turn, this leads to a decrease in the safety of pedestrian traffic in these areas.

1. Introduction
This paper proposes a new approach to solving the problem of optimizing pedestrian traffic, the sequence of developing a model of this approach is shown in Figure 1. The proposed approach is based not on functional zoning of territories, but on the construction of the shortest connecting network of communication routes. In the proposed model, it is proposed to use stops of urban passenger transport (UPT) as points of generation of pedestrian flows. The pedestrian traffic optimization technique is based on a block diagram, which consists of eight sequential blocks. Each of the blocks performs a specific function, collection of information. The result of the whole algorithm is a traffic management project. The first block is the collection and systematization of source information. It is impossible to get an accurate reliable result after using the technique if the initial indicators, the data were collected incorrectly. The reliability of decisions on the organization of pedestrian traffic is determined by the accuracy and reliability of the initial indicators. Therefore, the implementation of this paragraph of the methodology must be taken responsibly.[1] The next block is the definition of reduced lengths and the construction of the shortest network of communication routes, is the development of a map with the shortest communication routes. At this stage, with the help of overhead lines, pedestrian communication routes are built and their length is determined. When performing the third block, it is necessary to identify additional points of generation of pedestrians, these can be objects of mass attraction, stops of gas turbines. Select the links of the pedestrian network, in the work as the main links it is proposed to use the stopping points of the UPT. The next point is to define the characteristics of pedestrian traffic: intensity, speed, density, etc. The intensity indicator plays an important role, based on the data obtained, it is concluded which of the routes can be neglected, and where, on the contrary, it is necessary to add pedestrian paths. Also, based on the characteristics of pedestrian traffic, measures are being developed to improve traffic safety associated with the use of technical means of regulation (installation of road signs, marking, etc.). Based on the data obtained, the next section of the algorithm is performed, this is the calculation of the...
technical characteristics of the communication routes. It includes the calculation of the width of the sidewalks, the width of the pedestrian crossings, the size of the stopping areas of the UPT.

Figure 1. Block diagram of the optimization of pedestrian traffic
Currently, special attention is paid to the movement of low-mobility groups of the population (LMGP), since the UDS should be available for all categories of citizens. Therefore, in the proposed methodology there is an item called the adjustment of individual links, taking into account the movement of low-mobile groups of the population. It is necessary to conduct research on the movement of MGN, to identify areas where there is an active movement of this population group and to develop measures to create a barrier-free traffic environment.

Further, the optimality of the indicators is checked, if all indicators are normal, then a project for the organization of pedestrian traffic is developed and approved. If the data does not pass the check, it is necessary to return to the third block of the methodology and re-point everything to the standard indicators.

A model for the development of pedestrian traffic within the framework of spatial planning is being developed in accordance with the Urban Planning Code of the Russian Federation to substantiate the chosen option for the placement of infrastructure facilities based on an analysis of the modern use of the territory, possible directions of its development and projected restrictions. Similarly to these requirements, the sequence of model development “from general to specific” is determined.

To get a general idea of the planned territory of pedestrian traffic, it is possible to develop a model of its spatial organization with the allocation of enlarged zones of intensive, extensive and limited development of the territory, differing in transport accessibility.

Preparation and systematization of initial data to determine the general potential of the territory includes information on the presence of planning restrictions, natural and man-made risks of urban development and the possibilities of their reduction. A comprehensive assessment of the state and modern use of the territory involves studying the level of development of the socio-economic complex and the settlement system, assessing the possibilities for sustainable development of the territory and balanced socio-economic development, as well as identifying problem situations and priority tasks for solving them.

To analyze and assess the current state and use of the planned territory, different types of information and materials can be used: cartographic, statistical, legal, analytical about the state of the territory, its natural resource potential, including about natural conditions that affect the features of the organization of urban planning and economic activities, on the level of development of the socio-economic complex, on the restrictions on the territory.

Based on the analysis and assessment of the current state and use of the planned territory, a map is being developed showing the predominant use of the territory, zones of restrictions for organizing pedestrian traffic, incl. territories at risk of emergencies. Based on the analysis of the planning organization of the territory, a model of pedestrian traffic is being developed.

The task of urban planning studies in general [2] is to link the priority areas of socio-economic development to the territory in the form of transport infrastructure facilities based on a balanced account of environmental, economic and social factors (fundamental external conditions and restrictions) and the formation of safe, favorable conditions for human life (i.e. structuring the territory according to priority uses).[3,4]

2. Materials and methods

The implementation of these principles is ensured by the formation of a system of frameworks of the territory based on a balanced account of fundamental external conditions and restrictions on the development of the territory [5]:

- an economic framework formed by planning axes and centers: territorial production complexes, industrial centers, clusters of various profiles, industrial parks, centers of innovative development, large engineering and transport infrastructure facilities, etc.;
- a social framework formed by settlement centers (centers of administrative, organizational, economic, cultural and consumer services in the field of education, health care, social security, physical education and sports - centers of settlement systems of various ranks, formed on the basis of the most developed and conveniently located urban and rural settlements);
- an ecological framework formed by territories with a special nature conservation status (specially
protected natural areas, health resort and recreational areas, water protection zones, forest protection belts, green zones of cities, etc.).

The development model of the territory, formed by the system of economic, social and ecological frameworks, makes it possible to create favorable conditions for human life, to provide infrastructural conditions for development (including the formation of zones of advanced development of various types and "growth points"), to ensure the rational use of natural resources and conservation valuable natural complexes, and also allows predicting the rational development of various parts of the territory. Justification of the planned location of transport facilities must be carried out from the point of view of their compliance with the planned location of the economic, social or ecological frameworks and their impact on the integrated development of the territory.

With the approach described above to solving the problems of optimizing pedestrian traffic, it is possible with a high degree of reliability to determine the weight of transport links and solve the problem of placing transport infrastructure objects according to a given criterion of optimality - the minimum time spent by pedestrians on the road network.[6]

In the course of the work, overhead lines of the pedestrian route were drawn on the map of the section under consideration Figure 2.

![Figure 2. Matrix of pedestrian correspondence](image)

In the figure, the numbers indicate the pedestrian generation nodes, and the red lines mark the pedestrian paths. Stops of the gas turbine are proposed as generation points. This scheme is not the final proposed structure of the communications. It is proposed to analyze the pedestrian communication routes on its basis. Add or remove some of the lines as needed.

When developing this scheme, the location of the existing residential buildings was not taken into account. It would not be rational to propose to demolish most of the development in the area under consideration to optimize pedestrian traffic. Therefore, a more detailed scheme will be presented further in the work, taking into account the existing development of the area.[7]

In the course of the work, the distance of the proposed paths of movement was measured, which is presented in Table 1. The distance was measured between the generation nodes to analyze the length of the communication paths. The table compares the existing distance between the generation points and the one proposed by the first scheme.
### Table 1. Leverage between generation nodes

| Shoulder | Distance along the existing UDS, m | Overhead line distance, m | Shoulder | Distance along the existing UDS, m | Overhead line distance, m |
|----------|-------------------------------------|---------------------------|----------|-------------------------------------|---------------------------|
| 1-3      | 605                                 | -                         | 12-13    | 271                                 | -                         |
| 1-2      | 411                                 | 357                       | 12-19    | 995                                 | 702                       |
| 1-4      | 1100                                | 811                       | 12-21    | 513                                 | -                         |
| 1-18     | 672                                 | 579                       | 12-27    | 443                                 | -                         |
| 1-21     | 1110                                | 849                       | 13-14    | 261                                 | -                         |
| 2-4      | 1480                                | 1000                      | 13-19    | 737                                 | 584                       |
| 2-29     | 218                                 | -                         | 13-20    | 779                                 | 533                       |
| 3-4      | 460                                 | 386                       | 14-15    | 490                                 | -                         |
| 3-18     | 1260                                | -                         | 14-19    | 721                                 | 587                       |
| 3-19     | 991                                 | 792                       | 14-28    | 855                                 | 596                       |
| 3-21     | 1200                                | 879                       | 14-30    | 962                                 | 653                       |
| 4-5      | 437                                 | -                         | 15-16    | 263                                 | -                         |
| 4-21     | 746                                 | 685                       | 15-28    | 396                                 | -                         |
| 4-25     | 658                                 | 535                       | 16-17    | 306                                 | -                         |
| 5-6      | 262                                 | -                         | 16-28    | 483                                 | 332                       |
| 5-26     | 75                                  | -                         | 17-18    | 339                                 | -                         |
| 6-7      | 569                                 | -                         | 17-28    | 180                                 | -                         |
| 6-23     | 813                                 | 656                       | 17-29    | 489                                 | 376                       |
| 6-25     | 676                                 | 442                       | 18-29    | 218                                 | -                         |
| 6-26     | 348                                 | 247                       | 19-20    | 354                                 | -                         |
| 7-8      | 562                                 | -                         | 19-30    | 264                                 | -                         |
| 7-24     | 124                                 | -                         | 20-21    | 91                                  | -                         |
| 7-25     | 831                                 | 619                       | 21-22    | 584                                 | 393                       |
| 8-9      | 168                                 | -                         | 21-25    | 434                                 | -                         |
| 8-24     | 344                                 | 263                       | 21-27    | 156                                 | 85                        |
| 9-10     | 583                                 | -                         | 22-23    | 426                                 | -                         |
| 9-24     | 432                                 | 300                       | 22-25    | 545                                 | 447                       |
| 9-22     | 841                                 | 638                       | 22-27    | 400                                 | -                         |
| 10-11    | 258                                 | -                         | 23-24    | 121                                 | -                         |
| 10-22    | 409                                 | 255                       | 23-25    | 758                                 | 550                       |
| 11-12    | 126                                 | -                         | 25-26    | 292                                 | -                         |
| 11-22    | 486                                 | 358                       | 28-29    | 315                                 | -                         |
| 11-27    | 569                                 | 401                       | 28-30    | 578                                 | 413                       |

3. Conclusion

When studying the data obtained, reflected in table 1, the conclusions about the longest route in this area and the shortest. The table shows that most of the existing communication routes are much longer than the proposed ones. The longest distance connecting the pedestrian generation points is 1480m, and the shortest distance is 75m. On air lines the greatest is 1000m. and the smallest is 85m. The number of overhead lines is two times less than the existing number of routes. The total number of edges connecting the vertices, that is, the pedestrian generation points are 66, and 33 overhead lines.

The main goal of the work is to optimize the movement of pedestrians, to create safe traffic, taking into account the construction of the shortest driving distances. Therefore, great attention is paid to the length of the pedestrian paths.[8-10]

One of the methods used in the work is to reduce the number of paths for pedestrians, in order to
streamline and direct pedestrians. This can reduce the number of accidents in the area under consideration.

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