Ways of comfort radius definition of accessibility for pedestrians to the first service objects

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Summary. In this article is briefly exposed one of the main problem of civil construction of nowadays − accessibility of pedestrian areas. Were investigated normative documents of Ukraine connected with this question, were defined and classified main factors, that influence on the comfort of walker's move. Were also defined factors that are influencing on the planing aspect of comfort of the movement- pedestrian accessibility.

The given results of definition of the influence of such factors as type of attraction object, type of the layout of site development and dilatational slope of the track. The influence of the type of the priority service object was made with pedestrian audition. The grade of influence of the site development type was defined with misalignment coefficient, usual for several layout types of pedestrian tracks. The influence of longitude inclination is being defined through monitoring of the changes in cardiovascular system and inner body temperature during the movement with permanent speed on different slopes.as a result, was given a method of definition of the comfort of accessibility for pedestrians to the object of priority service, that can be used during the planing of new development and during the estimation of one already existing. According to achieved results, the comfort radius can be both smaller and bigger of the normative, that gives corresponding economical benefits with the usage of the method.

Key words: accessibility for pedestrians, radius, normative, type of site development, slope, pedestrian audition, misalignment coefficient.

INTRODUCTION

Urban construction — one of the most important sciences of the modern urban society. The theory of urban construction is investigating the planning organization of displacement and populated places, peculiarities of theirs formation, functioning and development in correlation with socio- economic and natural conditions. In urban construction theory are being investigated regularities of formation and function of urban construction developments, are being developed principles and criteria of project decision making [20]. One of the main problem of urban construction is arrangement of pedestrian flow in residential area. Accessibility for pedestrians — is the factor that influences on the definition of people's living comfort, shopping, different objects visiting, rest and time passing on the territory [8].

MATERIALS AND METHODS

In Ukraine accessibility for pedestrians is being regulated by the number or governing documents that have a long history. In 1955 in USSR were admitted several construction norms and rules – SNIP 2-V.1 “Laying-out of populated locality”[16], and in 1958 – SN 41-58 “Rules and norms of laying-out and site development of cities” [12], that com-

pleted the one published before [16] and was regulating the radius of accessibility for pedestrians of 500 meters to the majority of target places among people. After that, had appeared several legislating documents, that replaced the previous, in which was changing the radius of accessibility for pedestrians [17, 18, 19]. Finally, when Ukraine has got Independence, was adopted a document that is active nowadays – Governmental Building Codes DBN 360-92 [3].

The brief analysis [6] of accessibility for pedestrians radius changes in this documents, showed, that the majority of numbers stayed unchangeable from one to another document.

There are no proves of investigations that caused the admission of noted radiuses in area of accessibility for pedestrians in cities [12]. According to [13], they were determined by 5-minutes walking accessibility, but it can not be considered sufficient for the arrangement of normative radius. Besides the growth of density of population, character of transport traffic and specificity of attraction points of last 50 years, the norms in [3] are basing on norms in [12]. They are presented in the table 1. Appears the necessity of its grounding or changeover.

There is a big amount of factors that are influencing on the accessibility for pedestrians and they have to be investigated and classified. There are several factors that are being defined as impact causers on accessibility for pedestrians: degree of street network transmissibility, land-use management, built-upends, trees and other plants presence, entrances and another element alongside front, visibility, free places presence around houses, that can be visited, urban design etc [5].

Table 1. Definition of attraction object type coefficient on the radius of accessibility for pedestrians to them

Attraction object	Normative radius of accessibility for pedestrians (m)	Desirable radius of accessibility for pedestrians (m)	Attraction object type influence coefficient
Kindergarten	300	600	2,00
School	750	800	1,07
Market	500	510	1,02
Workshop	500	640	1,28
Polyclinic	1000	810	0,81
Pharmacy	500	440	0,87
Sport	1500	850	0,57
Stops	500	350	0,70
Garages	1000	330	0,33
Parking	150	230	1,96
Bank	500	600	1,21
Post office	500	580	1,16

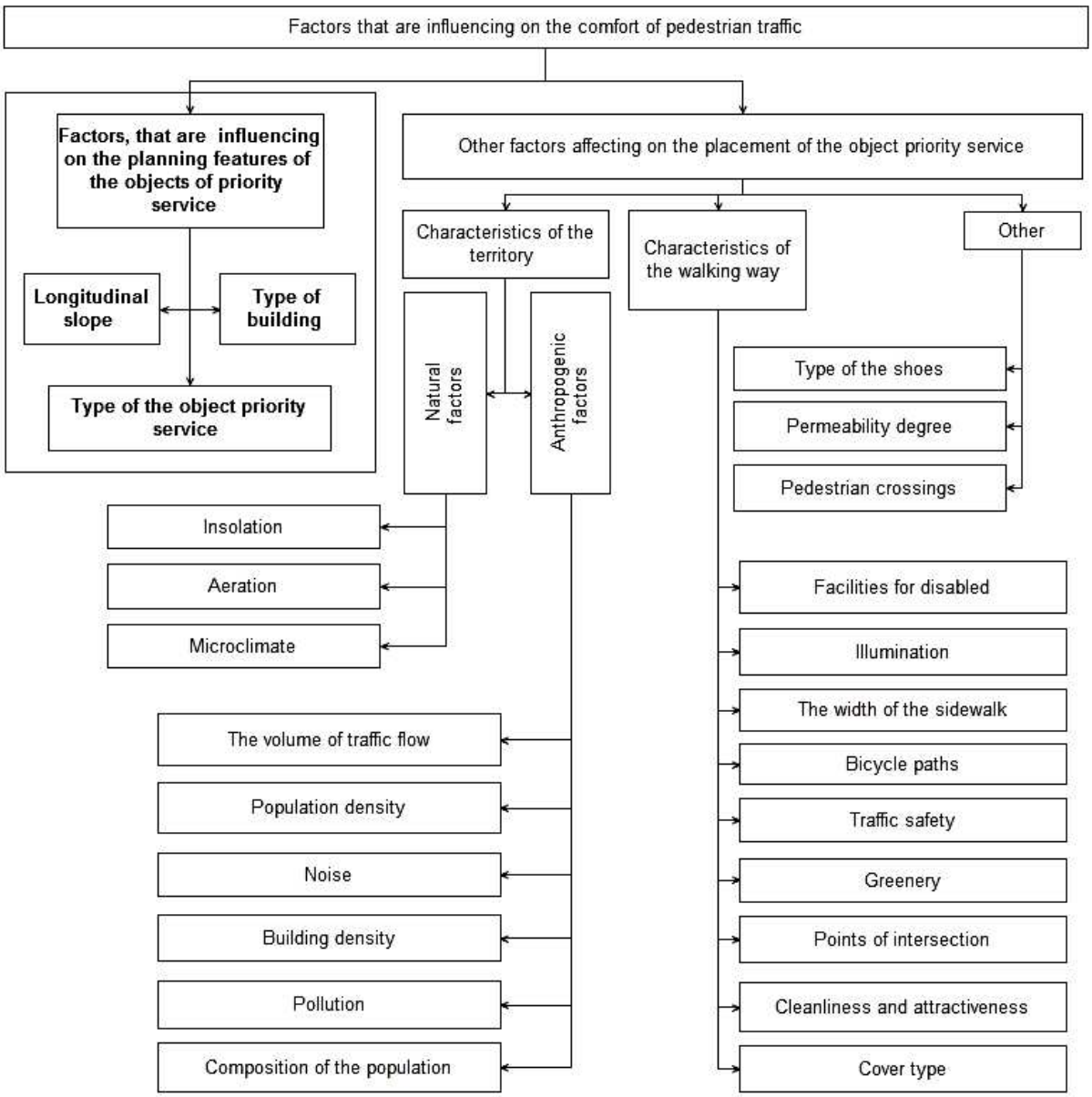

Fig. 1. Factors that are influencing on the comfort of pedestrian traffic

Infrastructural factors are: existence of public transport stops, presence and quality of walkways, presence of obstacles on the walking way lines, insolation, aerification, noise and speed of the traffic and so on [10]. This and other factors are divided into the groups and are presented in the figure 1. Also was defined character of factors' influence on each other, the degree of the influence and dependence of each factor (Tab. 2). Finally were defined the most fundamental (most depended and most powerful) from the point of view of comfort movement factors. It is built-upness, volume of transport traffic, character of bicycle tracks placement, green plants and pedestrian paths. Also was defined the factors' group, that is influencing on the first service objects placement, according to what the investigation is being held (Fig. 1).

In this work factors that are influencing on pedestrian radius is look like a numbers indices that characterizes each of them. Such index is a coefficient that takes into consideration moving comfort according to one or another factor. The presence of several coefficients like this permits to make a model that

will make the displacement of pedestrians more comfortable through optimization of first-service object placement. Moreover, this model gives a possibility to appreciate built-up territory from the point of view of the living comfort in any of its part. That is why here are examined factors, that are influencing on gravity objects.

One of the most significant factors is the territory planning lay-out of built-up. There are 5 types of this built-up kind – perimetral, group-wide, linage, free and compound built-up [4]. Each of it has its own influence on the movement track of pedestrian, that is why the coefficient of nonlinearity, that is common for each of them. Coefficient of nonlinearity – measurement, that reflects the correlation of length of the path between two points with air distance.

In a result of analysis of the planning structure of Kiev [14], were chosen territories with the most characteristic type of built-up. As perimetral – Podil, group-wide – Nykilska Borchagivka, lainage – Rusanivka, free – Batyev hill. Compound built-up combined elements of other types, that is why the coefficient of nonlinearity, that is typical for it, is direct average of all other coefficients.

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In a result of analysis of the planning

Table 2. The degree of influence and dependence of factors affecting the comfort of pedestrians (where *M* is the degree of effect) − part 1

Factor	1	2	3	4	5	6	7	8	9	10	11	12
1. Insolation		0	1	0	0	0	0	0	0	0	0	0
2. Aeration	0		0	0	0	0	0	0	1	1	0	0
3. Microclimate	0	0		0	0	0	0	0	0	0	0	0
4. Lay-out type	1	1	1		0	1	0	0	1	0	0	0
5. Attraction object type	0	0	0	0		0	0	1	0	0	0	0
6. Built-upness	1	1	1	1	0		1	0	1	1	1	0
7. Density of population	0	0	0	0	0	1		0	1	1	1	0
8. Population composition	0	0	0	0	1	0	0		1	1	1	0
9. Noise	0	0	0	0	0	0	0	1		0	0	0
10. Pollution	0	0	0	0	1	0	0	1	1		0	0
11. Traffic volume	0	0	0	0	1	0	0	0	1	1		1
12. Longitudinal slope	0	0	0	0	0	1	0	0	0	0	1	
13. Illumination	0	0	0	0	0	0	0	1	0	0	1	0
14. Width of footpath	0	0	0	0	0	0	0	1	0	0	0	0
15. Bikeway presence	0	0	0	0	0	0	0	1	0	0	0	0
16. Traffic safety	0	0	0	0	0	0	0	1	0	0	0	1
17. Green space presence	1	1	1	0	0	0	0	1	1	1	0	0
18. Flows cross point	0	0	0	0	0	0	0	1	0	0	1	0
19. Cleanness and attractivety	0	0	0	0	0	0	1	1	0	1	0	0
20. Coverage type	0	0	1	0	0	0	0	0	1	0	0	0
21. Conditions for disabled	0	0	0	0	0	0	1	1	1	1	0	1
22. The degree of permeability	0	0	0	0	0	0	0	0	0	0	0	0
23. Type of shoes	0	0	0	0	0	0	0	0	1	0	0	0
24. Type of pedestrian crossings	0	0	0	0	0	0	0	1	0	1	1	0
The degree of dependence	3	3	5	1	3	3	3	12	11	9	7	3

structure of Kiev [14], were chosen territories with the most characteristic type of built-up. As perimetral – Podil, group-wide – Nykilska Borchagivka, lainage – Rusanivka, free – Batyev hill. Compound built-up combined elements of other types, that is why the coefficient of nonlinearity, that is typical for it, is direct average of all other coefficients.

For investigation was chosen one of the objects type of attraction – school, as a big amount of permanent users that has the biggest fixed radius, that is why margin of error will be the lowest. Every territory was divided into zones through the making a Voronoy diagram [1], each part of that was served by its own school. Afterwards were made tracks of pedestrian ways from the farest entrances. For this tracks are defined coefficients of nonlinearity, the average meaning of which are coefficients of influences of territory lay-out.

For evaluation of accessibility for pedestrians there are several international internet resources as Walkonomics, Walk Score, RateMyStreer ets. They are evaluating and measuring accessibility for pedestrians trough making pedestrian audition. For example, RateMyStreet gives possibility for users to rate any street in eight categories − commodity of road crossing, the width of pavement, driving risks, traffic organization commodity, safety from the point of view of criminality rate, cleanness and attraction, accession for handicapped. In countries of western Europe and Northern America, in contrast to Ukraine, this systems are being used intensively for evaluation of pedestrian accessibility. Correspondingly to gather statistics about Ukrainian cities using this programs is impossible.

Table 2. The degree of influence and dependence of factors affecting the comfort of pedestrians (where *M* is the degree of effect) − part 2

Factor	13	14	15	16	17	18	19	20	21	22	23	24	M
1. Insolation	1	0	0	1	1	0	1	0	0	0	0	0	5
2. Aeration	0	0	0	1	0	0	0	0	0	0	0	0	3
3. Microclimate	0	0	0	1	0	0	0	0	0	0	0	0	1
4. Lay-out type	1	0	0	1	0	0	1	0	0	1	0	0	9
5. Attraction object type	1	1	1	0	1	1	0	0	1	0	0	1	8
6. Built-upness	1	1	1	1	0	0	0	0	0	1	0	0	13
7. Density of population	0	1	1	1	0	1	0	0	0	0	0	1	9
8. Population composition	0	1	0	1	0	0	1	0	1	1	1	1	11
9. Noise	0	0	0	1	1	0	1	0	1	0	0	0	5
10. Pollution	0	0	1	1	1	0	1	0	1	0	0	1	9
11. Traffic volume	1	1	0	1	1	1	1	0	0	0	0	1	11
12. Longitudinal slope	0	0	1	1	0	0	0	0	1	0	0	0	5
13. Illumination		0	0	1	0	0	1	0	1	0	0	0	5
14. Width of footpath	1		0	1	1	0	1	0	1	1	0	0	7
15. Bikeway presence	1	1		1	1	1	1	1	1	1	0	1	11
16. Traffic safety	1	1	1		1	1	0	1	1	1	0	1	11
17. Green space presence	1	1	0	1		0	1	0	1	0	0	0	11
18. Flows cross point	1	1	0	1	0		0	0	1	1	0	1	8
19. Cleanness and attractivety	1	1	1	0	1	0		0	0	0	0	0	7
20. Coverage type	1	0	1	1	0	0	1		1	0	1	0	8
21. Conditions for disabled	1	1	0	1	1	1	0	1		1	0	1	13
22. The degree of permeability	0	1	1	1	0	0	0	0	1		0	0	4
23. Type of shoes	0	0	0	1	0	0	0	0	0	0		0	2
24. Type of pedestrian crossings	1	1	1	1	1	1	0	0	1	1	0		11
The degree of dependence	14	13	10	21	11	7	11	3	14	9	2	9	

Taking into consideration the fact that for this article the evaluation of concrete territories is less important then tendencies, lows and principles of accessibility for pedestrians formation, there was held questionnaire of Kiev citizens, with the aim to find out time loses on movement to every first service object. The reason why time was chosen as figure of merit – it is easier to define time, for the average person, then the distance, and absence of strong dependence on the norm, with which the majority of pedestrians are unfamiliar. Citizens were divided into categories according to their age, and during the investigation was estimated their speed of walking. That gave a possibility to turn time results received from the questionnaires into the distance. After cancelation of mistakes made during questionnaire on Dixon's *Q*-test [11] were defined correlations between desirable and normative radiuses for every first service objects [7]. This correlation is coefficient of the first service object type influence and presented in table 1.

Longitudinal slope of pedestrian way also influences on comfort of motion. Usually pedestrians are walking at sidewalk along carriageway. At big slopes rises the amount of oxygen that organism consumes, along with that rises the amount of harmful moieties that come into lungs. In the Building Code DBN 360-92 [3] you can find a table of radius change at accessibility for pedestrians in dependence of territory slope (Tab. 3). As in case with normative radius, there are no links on investigations in this theme. It appears a question of benefit of usage of this results in urban construction conditions.

The moment of now is being held the investigation of regime changes of pedestrian organism on different slopes, with condition that he moves always with one speed. The influence is being determined by next parameters: pulse, temperature and oxygen level in blood. In this case are being used – pulse oximeter Kernel KN-601E, thermometer Microlife MT3001 and stop watch. Such investigation permits to receive the coefficient of longitudinal slope of pedestrian way on radius of accessibility for pedestrians.

RESULTS AND DISCUSSION

Basing on results that we achieved during investigation, was made formula of computation of comfort radius definition service for objects of attraction:

$$R_C = R_N \times \frac{K_1 \times K_2}{\ldots},$$

were R_C − is comfort target radius, R_N — normative radius from Building Code DBN 360-92** [3] (Tab. 3), K_1 — coefficient of attraction object type formed according to results of pedestrian audition, K_2 — coefficient of longitudinal slope way, K_3 — coefficient of lay-out territory type influence, that was defined before with non-lineral coefficient. This kind of correction of normative mark gives possibility not only to create new building-up with more comfortable life conditions, but to make right evaluation of comfort of already existing territories.

Table 3. Service radius reduction depending on territory slopes (Building Code 360-92, application 6.3 Tab. 2)

Slope(permille)	Service radius reduction for different objects depending on territory slide				
0-5	300	500	750	1000	1500
10	180	300	450	600	900
20	90	150	225	300	450

CONCLUSIONS

1. Analysis of normative base showed that actual normative radiuses don't have enough objectivations for being considered comfortable in actual urban construction situation.
2. Were defined and classified big amount of factors that influence on pedestrian traffic, that caused the necessity of taking those of them into consideration, that are influencing on lay-out principles of citizens objects of attraction.
3. Investigation results usage in urban-construction and lay-out activity will rise the comfort of living territories from the point of view of accessibility for pedestrians.

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ПУТИ ОПРЕДЕЛЕНИЯ КОМФОРТНЫХ РАДИУСОВ ПЕШЕХОДНОЙ ДОСТУПНОСТИ ДО ОБЪЕКТОВ ПЕРВООЧЕРЕДНОГО ОБСЛУЖИВАНИЯ

Аннотация. В статье кратко очерчена одна из основных градостроительных проблем нашего времени — пешеходная доступность. Изучена нормативная документация Украины по этому вопросу, определены и классифицированы основные факторы, влияющие на комфортность движения пешехода. Определены факторы, влияющие на планировочный аспект комфортности движения — пешеходную доступность. Представлены результаты исследований по определению влияния на неё таких факторов как тип объекта тяготения, планировочный тип застройки и продольный уклон пути. Влияние типа объекта первоочередного обслуживания определено с помощью проведения пешеходного аудита. Влияние типа застройки территории выведено с помощью определения коэффициента непрямолинейности, характерного для пешеходных путей того или иного планировочного типа. Влияние продольного уклона определяется с помощью мониторинга изменений работы сердечно-сосудистой системы и внутренней температуры тела при движении с постоянной скоростью на различных уклонах. В результате представлен метод определения комфортной пешеходной доступности к объектам первоочередного обслуживания, который можно использовать как при планировке новой застройки, так и при оценке уже существующей. Согласно полученным данным, комфортный радиус может быть как меньше, так и больше нормативного, что даёт соответствующие экономические выгоды при использовании метода.

Ключевые слова: пешеходная доступность, радиус, норматив, тип застройки, уклон, коэффициент непрямолинейности.