

Methods of Evaluating Pedestrian Level of Comfort

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Abstract – Urban traffic system cannot exist without infrastructure for pedestrians. The needs of the pedestrians should be considered while designing new roads or planning reconstruction of already existing roads. Unfortunately, in many cities of Ukraine there are a lot of problems linked with sidewalks and other elements of pedestrian facilities so they need to be assessed and reconstructed if it needed.

The focus of this study is to show existing methods of evaluating pedestrians' level of comfort, which successfully used in the world.

Key words – sidewalks, pedestrian comfort, level-of-service, evaluation methods, qualitative factors.

I. Introduction

Pedestrian comfort conditions may be determined as a kind of emotional response to the environment in different situations. In other words under this concept can be understood accessible for pedestrians personal space, which allows to freely perform their movement.

There are three types of pedestrian comfort: physical, psychological and physiological [1].

Physical comfort means minimum effort needed for pedestrian movement. Physical comfort depends on adequate walkway, continuous sidewalk, absence of impediments, comfortable walking surface, presence of seating and protection from extreme weather conditions.

Psychological comfort is achieved when pedestrian has ability to maintain desired walking speed and ability to participate in various pedestrian activities.

Level of air pollution and noise pollution defines physiological state of pedestrian [2].

II. Existing methods

Physical comfort of pedestrian usually defined by calculation of level-of-service (LOS) using Level-of-Service approach.

Pedestrian LOS by Nicole Gallin:

Nicole Gallin at his paper [3] made calculation of LOS based on the influence design factors (physical characteristics), location factors and user factors.

Design factors were defined by next assessments:

- Measurement of sidewalks width that is available to pedestrians;
- Evaluation of surface quality. Good quality means smooth surface;
- Measurement of the number of obstructions on the path. This is important parameter as it determines the accessibility of sidewalks to people with disabilities;
- Assessment of presence of support facilities that includes tactile paving, color contrast curbing, rest places, curb ramps, lanes for cyclists;

Location factors:

- Evaluation of the degree of path directness and logicalness between departure points and destinations;
- A measure of the quality of the environment. In other words the "pleasantness" of the surrounding environment;
- A count of the number of potential vehicle conflict points along the route.

User factors:

- Calculation of pedestrian volume;
- Evaluation of flow structure. It means an estimate of the various groups who use the path such as cyclists, pedestrians, etc. including recreational pedestrians and pedestrians with a purpose;
- Qualitative measurement of the degree to which the path is safe for users (lightning level, path visibility).

Assessment scale of LOS was divided into 5 grades A to E (where A - ideal conditions for movement and E - unacceptable conditions). Each of the factors should be evaluated in terms of the quality and importance.

Time-Space Concept by Gregory Benz:

Gregory Benz proposed a new approach for evaluating LOS [4] and called it time-space concept. He consider that pedestrian activities generate time-space needs in some areas, which called time-space zones. He also showed mathematical equation, which describes his method:

$$T - S_{req.} = \sum P_i M_i T_i \quad (1)$$

Where, $T - S_{req.}$ – time-space required; P_i – number of people involved in activity i; M_i – space required per person for activity i; T_i – time required for activity i.

Pedestrian LOS by TAN Dandan:

In a research of TAN Dandan [5] evaluation of LOS was made by analyzing the relationship between the pedestrian's subjective perceptions and the quality of the road physical facilities. The following mathematical equation was developed.

$$LOS = -1.43 + 0.006 \cdot Q_B - 0.003 \cdot Q_P + \frac{0.056 \cdot Q_V}{W_R} + 11.24 \cdot (P - 1.17 \cdot P^3) \quad (2)$$

Where, Q_B – bicycle traffic during a five-minute period; Q_P – pedestrian traffic during a five-minute period; Q_V – vehicle traffic during a five-minute period (pcu); P – driveway access quantity per meter; W_R – distance between sidewalk and vehicle lane (m).

As a result, the following grades scale can be used:

- A – LOS < 2.0;
- B – 2.0 <= LOS < 2.5;
- C – 2.5 <= LOS < 3.0;
- D – 3.0 <= LOS < 3.5;
- E – 3.5 <= LOS < 4.0;
- F – LOS >= 4.0

Highway capacity method (HCM) of pedestrian LOS [6]:

This method based on the measurement of pedestrian flow volume, speed and density. Assessment of the

sidewalk LOS uses the calculation of pedestrians per minute per foot (ped/min/ft).

According to this method pedestrian speed declines as volume and density increase, the degree of mobility afforded to the individual pedestrian declines as density increases and pedestrian space decreases.

Evaluation scale given in Table 1.

TABLE 1
SIDEWALK LEVEL OF SERVICE CLASSIFICATION

Sidewalk LOS	Pedestrian Space	Flow Rate
LOS A	> 60 ft ² /p	= 5 p/min/ft
LOS B	> 40-60 ft ² /p	> 5-7 p/min/ft
LOS C	> 24-40 ft ² /p	> 7-10 p/min/ft
LOS D	> 15-24 ft ² /p	> 10-15 p/min/ft
LOS E	> 8-15 ft ² /p	> 15-23 p/min/ft
LOS F	= 8 ft ² /p	Variable

This method has some weaknesses. It do not assess qualitative dimensions such as sidewalk surface condition, walking environment and safety.

Evaluation of comfort by Sakhar:

Evaluation of pedestrian comfort proposed in Sarkar S. paper [2] involves two separate evaluations: Service Level evaluation (physical and psychological comfort), which give standards for the overall desirable and undesirable comfort conditions at the macro level and Quality Level evaluation (physiological comfort) which assess pedestrian comfort conditions at the micro level. Evaluation scale divided to 5 grades: A, B, C, D, F. These levels, based on physical, physiological, and psychological comfort.

The attributes of physical comfort: adequate walkway, continuous sidewalk, walkway free of impediments, comfortable walking surface, presence of seating, protection from extreme weather conditions.

Psychological comfort is defined by these attributes: ability to maintain desired walking speed and ability to participate in various pedestrian activities.

The attributes that has influence on physiological comfort are noise and air pollution.

This method is not quantative and gives only qualitative assessment of pedestrian environment. This method has weak points: it requires considerable financial commitment and human resources and it takes a lot of time to perform while evaluating large sections of the cities.

Georgia Tech Sidewalk Assessment System [7]:

Researchers at the Georgia Institute of Technology made differently new assessment system using modern technologies. They remade manual wheelchair to "research station". Tablet with gyroscope, accelerometer, video camera, GPS transceiver was installed to wheelchair. This assessment system is able to evaluate condition and quality of sidewalks with digital data (gyroscope, accelerometer and video data) with connection to GPS coordinates. This assessment was performed to collect data of sidewalk width, pavement surface condition, presence of curb ramps, and presence of obstructions.

Archana.G P-LOS model [8]:

This method was developed for evaluation of LOS for pedestrian crosswalks at signalized intersections. At this

model, a statistical method called multiple linear regression analysis was used. The influence factors were grouped into three categories.

Pedestrians were asked to rate the crosswalks in terms of safety and comfort. For statistical analysis software "Statistical Product and Service Solutions" was used. The following equation was produced:

$$P-LOS = 7.443 - 0.002 \cdot PFH - 0.061 \cdot PCT + 0.679 \cdot CSR \quad (3)$$

Where, *PFH* – pedestrian flow (ped/hr); *PCT* = pedestrian crossing time (sec); *CSR* – crosswalk surface condition rating. (0 - poor, 1 - moderate, 2 - good)

To convert P-LOS numerical result to LOS evaluation scale table 2 was developed:

TABLE 2
CROSSWALKS LEVEL OF SERVICE

Crosswalk LOS	P-Los score
LOS A	8.5 < x < 10.0
LOS B	7.0 < x < 8.5
LOS C	6.0 < x < 7.0
LOS D	5.0 < x < 6.0
LOS E	4.0 < x < 5.0
LOS F	x < 4.0

Conclusion

In the paper the main existing methods of evaluating pedestrian comfort using LOS approach were shown. Some of these methods can assess the comfort level differently when are used at equal conditions. Time-Space Concept of Benz is better suited for transportation terminals and other complex pedestrian spaces. Method of Nicole Gallin perfectly assess physical state of sidewalk areas but the perception of pedestrians was not taken into consideration. Sakhar model gives deep analysis of pedestrian comfort but the grades are personal bias of the surveyor dependent. Highway capacity method do not assess physical state of sidewalks and other factors that have influence on pedestrian flow. Georgia Tech Sidewalk Assessment System can be easily used for accessibility of sidewalks to people with disabilities.

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