Influence of pedestrians' behavior on the scenario of urban streets public spaces functional zoning

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Abstract. The article is devoted to the research issue of comfortable urban environment formation due to the development of pedestrian spaces of city streets. The purpose of this article is to find new approaches to the functional planning organization of pedestrian zones of city streets. The study is based on a systematic analysis of data from a full-scale survey of the existing condition of Moscow city streets. During the experimental study of 450 sections of pedestrian spaces of streets, 4 groups of object filling of the public space of a city street were identified for the use of the territory: transit movement, long stay, short-term stop, maintenance of street territories, and 4 scenarios of user behavior corresponding to them: movement, stop, stay and absence of action. A matrix of functional organization of public spaces of city streets has been developed, which determines the possibility of placing 8 microzones with various functions and object content on the territory of the public space of a city street, depending on the scenario of its use. Differentiation of the street area will improve the quality of the urban environment by creating safe and comfortable pedestrian spaces for different groups of users.

1 Introduction

Urban areas are a valuable limited resource in the scarce conditions of compressed city boundaries and the issue of their rational use is the relevant topic of an urban policy. Rational use is supposed to meet the needs of all groups of users, providing the most effective way of territories’ economic development while reducing the hazardous impact on the environment [1]. Increasing the efficiency of urban land use can be achieved by saturating spaces with different functions to meet the maximum number of needs of the population. Therefore, the creation of multifunctional public spaces with wide flexibility to the population's demands is a prerequisite for the formation of a comfortable living environment and the activation of social processes and public initiatives [2-4].

Urban streets are important components of the transport and planning framework of any city, they provide a link between the functional elements of the city and the movement of people and goods [5]. The main purpose of planning and design of urban streets is to ensure

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the continuous movement of large flows of users and the reliability of all elements of the streets.

The article focuses on the most intensive public spaces of the city - urban streets. Urban streets are important components of the spatial and transport frameworks of any city as they provide a link between city parts and the movement of people and goods [5]. Also, it is very important that they are not nor boundary places but linear spaces. They have a number of important differences from other types of public spaces. First, the variety of different groups of users - pedestrians, cyclists, passenger transport waiters, holidaymakers, tourists and many others, whose interests intersect in a limited pedestrian space. The second, the predominance of transit users, who can move at different speeds. The third point is the increased environmental requirements in conditions of significant traffic load and dense perimeter buildings.

The problem of city streets public spaces design lays in the field of the most attention is paid to the organization of safe transport traffic conditions. Although modern trends and advanced experience of sustainable cities dictate the need for priority attention to the design of pedestrian spaces and the development of active mobility [5 - 9]. In addition, sociological studies show that the intensity of pedestrian traffic and the popularity of public spaces use by the population for various purposes is growing. Thus, the persons ‘demands for services provided by city streets is growing. In response of city authorities, in order to ensure the sustainable development of the living environment, an urban proposal should be formed, which is reflected in new approaches to the land use of pedestrian spaces of city streets [10-11].

In the article, the pedestrian spaces of city streets, which serve as a public space, act as an object of research. The research question is to develop scenarios from land use depending on two main aspects:

- the types of users for whom it is an object of attraction and
- its location and the role it plays in ensuring the connectivity and accessibility of the good environment.

These aspects determine the functions performed by each of the considered elements of public space, which directly affects the composition of the planned functions and the design of land use. The purpose of this study is to find new approaches to the functional planning organization of pedestrian zones of city streets.

2 Methods and materials

The first stage of the study was the analysis of external and internal factors that affect the use of urban street space. Further, we determine in what way they influence on the planning design of a city street.

The research was carried out on the streets of Moscow. The choice of the city of Moscow is due to the high number, density and level of mobility of the population, providing a high intensity of use of pedestrian spaces of city streets, as well as best practices in the field of spatial development of the road network [12].

The study is based on a systematic analysis of data from a full-scale survey of the existing condition of Moscow city streets. The objectives of the study included:

1. determination of the object content of pedestrian spaces of city streets;
2. allocation of scenarios for the use of public spaces of city streets.

The actions algorithm is presented on the figure 1.
Usually the street has a different transverse profile along its entire length. For this reason, sections of the pedestrian space of the city street were allocated for the study – linear elements of the pedestrian space of the street and road network, having a constant transverse profile and uniform nature of the use of the territory.

The boundaries of the considered elementary section were the territory from intersection to intersection. The longitudinal boundaries were the front of the building on one side and the curb separating the roadway from the pedestrian on the other (Fig. 2).

The appearance and content of a city street depend on the following factors:

- classification of the street and road network:
  - each street class performs a certain functional role in the structure of the city and accommodates groups of users different in number and composition. Streets of lower categories provide access to territories and various objects within neighborhoods. The main users on these streets are residents of nearby houses located within walking distance. The main streets contain large pedestrian flows, respectively, the number of services provided and the normative dimensions of the pedestrian spaces themselves are increasing.
  - the functional purpose of the adjacent territories to the road network: the behavior of users in general will depend on the adjacent buildings and objects of attraction. On the territory of public, natural and residential areas, pedestrians actively use the
street space not only for transit movement, but also for using various services, walking and as a meeting place and socializing.

The streets bordering these functional zones are characterized by high density and diverse filling of social service facilities. Data was collected on the presence or absence of a particular infrastructure object on the territory of the pedestrian space.

During the experimental study, 450 typical sections of streets of each category were examined, taking into account the existing land use and development of the territory adjacent to the street (Fig.3).

3 Results

The results of the analysis of the data obtained are the definition of groups of object filling of public space.

*Group 1* – infrastructure facilities that provide transit traffic for users. In the plan, linear corridors are represented, along which straight-line and unhindered movement is provided. The width is determined based on the regulatory requirements for throughput [5, 13-18].

*Group 2* – infrastructure facilities whose users stay on the street for a long time to participate in the event, i.e. perform any long-term actions: they sit in a street cafe, walk around the square, participate in a performance, etc. In the plan for this type of event, separate zones are allocated, separated from transit routes.

*Group 3* – infrastructure facilities whose users perform short-term actions, i.e. make a stop on the territory of the street to receive a service. These zones include objects of social accompanying and transport infrastructure.

*Group 4* - infrastructure facilities intended for technical operation of the street territory, placement of various engineering structures and security zones.

For every group of city objects the special land use scenario was developed according to its characteristics of function description and user behavior (Table 1).

Table 1. Urban streets land use scenarios depending on their function description and user behaviour

<table>
<thead>
<tr>
<th>Group</th>
<th>Objects location</th>
<th>Land use scenario</th>
<th>Function description</th>
<th>User behaviour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>Pedestrian way</td>
<td>Transit movement across the street</td>
<td>They move in a straight direction without making a stop on the territory of the street</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bike way</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 2</td>
<td>Street restaurants</td>
<td>Long stay on the street to participate in the event</td>
<td>They are on the street for a long time to participate in the event</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Street trade</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Street recreation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 3</td>
<td>Entrances to adjacent buildings</td>
<td>A short stop on the territory of the street to receive a service</td>
<td>Briefly use the territory of the street</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Entrances to metro / rail stations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fast services</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Meetings points</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Public transport stops</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Parkings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Street food</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group 4</td>
<td>Street lightning</td>
<td>Maintenance of the street territories</td>
<td>No action (no people)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Trash bins</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Buffer green lines</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Each group of objects corresponds to four possible scenarios for the use of territories:

**Scenario 1:** Traffic – transit traffic of street users in order to move from one point to another.

**Scenario 2:** a stop is a short-term stay of users on the territory of a public space in order to receive a service.

**Scenario 3:** stay – a long stay of users on the territory of a public space in order to receive a service.

**Scenario 4:** no action – territories for engineering maintenance of the street.

The survey of city streets made it possible to identify the dependence of the functional planning organization of pedestrian spaces on the influence of two main aspects - "human behavior" and "use of territories", where two zones of functional organization are defined for each scenario (Fig. 3).

### FUNCTION DESCRIPTION

<table>
<thead>
<tr>
<th>MOVE</th>
<th>STAY</th>
<th>STOP</th>
<th>NO ACTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEDESTRIAN TRAFFIC</td>
<td>ACTIVE MOBILITY VEHICLE TRAFFIC</td>
<td>ACCESS TO SOCIAL AND PUBLIC INFRASTRUCTURE</td>
<td>ACCESS TO TRANSPORT INFRASTRUCTURE</td>
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</table>

**Fig. 3** Matrix for city streets public pedestrian spaces land use definition

Each of the zones performs certain functions and is designed to accommodate various urban infrastructure.

**Transit zone for MOVE** includes pedestrian transit ways and special lines for bikes and individual motor vehicles that provide continuous and connected movement of users with specified values of capacity, intensity and density of pedestrian traffic. Basic requirements are [12-22]:

- the minimum number of intersection points with other users;
- absence of obstacles on the way;
- compliance with the standard width of the sidewalk;
- availability of clear navigation.

With the development of means of individual mobility, it became necessary to allocate a separate zone for their transit traffic. Since the technical capabilities of electric scooters and other means allow you to reach speeds of more than 30 km / h, which leads to dangerous situations on the road network. The requirements for the transit zone of individual mobility vehicles are the same as for sidewalks, in this case only the regulatory characteristics (track width, number of lanes, traffic lane capacity) and users change.

*STAY zones of social, public infrastructure and recreation facilities* enhance the public function of the street by creating public spaces for long-term social interaction. Since these places are the focus of attraction of a large number of people, sanitary and epidemiological requirements must be observed to protect people from anthropogenic load from vehicles on the one hand (the use of planning techniques separating recreation areas from the roadway), and from the spread of various diseases on the other hand (the possibility of observing social distances). To create a harmonious and attractive environment, these objects must also correspond to the established appearance of the street, preserving the historical unity of the urban environment.

*STOP zones for long – stay public service areas and areas of the transport facility* contribute to the receipt of services by users. Public service areas include: related services, household service facilities and the street front of the building/entrance groups. And to the zones of transport facilities: bus stops, metro entrances, off-street pedestrian crossings, as well as bicycle parking. Each group of facilities will be subject to technical and regulatory requirements to create favorable conditions for servicing the population.

*NO ACTION zone is a buffer zone and a landscaping zones.* There are facilities that provide operational and engineering maintenance of the territory of the road network. Additional requirements for these objects of public spaces of streets are aesthetic attractiveness (objects must fit into the general appearance of the street) and reduction of anthropogenic load from vehicles (the organization of buffer zones is one of the main planning techniques to protect users from the impact of cars).

Zoning of pedestrian space allows rational and efficient use of the territory of the street, allocating areas for the prevailing function and separating the flows of people, which ensures not only comfort, but also the safety of all groups of users. (Fig.4).

*Fig.4. Example of functional zoning of a street*
The analysis allows to determine the patterns of functional organization of pedestrian spaces of streets to create a high-quality urban environment. The creation of favorable living conditions for the population is possible in the case of effective and rational use of the territory for the placement of demanded objects, which contributes to improving the quality of the urban environment.

Differentiation of the street territory allows you to create a high-quality pedestrian space, where each of the use cases is allocated its own part of the street. This idea meets the issues of safety and comfort of users, connectivity and continuity of pedestrian spaces and the formation of the best living conditions.

4 Conclusions

Increasing role of public life on city streets is a necessary condition for the formation of a comfortable urban environment of megacities and determines the relevance of the issue of developing new approaches to the urban development of pedestrian spaces on city streets.

The development of new technologies, measures to reduce the level of motorization, the appearance of an increasing number of means of individual mobility on the streets, the consequences of coronavirus infection (COVID-19) require the development of new standards and norms for planning and designing the road network.

In a modern city, a new vector of spatial development is behind a new look at streets that integrate various functions and act as new linear centers of cities. With the new functional and planning organization of the territories of the road network, it is possible to achieve high quality and integrity of the urban environment, to ensure compactness and efficiency of the use of territories.

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