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Proposal of a Methodology for Assessing the Safety of Public Passenger Transport Stops

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Abstract This article focuses on developing a methodology for evaluating the safety of stops from the perspective of passengers outside the vehicle - those boarding, alighting, or approaching the stop. However, before that, it is necessary to analyze the current regulations that deal with this issue. The methodology consists of several steps: identifying the evaluated parameters, measuring them, creating a rating scale, and scoring the stops based on field data. It is then applied in a selected area of Bratislava, covering both urban (MHD) and regional (RAD) stops, in order to verify its universality for different types of stops. The results allow for the comparison of safety levels across stops and the proposal of improvements that can contribute to more efficient, safer, and more modern public transport.

Keywords methodology, stop, terminal, safety of passengers, public transport

JEL R41

1. Introduction

This article deals with public passenger transport stops, which were initially subjected to an analysis with an emphasis on creating a methodology determining the method and frequency of their assessment.

Evaluating stops is important primarily for identifying their current condition and subsequently proposing appropriate measures and reconstruction projects to ensure that a stop is safe for all users. Based on the knowledge gained and the available literature, a procedure was proposed that should be generally valid and applicable to any type of stop. [3]

Before proposing the methodology, a review of existing methodological approaches, scientific sources, and regulations concerning the location and equipment of public transport stops in various countries was conducted, specifically in the Czech Republic, Germany, and the United States. For example, American standards classify stops into several categories, such as bus bay stops, curbside stops, and extended curbside stops that allow parking by other vehicles. This type is particularly common in San Francisco, California. The standards also discuss shelter design, the number of passengers a stop should serve before shelter installation becomes effective, and the placement of advertisements at stops. [1]

In Slovakia, the issue of public transport stop evaluation is addressed by the Technical and Operational Standards of IDS BK, which deal with the topic only superficially because they also cover vehicles, tickets, and other aspects of public transport.

Based on an appropriate methodology, suitable measures for reconstruction and modernization can be proposed, leading to an increase in the quality of services provided in a given area. This is also the objective of the proposed methodology. [3]

2. Methodology design

The work focuses on the creation of the methodology itself. First, the subject of measurement was defined, i.e., the specific stop parameters that would be evaluated at each location. Subsequently, the interval and method of checking these parameters were determined. The next step involved defining evaluation levels with a precise explanation of their meaning.

A list of stops intended for measurement was then created, and sketches of these stops were prepared. In the final stage, points were assigned to individual stops based on actual field measurements. The methodology also includes tables recording compliance or non-compliance with the specified parameters, or containing value ranges with assigned scores.

The proposed methodology must be designed to be applicable to various types of stops. Therefore, it includes a broader set of parameters to cover different stop types and levels of equipment—from less-used rural stops with low passenger volumes to heavily used transport hubs in city centers where multiple modes of transport intersect.

The final part of the work involved practical verification of the methodology through real measurements. Actual stop sketches and completed evaluation tables based on field data collection were presented. The stops were then compared with each other, and the results were processed into tables and graphs illustrating their quality levels. Comparisons were carried out both among all evaluated stops and within the same transport mode. The contribution of the methodology lies in the clear identification of deficiencies at specific stops.

The methodology consists of three main parts:

1. Subject of measurement
2. Measurement procedure
3. Stop evaluation [3]

2.1. Subject of measurement

The subject of measurement consists of stop parameters defined in an evaluation form. This form serves for the clear recording of parameters of the stop being evaluated.

The form consists of several sections:

1. General parameters applicable to all stop groups
2. Detailed specifications for each stop separately
3. Detailed specifications for bus and trolleybus stops
4. Detailed specifications for tram stops

The template of the form is included in the appendix.

Each parameter was described to clarify its meaning. For example, the parameter "Number of traffic lanes within the terminal" was defined as the number of traffic lanes that must be crossed when transferring from one mode of transport to another. Only lanes designated for motor vehicles are counted, including bus lanes, trolleybus lanes, and properly marked taxi lanes. Bicycle lanes are not considered traffic lanes. The total number of parameters evaluated at each stop was 35. [3]

An example is the Bratislava, Zlaté Piesky stop, which is equipped with a Kassel curb and a comfortable pedestrian overpass for passengers.

Figure 1. Stop Bratislava, Zlaté Piesky**.**

2.2. Measurement procedure

This part of the methodology determines, based on the evaluation form, how individual parameters should be measured, by what means, and how frequently. Each parameter is described individually.

For example, the parameter "Presence of a sidewalk leading to the stop" is measured visually from the stop. The evaluator observes all directions around the stop and determines whether a sidewalk leads away from the stop in at least one direction. The uninterrupted length of the sidewalk must be at least 200 meters unless the destination (building, park, etc.) is located closer than 200 meters. This parameter should be measured once per year. [3]

2.3. Stop evaluation

In this part of the methodology, individual stops are assigned ratings.

The evaluation is based on a scoring system shown in Table 1. If a parameter is of the YES/NO type, a YES response is generally awarded 5 points, while a NO response receives 1 point. In some cases, the scoring may be reversed depending on the specific parameter. [3]

Table 1. Stop evaluation scale

Rating level	Meaning of the Rating Level
5	Parameter fully meets requirements
4	Parameter almost fully meets requirements
3	Parameter moderately meets requirements
2	Parameter only slightly meets requirements
1	Parameter does not meet requirements at all

2.4. List of Stops and Stop Sketches

This section creates a list of stops and defines how many associated stop platforms belong to the same stop name. A visual sketch of each monitored stop is also prepared.

An example is the stop group Bratislava, Pod stanicou, where:

A = Bus

T = Trolleybus

E = Tram

Figure 2. Sketch of stop Bratislava, Pod stanicou.

2.5. Assignment of Points to Stops

This section defines how individual parameters are scored. Each parameter is evaluated either for all stops within a stop group collectively, or separately for each stop.

For example, the parameter "Walking time for transfer within the terminal" is evaluated according to the scale in Table 2. [3]

Table 2. Walking time for transfer within the terminal

Up to 10 s	5
11 – 20 s	4
21 – 30 s	3
31 – 40 s	2
More than 40 s	1

2.6. Evaluation of measurements

The methodology concludes with the evaluation of each parameter for every monitored stop and with the comparison of multiple stops. The first step is determining importance weights. A questionnaire completed by qualified experts is recommended to establish the importance of each parameter. This approach was also used in this study.

The next step involves constructing a Saaty matrix, i.e., applying multi-criteria analysis. Each quality attribute is treated as a parameter. The most frequent questionnaire response for each parameter is entered into the matrix and used to calculate parameter weights (Table3).

Table 3. Saaty comparison scale

Number of Services	Modernization Recommendation
1-100	Slight recommendation
101-200	Recommended
201-500	Necessary
501 a viac	Highly necessary

The next step of the evaluation is the overall evaluation of the parameter, the value of which corresponds to the product of the importance weight assigned to the given parameter and the number of points allocated to the given stop. Subsequently, the overall so-called "score" of the stop was determined based on the product of these values. This evaluation was carried out for each monitored stop.

Based on the "score", a comparison of the stops with one another was conducted. From the individual stop "scores", the arithmetic mean was calculated, or alternatively the proportion of parameters with the worst rating, in the event that there was a parameter that significantly reduced the average stop "score". The individual "score" values of the entire stop group from each table for each stop group were arranged from the highest value to the lowest value and were subsequently evaluated against one another in such a way that the stops with the highest "score" were considered the highest-quality stops, while, conversely, the stops with the lowest "score" were considered the lowest-quality stops.

The final step within the evaluation process is the assessment of the number of services that serve the monitored stop within a 24-hour period. This step is crucial when deciding whether or not to modernize the stop. In the event that the stop achieves 5 points, meaning that its level of safety is high, the number of services does not play a significant role in such a case. This parameter is monitored only for stops that achieved a "score" of less than 5 points. The number of services refers to the total number of all services operating on a working day in both directions for all modes of transport. The threshold values for the number of services required for stop modernization are presented in Table 4. [3]

Table 4. Service frequency thresholds

Value	Meaning
1	Criteria are equally important
3	Slight preference
5	Strong preference
7	Very strong preference
9	Extremely strong preference

3. Results

The proposed methodology in this work was verified at 5 stops in Bratislava. The measurement procedure was carried out exactly according to the steps of the methodology. Therefore, the form was completed, a list of stops and their sketches was created, and points were assigned to the stops, as shown in the table below, where the stop Bratislava, Pod stanicou was presented as an example. The yellow section is the part of the parameters that was evaluated exclusively for bus and trolleybus stops, while the green section represents the parameters evaluated only for tram stops. The parameters are numbered according to the order in which they appear in the list of parameters in the appendix to the article.

Table 5. Number of points awarded to stop Bratislava, Pod Stanicou

Parameter	Number of points awarded					
	E1	E2	AT1	AT2	A1	A2
1	1	1	1	1	1	1
2	1	1	1	1	1	1
3	1	1	1	1	1	1
4	1	1	5	5	5	5
5	5	5	5	5	5	5
6	4	4	4	4	2	2
7	5	5	5	5	5	5
8	5	5	5	5	5	5
9	3	3	4	4	5	5
10	5	5	5	5	5	5
11	1	1	1	1	1	1
12	5	5	5	5	5	5
13	1	1	5	5	5	5
14	5	5	5	5	5	5
15	5	5	5	5	5	5
16	1	1	1	5	1	1
17	5	5	5	5	5	5
18	5	5	5	5	5	5
19	5	5	5	5	5	5
20	4	4	4	4	4	4
21	5	5	1	1	2	2
22	1	1	1	1	1	1
23	1	1	2	2	2	2
24	-	-	5	5	5	5
25	-	-	5	5	5	5
26	-	-	5	5	5	5
27	-	-	1	1	1	1

28	-	-	1	1	1	1
29	-	-	5	1	1	5
30	2	2	-	-	-	-
31	5	5	-	-	-	-
32	1	1	-	-	-	-
33	1	1	-	-	-	-
34	5	5	-	-	-	-
35	3	3	-	-	-	-

As part of the evaluation of the measurements, the method of multi-criteria analysis was used, whereby the importance weights were determined by experts, and subsequently a graph was created from them, shown below, which indicates the extent to which the individual parameters are important. The most important parameters are 10 and 14, namely "Presence of a Sidewalk Leading to the Stop" and "Pedestrian Crossing within the Terminal."

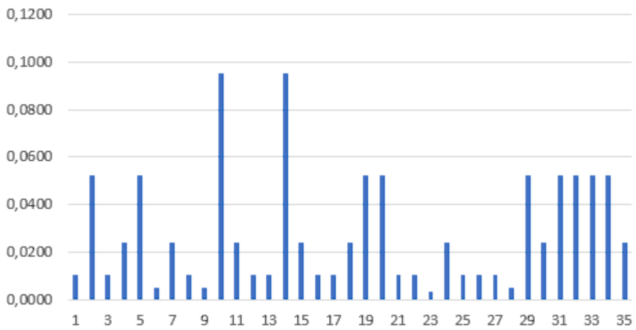

Figure 3. Importance weights of individual parameters

After multiplying the importance weights by the point value of the parameter, a point value was obtained for each parameter. These values were listed in the table 6, where, after their summation, the overall "score" of the stop is also presented (in this case, Bratislava, Pod Stanicou).

Table 6. Overall rating of stop Bratislava, Pod Stanicou.

Parameter	Váha parametra	Bodové hodnotenie parametra						Výsledné hodnotenie parametra					
		E1	E2	AT1	AT2	A1	A2	E1	E2	AT1	AT2	A1	A2
1	0,0105	1	1	1	1	1	1	0,0105	0,0105	0,0105	0,0105	0,0105	0,0105
2	0,0524	1	1	1	1	1	1	0,0524	0,0524	0,0524	0,0524	0,0524	0,0524
3	0,0105	1	1	1	1	1	1	0,0105	0,0105	0,0105	0,0105	0,0105	0,0105
4	0,0241	1	1	5	5	5	5	0,0241	0,0241	0,1207	0,1207	0,1207	0,1207
5	0,0524	5	5	5	5	5	5	0,2618	0,2618	0,2618	0,2618	0,2618	0,2618
6	0,0052	4	4	4	4	2	2	0,0208	0,0208	0,0208	0,0208	0,0104	0,0104
7	0,0241	5	5	5	5	5	5	0,1207	0,1207	0,1207	0,1207	0,1207	0,1207
8	0,0105	5	5	5	5	5	5	0,0526	0,0526	0,0526	0,0526	0,0526	0,0526
9	0,0052	3	3	4	4	5	5	0,0156	0,0156	0,0208	0,0208	0,0260	0,0260
10	0,0953	5	5	5	5	5	5	0,4765	0,4765	0,4765	0,4765	0,4765	0,4765
11	0,0241	1	1	1	1	1	1	0,0241	0,0241	0,0241	0,0241	0,0241	0,0241
12	0,0105	5	5	5	5	5	5	0,0526	0,0526	0,0526	0,0526	0,0526	0,0526
13	0,0105	1	1	5	5	5	5	0,0105	0,0105	0,0526	0,0526	0,0526	0,0526
14	0,0953	5	5	5	5	5	5	0,4765	0,4765	0,4765	0,4765	0,4765	0,4765
15	0,0241	5	5	5	5	5	5	0,1207	0,1207	0,1207	0,1207	0,1207	0,1207
16	0,0105	1	1	1	5	1	1	0,0105	0,0105	0,0105	0,0526	0,0105	0,0105
17	0,0105	5	5	5	5	5	5	0,0526	0,0526	0,0526	0,0526	0,0526	0,0526
18	0,0241	5	5	5	5	5	5	0,1207	0,1207	0,1207	0,1207	0,1207	0,1207
19	0,0524	5	5	5	5	5	5	0,2618	0,2618	0,2618	0,2618	0,2618	0,2618
20	0,0524	4	4	4	4	4	4	0,2094	0,2094	0,2094	0,2094	0,2094	0,2094
21	0,0105	5	5	1	1	2	2	0,0526	0,0526	0,0105	0,0105	0,0210	0,0210
22	0,0105	1	1	1	1	1	1	0,0105	0,0105	0,0105	0,0105	0,0105	0,0105
23	0,0032	1	1	2	2	2	2	0,0032	0,0032	0,0064	0,0064	0,0064	0,0064
24	0,0241	-	-	5	5	5	5	-	-	0,1207	0,1207	0,1207	0,1207
25	0,0105	-	-	5	5	5	5	-	-	0,0526	0,0526	0,0526	0,0526
26	0,0105	-	-	5	5	5	5	-	-	0,0526	0,0526	0,0526	0,0526
27	0,0105	-	-	1	1	1	1	-	-	0,0105	0,0105	0,0105	0,0105
28	0,0052	-	-	1	1	1	1	-	-	0,0052	0,0052	0,0052	0,0052
29	0,0524	-	-	5	1	1	5	-	-	0,2618	0,0524	0,0524	0,2618
30	0,0241	2	2	-	-	-	-	0,0483	0,0483	-	-	-	-
31	0,0524	5	5	-	-	-		0,2618	0,2618	-	-	-	-
32	0,0524	1	1	-	-	-	-	0,0524	0,0524	-	-	-	-
33	0,0524	1	1	-	-	-	-	0,0524	0,0524	-	-	-	-
34	0,0524	5	5	-	-	-	-	0,2618	0,2618	-	-	-	-
35	0,0241	3	3	-	-	-	-	0,0724	0,0724	-	-	-	-
SUMA								3,20	3,20	3,06	2,89	2,86	3,07

As the final step, a comparison of the stops with one another was carried out. In this case, it is a comparison of five monitored stops, namely Bratislava, Zlaté Piesky; Bratislava, Kuchajda; Bratislava, Pod Stanicou; Bratislava, Prístavný most; and Bratislava, Súmračná. The final evaluation of these stops in comparison with one another is presented in the Figure 4. The safest stop among those monitored is Bratislava, Zlaté Piesky. On the other hand, the least safe stop is Bratislava, Súmračná. [3]

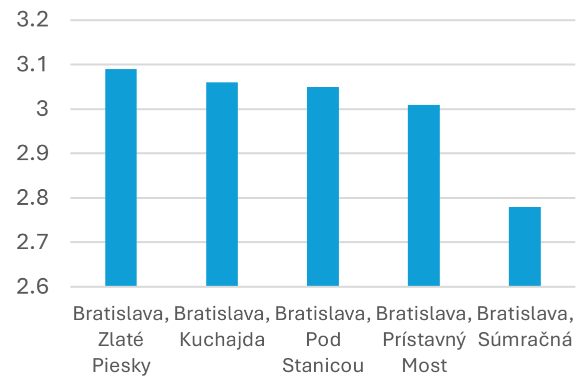

Figure 4. Mutual evaluation of stops.

4. Conclusions

The results of the study indicate that the proposed methodology for evaluating public transport stops is applicable in various types of environments and enables a systematic comparison of the qualitative level of individual stops. The practical verification of the methodology demonstrated its functionality under real field measurement conditions, while confirming that the established parameters are relevant for identifying differences between stops of different characteristics.

In comparison with existing approaches that address only selected aspects (for example, technical equipment or safety) [1], or a methodology that categorizes stops into 3 groups but does not address in greater detail the parameters associated with a stop [4], or a methodology that approaches stops only marginally and focuses on several aspects of public passenger transport [5], the proposed methodology is conceived as a universal evaluation tool, while this proposal integrates a broader set of parameters including infrastructure, passenger information, accessibility, and the overall technical condition of the stop.

A significant strength of the methodology can be considered its universality. The evaluation criteria were designed in such a way as to allow application to stops located in rural areas with a low frequency of passengers as well as to heavily used stops in city centres. The scoring system also enables simple comparison and evaluation of individual facilities.

Despite the aforementioned contributions, the research also has certain limitations. Some of the evaluated parameters may, to a certain extent, be influenced by the subjective assessment of the evaluator; however, for some parameters this cannot be avoided.

From a practical point of view, the proposed methodology may be useful as a basis for decision-making by local governments, transport operators, or road administrators when planning the reconstruction and modernization of stops. The

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identification of specific deficiencies enables a more effective direction of investments and the proposal of measures where their need is the greatest.

For further research, it is recommended to apply the methodology to a larger number of stops in different regions and to verify its applicability under different transport conditions.

Based on the results, it can be concluded that the verification of the functionality of the methodology was successful. Given that this study succeeded in identifying the safest and the least safe stop, it can be concluded that the proposed methodology was correctly designed and therefore fulfills the requirement of universality.

The use of this methodology should consist of a more efficient allocation of financial resources by cities and municipalities dealing with the issue of public transport stops. The result of the evaluation of stops using the proposed methodology should determine the priority of stop reconstructions, according to which stops achieved better positions and which stops achieved worse positions. It is recommended to prioritize the reconstruction and modernization of stops that were assigned the lowest "score", thereby ensuring an adequate level of safety at all monitored stops.

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Appendix

No.	Evaluated Parameter
1	Traffic passing by the stop
2	Walking time for transfers within the terminal
3	Need to cross a road within the terminal
4	Presence of a shelter
5	Presence of lighting
6	Platform length
7	Presence of a stop curb
8	Presence of a horizontal curve
9	Presence of a vertical curve
10	Presence of a sidewalk leading to the stop
11	Facilities for visually impaired passengers
12	Vienna-type stop
13	CCTV surveillance – audible warning system
14	Pedestrian crossing within the terminal
15	Presence of a grade-separated pedestrian crossing within the terminal
16	Number of traffic lanes within the terminal
17	Signal-controlled pedestrian crossing between stops within the terminal
18	Presence of vertical signage for the pedestrian crossing
19	Visibility of the pedestrian crossing
20	Maximum permitted speed at the stop
21	Number of traffic lanes at the stop
22	Type of stop curb
23	Number of vehicles that can fit at the stop
24	Pedestrian crossing between opposite-direction stops
25	Presence of a grade-separated pedestrian crossing between opposite-direction stops
26	Signal-controlled pedestrian crossing between opposite-direction stops
27	Walking time between opposite-direction bus/trolleybus stops
28	Traffic signal for vehicles departing from the stop
29	Type of stop location
30	Length of the field of vision when crossing between tracks
31	Presence of a pedestrian crossing between tracks
32	Presence of a grade-separated pedestrian crossing between tracks
33	Visibility obstacles at the crossing between tracks
34	Signal-controlled pedestrian crossing between tracks
35	Walking time between opposite-direction tram stops

FORMULÁR NA HODNOTENIE ZASTÁVKY

Všeobecné parametre pre celú skupinu zastávok

Sledovaný parameter	Špecifikácia parametra		
Názov zastávky			
Umiestnenie zastávok	**Extravilán/Intravilán**		
Doprava prechádzajúca okolo zastávky	**vylúčená IAD/nie je vylúčená IAD**		
Typ zastávky podľa druhov dopravy	**RAD**	**MHD**	**KOMBINOVANÁ**
Dopravcovia obsluhujúci zastávku			
Terminál s prestupom na iné druhy dopravy	**ANO/NIE**		
Typ terminálu z hľadiska druhov dopráv	**Električka – Autobus / Električka – Trolejbus / Autobus – Trolejbus**		
Čas chôdze na prestup v rámci terminálu (najvzdialenejší)			
Nutnosť prechádzať cez cestu pri termináli	**ANO/NIE**		

Bližšie špecifikácie parametrov každej zastávky zvlášť

Bližšie špecifikácie pre zastávky všetkých typov dopravy

Sledovaný parameter	ANO/NIE	Slovné hodnotenie parametru
Prítomnosť prístrešku	**ANO/NIE**	
Prítomnosť osvetlenia	**ANO/NIE**	
Dĺžka nástupišťa		
Prítomnosť obrubníka zastávky	**ANO/NIE**	
Prítomnosť smerového oblúka	**ANO/NIE**	
Prítomnosť výškového oblúka	**ANO/NIE**	
Prítomnosť chodníka na zastávku	**ANO/NIE**	
Vybavenie pre zrakovo postihnutých	**ANO/NIE**	
Viedenský typ zastávky	**ANO/NIE**	
Kamerový dohľad – zvuková výstraha	**ANO/NIE**	
Priechod pre chodcov v termináli	**ANO/NIE**	
Prítomnosť mimoúrovňového priechodu v termináli	**ANO/NIE**	
Počet jazdných pruhov v termináli		
Svetelne riad. priechod medzi v termináli	**ANO/NIE**	
Prítomnosť zvislého značenia priechodu	**ANO** **NIE**	
Viditeľnosť priechodu pre chodcov		**1 2 3** **4 5**
Maximálna povolená rýchlosť pri zastávke		
Počet jazdných pruhov pri zastávke		
Typ obrubníka zastávky		KASSELSKÝ OBYČAJNÝ
Počet vozidiel, ktoré sa zmestia na zastávku		

Pri hodnotení od 1-5 platí: 1 = najhoršie, 5 = najlepšie

Bližšie špecifikácie pre zastávky autobusov a trolejbusov

Sledovaný parameter	ANO/NIE	Slovné hodnotenie parametru
Priechod pre chodcov medzi protiľahlými zastávkami	**ANO/NIE**	
Prítomnosť mimoúrovňového priechodu medzi protiľahlými zastávkami	**ANO/NIE**	
Svetelne riadený prechod medzi protiľahlými zastávkami	**ANO/NIE**	
Čas chôdze medzi protiľahlými zastávkami		
Semafor pre vozidlo vychádzajúce zo zastávky	**ANO/NIE**	
Typ umiestnenia zastávky		V JAZDNOM PRUHU V ZÁLIVE

Bližšie špecifikácie pre zastávky električky

Sledovaný parameter	ANO/NIE	Slovné hodnotenie parametru
Dĺžka zorného poľa pri prechádzaní cez priechod medzi traťami		
Priechod pre chodcov medzi traťami	**ANO/NIE**	
Prítomnosť mimoúrovňového priechodu medzi traťami	**ANO/NIE**	
Prekážky pri viditeľnosti na priechode medzi traťami	**ANO/NIE**	
Svetelne riadený priechod pre chodcov medzi traťami	**ANO/NIE**	
Čas chôdze medzi protiľahlými zastávkami električky		