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TRAM STOP INFRASTRUCTURE IN POLAND IN THE ASPECT OF SAFETY

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Abstract:

Travel comfort depends on many criteria, including, to a large extent, the passenger's sense of security while waiting for the vehicle and while driving. For this reason, tram stops play an essential role in the overall assessment of the functioning of the tram system in cities. The presented results of the literature review indicate that few publications related to safety in the tram transport system concern aspects of the infrastructure of stops. The articles we distinguished in this area also prove the lack of publications in which the researchers focus on the criteria for assessing the safety of tram stops. The paper aims to present the results of research conducted among experts, which concerned identifying criterions influencing the safety of tram stops and the selection of criteria for their evaluation. In addition, the obtained results are the basis for further analysis of safety at tram stops. The research was conducted among experts representing almost all cities in Poland with a tram service system for residents. The obtained results showed that the critical elements from the safety point of view are those related to technical aspects, i.e., length, width, and height of platforms, which are adapted to both the rolling stock and the size of passenger flows. The second significant group of criteria determining the safety of stops is equipping them with elements supporting their use by people with disabilities, i.e., placing warning fields at the edges of the platform, designating a waiting area for people with reduced mobility, or the use of guiding lanes. It is also crucial to maintain adequate separation of traffic between its various participants so that other people do not use the waiting and passenger exchange zone. The results obtained as part of the analysis will form the basis for the development of a detailed method of assessing tram stops in Poland in terms of their safety.

Keywords: *tram stop, safety, expert assessment, survey interview*

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1. Introduction

The concept of sustainable development of large cities makes public transport, and in particular tramway transport, an increasingly important focus for city infrastructure managers and a challenge in the safety policy of the city authorities. This is primarily due to the characteristics of tramway transport. Trams have a higher capacity than buses and trolley buses, which means they can transport more passengers per unit of time (Kornalewski & Malasek, 2013). If they travel on a separate track, they can avoid other road traffic, which in the situation of traffic congestion during peak hours becomes an essential argument for further development of this mode of transport (Bujak et al., 2017). Trams are also a green mode of transportation, and their use reduces the emission of pollutants to the environment. Therefore, the development of tram transport is an element of improving the quality of life in cities. According to Kornalewski & Malasek (Kornalewski & Malasek, 2013), easy accessibility, high transport capacity, low environmental impact, relatively high independence from urban traffic, and relatively low investment and operating costs justify treating a tram as a forward-looking mode of transport.
Research shows that residents of urban areas are also more likely to use trams, especially if they feel comfortable and safe (Ulatowski, 2007). The authors of many publications (including (Zehmed & Jawab, 2021)) emphasize that the performance of tramway service from the users' viewpoint is crucial in developing this system. Travel comfort depends on many criteria, including, to a large extent, the passenger's sense of security while waiting for the vehicle and while driving. This relationship was evident during the COVID-19 pandemic when the importance of personal safety among public transport passengers played an essential role in the perceived comfort of driving (Bauer et al., 2021). More than once, the sense of personal safety contributed to changing the transport behavior of inhabitants of large cities (Tubis, 2022). This fact confirms that the safety of using public transport services is one of the critical elements in assessing the quality of life of urban residents. For this reason, the safety of tram passengers while traveling is the most frequently indicated parameter for determining the quality of public transport.
The safety of tram transport is the subject of numerous studies described in the literature. The scope of analysis on this topic is broad and concerns various components of the transport system. Areas of research conducted worldwide are presented in Figure 1 and discussed in section 2 of the article. The presented results of the literature review indicate that few publications related to safety in the tram transport system concern aspects of the infrastructure of stops. The articles we distinguished in this area also prove the lack of publications in which the researchers focus on the criteria for assessing the safety of tram stops. And yet the correct selection of criteria is critical in creating tools supporting decision-making in planning transport development (Kaczorek & Jacyna, 2022).
For this reason, the article aims to present the results of research conducted among experts, which concerned identifying criteria influencing the safety of tram stops and the selection of criteria for their assessment. The collected results are the basis for determining the significance of the impact of selected criteria on the safety of users of tram stops. On this basis, it will be possible to develop a method for assessing the safety of tram stops in further research. The research was conducted among experts representing almost all cities in Poland with a tram service system for residents. A significant research contribution of the obtained results is the proposition of weights for individual assessment criteria based on the opinion of a strictly defined group of experts. Of course, the expert weighting of criteria is a common research practice. However, what is new in our case is the selection of a sample of experts who represent units of municipal offices in almost all cities in Poland that have a tram network. Thanks to this, it was possible to compile various strategies and standards that are in force in Polish cities. At the same time, the represented urban environments cover most of the areas of use of tram transport in Poland.
The outline of this paper is as follows: in Section 2, a literature review of tram transport safety is presented. The method of conducting expert research is presented in section 3. Section 4 presents the results obtained during the survey and their analysis. Finally, the discussion and conclusions are presented in section 5.

2. Literature review

Safety can be considered in both positive and negative terms(Czupryński et al., 2015). A positive approach describes the subject of interest and indicates the direction of its development. On the other hand, the negative approach is based on the perception of safety as the opposite of hazards. In safety engineering, the first approach dominates. Hazard analysis is defined as the heart of the created safety systems(Roland & Moriarty, 1991) This approach will also apply to our results. Many authors also emphasize that the safety system should be based on process and functional safety. According to the systematics presented in (Kozak, 2011), process safety concerns all issues related to the operation of technical systems in industrial sectors. Functional safety, on the other hand, is a field of engineering that deals with preventing threats through the appropriate design of protection with specific functions. Our attention will therefore focus primarily on functional safety.

Transport safety, including tram transport, is usually analyzed regarding hazards and risks associated with implementing transport services. Hazards may come from (Szaciłło et al., 2021): (a) internal sources resulting from the tested transport system or (b) external sources generated in its environment. It is also worth noting that a single risk can generate many adverse effects with varying degrees of impact. For this reason, their identification is so critical for the proper functioning of the entire system. In the case of tram services, two types of safety risks should be analyzed related to operation and maintenance. Szmagliński et al. (Szmagliński et al., 2018) state that there will be a different character of risk in using the tram system and others in its operation. It is assumed that during tram operation, passengers, tram personnel, and road users, including pedestrians, will be subjected to risk, and during tram maintenance, maintenance staff will be at risk. Therefore, research on tram system safety covers an extensive range of analyses in operation and maintenance areas. The studies should also consider all components of the transport system, i.e., traffic participants (including their behavior), infrastructure, and organization of the transport process. The results of the analysis of the literature on tram system safety are shown in Figure 1 and Table 1.

Research on the safety of the tram system is primarily associated with the statistical analysis of historical records of accidents. Among the research in this area conducted in Poland, the research described in (Bojar et al., 2012; Budzyński et al., 2019; Szmagliński et al., 2018) deserves attention. In (Budzyński et al., 2019) the results of statistical analyses of accidents and failures occurring on the tram network are presented. Bojar et al. (Bojar et al., 2012) analyzed accidents taking into account the type of event, the perpetrator, and the number of events occurring in individual months, days of the week, and hours. Similar studies in Algeria were carried out by Kahlouche & Chaib (Kahlouche & Chaib, 2017). The authors also analyzed the impact of human criteria (especially the tram driver) on transport safety. Statistical research into accidents involving trams in Algeria is also presented in (Abdelaziz & Rachid, 2017). The authors also carried out a risk analysis of the assessed tram system.

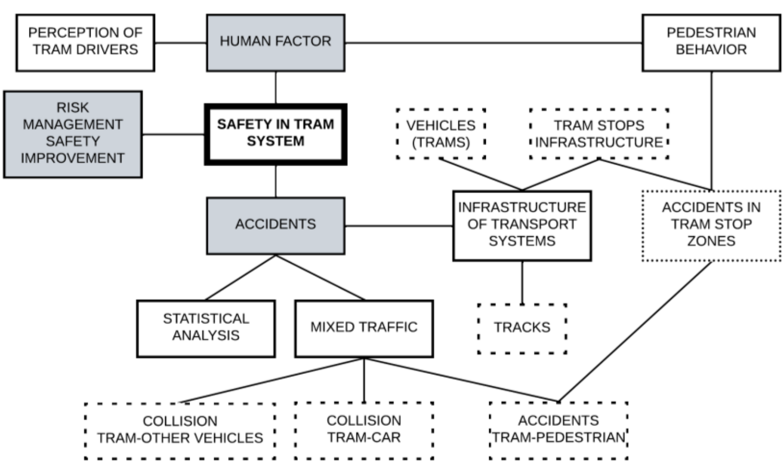

Fig. 1. Primary areas of research regarding the safety of the tram system

Table 1. Primary areas of research regarding the safety of the tram system - analyzed publications

Areas of research	Publications	
Risk management safety improvement	Kornalewski & Malesek, 2013; Currie & Shalaby, 2006;	Kadziński & Gill, 2011;
Perception of tram drivers	Szmagliński et al., 2018;	Naznin et al., 2017.
Pedestrian behavior	Ou et al., 2016; Kruszyna & Rychlewski, 2013; Bernhoft & Carstenen, 2018;	Yang et al., 2006; Yagil, 2000.
Statistical analysis	Szmagliński et al., 2018; Budzyński et al., 2019; Bojar et al., 2012;	Kahlouche & Chaib, 2017; Abdelaziz & Rachid, 2017.
Mixed traffic	Guerrieri, 2018.	
Collision tram-other vehicles	Castanier et al., 2012;	Marti, 2016.
Collision tram-car	Bujak et al., 2017; Budzyński et al., 2019;	Ostrowski, 2014; Farran, 2000.
Tracks	Bujak et al., 2017; Kornalewski & Malasek, 2013;	Szmagliński et al., 2018.
Vehicles (trams)	Bujak et al., 2017; Grulkowski & Zariczny, 2015;	Restel & Wolniewicz, 2017.
Tram stop infrastructure	Currie et al., 2011; Naznin et al., 2016; Szaumkessel et al., 2014;	Dźwigoń, 2012; Makuch, 1999.
Accidents in tram stop zones	Bauer & Dźwigoń, 2017; Hedelin et al., 1996; Marti et al., 2016; Currie & Reynolds, 2010; Currie et al., 2011;	Baier et al., 2007; Unger et al., 2002; Brandli & Kobi, 1989; Tubis et al., 2019.

Many transport accidents in cities occur when different means of transport share the same infrastructure of roads. For this reason, the most popular topic in tram system safety is hazards resulting from trams and passengers being participants in mixed traffic. In this regard, many researchers are analyzing the risks associated with the intersection of different road users. Several studies have identified safety concerns for tram systems, especially at tram stops under mixed traffic conditions, as trams, cars, and pedestrians share the same road infrastructure. In the case of cars, motorbikes, and bicycles, danger zones relate primarily to intersections and crossings. These hazards are generally described in (Budzyński et al., 2019; Bujak et al., 2017). However, detailed research, mainly concerning collisions in the tram-car system in the area of crossings, can be found in (Bujak et al., 2017; Farran, 2000; Ostrowski, 2014). In their analyses, other researchers, such as (Castanier et al., 2012), assessed the risk of tram accidents not only with cars but also with motorists, pedestrians, and cyclists.

A significant cause of accidents in the tram system is also the poor condition of the infrastructure. For this reason, some research on safety in this system focuses on assessing tram tracks (Bujak et al., 2017; Kornalewski & Malasek, 2013; Szmagliński et al., 2018), whose poor condition is one of the main causes of derailment. Vehicles are also analyzed from the point of view of meeting safety requirements. In the examples in the literature, researchers rated the tram for its efficiency and ability to provide safe transport services (Grulkowski & Zariczny, 2015), as well as requirements for vehicle maintenance (Restel & Wolniewicz, 2017).

Another area of research indirectly related to accidents are publications on risk management systems and programs to improve tram traffic safety. For example, Kornalewski & Malasek (Kornalewski & Malasek, 2013) presented the necessary assumptions for such a program, the aim of which was to develop Polish guidelines for improving the safety of tramway traffic in the public space of Polish cities. The program covered issues related to route planning, track design, traffic organization and management, and tram equipment. Also noteworthy are the studies described in (Kadziński & Gill, 2011), in which the authors presented the risk management method - TRAM-RISK. The method is based on the general principles of the Integrated Transport Safety System. Currie et al. (Currie & Shalaby, 2006) analyzed the challenge of creating modern, high-quality transit systems using streetcars. They have identified success criteria, including security aspects.

From the point of view of the research presented in the article, the most critical area of analysis is the safety of people in the area and the vicinity of tram stops. For those issues, the fundamental problems observed in city centers are conflicts between pedestrians and trams within tram stops, mainly when the stops are located near busy areas (Bauer & Dźwigoń, 2017). Although tramway accidents are minimal compared to the total number of road accidents, their consequences, especially when involving pedestrians, can be grave and, therefore, cannot be neglected (Guerrieri, 2018). Hedelin et al. (Hedelin et al., 1996) found that pedestrians were the most-injured category of participants in these accidents. For this reason, many researchers focus on pedestrian safety (Bauer & Dźwigoń, 2017; Marti et al., 2016). Passenger exchange zones are critical. The priority task of the tram stop is to provide users with safe areas for waiting and getting on and off the tram (Bujak et al., 2017). For this reason, many publications focus on pedestrian safety at tram stops. Aspects of pedestrian safety in the area of tram stops have been analyzed, among others in Australia (Currie et al., 2011; Currie & Reynolds, 2010; Currie & Shalaby, 2006), Germany (Baier et al., 2007), Austria (Unger et al., 2002), Switzerland (Marti et al., 2016), and Poland (A. Tubis et al., 2019). In publications, researchers pay attention to the type of stops and their impact on safety (Currie et al., 2011; Naznin et al., 2016), requirements for their infrastructure (Dźwigoń, 2012; Szaumkessel et al., 2014), including different conditions, for example, the edges of the stops (Makuch, 1999).

The critical aspect examined as part of safety in the tram stop area is also pedestrian behavior and its impact on the risk of accidents. As noted by Ou et al. (Ou et al., 2016), most accidents are caused by the unsafe behavior of people. Research on dangerous behavior in the area of stops has been described, among others, in (Bernhoft & Carstensen, 2008; Kruszyna & Rychlewski, 2013; Ou et al., 2016). Bernhoft and Carstensen (Bernhoft & Carstensen, 2008) stated that pedestrian behavior compromises safety, legality, and mobility. The desire to reach a public transport vehicle is one of the criterions affecting pedestrian mobility and, at the same time, may prompt them to adopt risky behaviors. This is also confirmed in the study described by (Kruszyna & Rychlewski, 2013). The authors studied the impact of an approaching tram at a stop on pedestrian compliance with traffic rules. The study aimed to determine whether the need to get into a vehicle approaching a stop had a visible impact on pedestrians' readiness to break traffic rules, despite the possibility of a traffic accident. The conclusions confirmed that the attempt to reach the tram is crucial in analyzing violations of the red signal, but its impact may also depend on other criteria. Additionally, Yang et al. (Yang et al., 2006) observed that the example of other pedestrians may encourage other waiting people to go on a red signal.

The previous study's area of work concerns the influence of human factors on adverse events. In addition to the articles described above on pedestrian behavior in the stop zone, research on risk and safety perceptions among tram drivers is also necessary. These surveys are usually based on face-to-face interviews and surveys of tram drivers. For example, the study in (Naznin et al., 2017) aimed to investigate how tram drivers' safety perceptions alter along various tram route sections, signal settings, and stop configurations. However, Szmagliński et al. (Szmagliński et al., 2018) analyzed factors reducing the concentration of tram drivers.

The conducted literature review in the area of tram transport safety shows a limited number of publications on the impact of elements of the stop infrastructure on the safety of passengers and people staying in the area and the vicinity of tram stops. Despite a detailed analysis of the literature in this area, it was impossible to identify any publications on the selection of criteria for evaluating stops in terms of safety. For this reason, the results presented in the article fill the research gap defined in this way.

3. Research method

3.1. Description of method

The conducted research uses the method of an expert evaluation carried out on a defined set of respondents with the required knowledge and experience in the scope of the conducted analyses. The interviews with the respondents were not statistical but expert research. The purpose of the interviews was to collect opinions on safety at stops from people acting as experts. Therefore, respondents who met specific criteria regarding knowledge and experience were invited to the study. Primary data was collected through a structured interview based on a previously prepared research tool in the form of a questionnaire. The research involved employees in units responsible for: managing urban infrastructure, designing new or reconstructing existing stops, and providing public transport services. The invitation to participate in the research was addressed only to representatives of Polish cities with a tram network. The presented studies differ from the examples discussed in the literature review in the aspect related to the direct participation of experts in determining the level of significance of selected criteria based on safety. The selection of experts for the study was determined by their experience in positions related to the management of stop infrastructure - the required minimum experience of an expert was 1 year. In addition, only people who were currently employed in the last local government units and whose official duties covered the thematic scope of the study could participate in the study. Another distinguishing feature was the inclusion of national and regional standards and guidelines related to the design of stops. The group of experts selected in this way allows for examining the approach to selected elements of stop equipment from a broad perspective of those responsible for the functioning and equipment of the stop platforms. The respondents had to demonstrate many years of experience both in the field of public transport and in the selected position. The research was carried out using the LimeSurvey online tool; it was a direct interview consisting of 20 questions of various forms and types. In the last part of the article, the partial results of the study, which relate to aspects related to safety, will be presented.

3.2. Characteristics of the research group

62 experts from Poland participated in the study; in their professional work, they are responsible for tram infrastructure, including stops. In their work, the surveyed experts are responsible for the management of tram stops in the area of (a) supervision; (b) designing new or upgrading existing facilities; (c) the use of stops from the point of view of urban carriers providing services in the public transport sector. The average work experience of the experts participating in the study in the area closely related to public transport is over 11 years, and the median of this group is over 8 years. Referring to the experience of experts in their positions at the time of the survey, they have been working for about 6 years (the median of this group is 7 years).

Out of 15 places in Poland with tram systems, experts from 12 units took part in the study, which is 80% of the total. Representatives of units from Częstochowa, Szczecin, and Toruń refused to participate in the study. There is the Upper Silesian Conurbation among the 12 territorial units where trams are used as part of public transport. The Upper Silesian Conurbation consists of 13 communes directly adjacent to each other and sharing one common tram system. For this reason, the Upper Silesian Conurbation will be treated as a single system (one research facility) in further analyses. Among the invited experts from the Upper Silesian Conurbation, representatives of 10 communes participated in the study, constituting 77% of this group. Detailed information on the cities from which the experts took part in the survey, and the number of responses provided is presented in Figure 2.

4. Results

One of the study's objectives was to identify significant criteria for assessing the stop infrastructure in the context of the safety of stop users. At the very beginning of the study, experts assessed the level of safety of the tram stop infrastructure in their cities. It was an overall assessment of the tram stop infrastructure in the city represented by the expert. The assessment was carried out on a five-point scale following the guidelines presented in Figure 3.

Detailed results are presented in Figure 4. It can be seen that Łódź received the highest safety rating (4.5). The least safe tram stop infrastructure was rated in Bydgoszcz (3.0). When analyzing individual results, in none of the cases was the answer 2 or 1 selected to indicate a bad or very bad safety assessment.

Based on experts' opinions, it can be concluded that the result indicates a generally good quality of the stop infrastructure, in which safety problems may be local and individual irregularities and not problems with the entire infrastructure of this type.

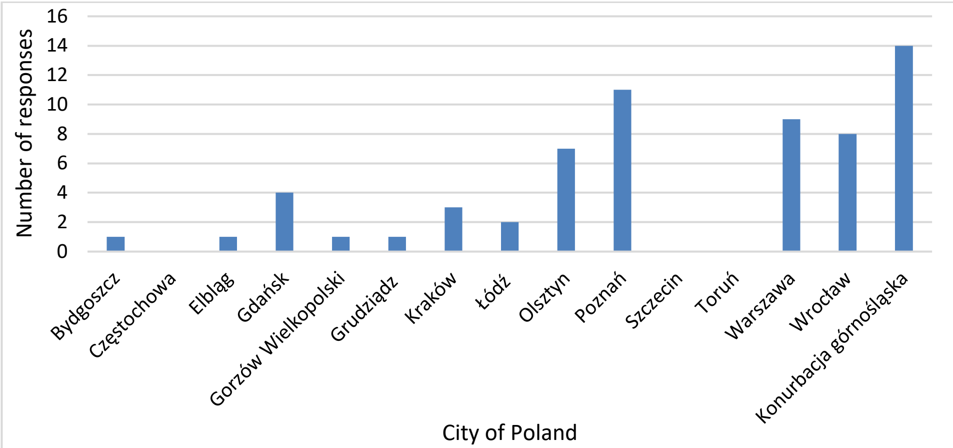

Fig. 2. The number of experts participating in the study in individual Polish cities

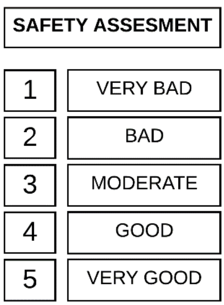

Fig. 3. Scale for assessing the safety level of the stop infrastructure

Knowing that dangerous situations at stops can be caused by the occurrence of hazards resulting from the elements constituting the equipment of the stop, it is crucial to regularly control the infrastructure of stops. For this reason, the experts were asked to provide information on aspects related to conducting audits and inspections of tram stops in their cities. According to the experts, in 75% of cities, various forms of safety inspections of tram stops are carried out. They take the form of audits, inventories, prioritization of the needs for corrective actions reported on an ongoing basis, etc. Many experts, in response to the question about the forms of safety inspections at tram stops, refer to inter-unit safety committees operating in their cities, attended by representatives of various public authorities, including the Police, the City Guard, and different administrative units of local government.

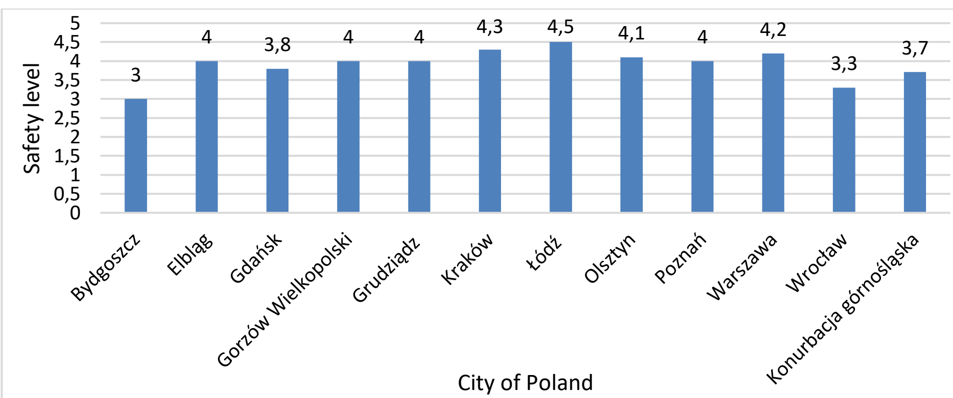

Fig. 4. Infrastructure safety assessment

The experts were also asked about the statistics on collisions and accidents in the area and the vicinity of tram stops in their unit. Unfortunately, such data is collected only in 25% of the cities interviewed. Reminder, 75% of the cities do not keep such statistics (47%), or the experts did not know about creating such lists (31%). These results indicate a significant lack of use of the data collected by the Police among decision-makers managing the infrastructure of stops. As noted in section 2, several different groups of stops are distinguished in the literature. Poland's most popular tram stops include five main types: A. island stop, B. stop at the sidewalk, C. Vienna stop, D. stop anti-bay, and E. stop on the road. These stops are shown in Figure 5.

In the study, experts were asked to rank these types of stops in terms of safety. The stops were to be ranked by them from the safest (rating 1) to the least safe (rating 5). The results of the obtained classification of stops concerning the assessment of their safety are presented in Figure 6.

a) island stop

b) stop at the sidewalk

c)Vienna stop

d) stop anti-bay

e) stop on the road

Fig. 5. Examples of tram stops, source: own work

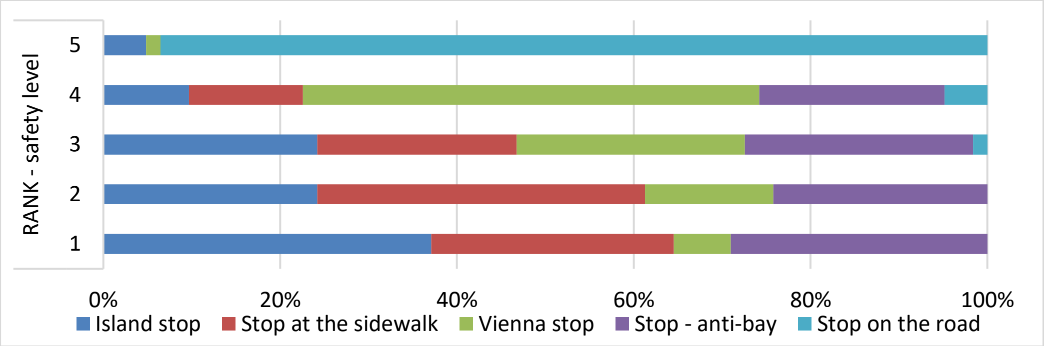

Fig. 6. Safety level of tram stops broken down by the type of stops

Island stops are the most common choice of the safest stop among the proposed variants. This choice was made by more than 33% of the experts participating in the study. A frequent choice of the safest stop was also the choice of a stop on the pavement or an anti-bay. Both forms of stops are very similar in their main features. The main issue determining the differences between these two types of stops is separating the waiting area and passenger exchange from the movement zone along the stop (pavement). The stop operated from the roadway is the least safe of all the analyzed ones - over 90% of the responses indicate this stop as unsafe. It is worth noting, however, that about 5% of respondents indicated the island stop as the least safe.

The prepared survey also raises the issue of the impact of the location of the stop in the intersection area on the level of its safety. According to 55% of respondents, the very place of the stop in the area of the intersection impacts its safety. Experts, however, could not unequivocally argue the reasons for this phenomenon. Experts point out the need to separate traffic in the intersection area: (a) location, i.e., separating space for movement, and (b) time control, i.e., using traffic lights to direct traffic.

People participating in the research were also asked to indicate the most critical criteria in their opinion that affect safety in the area of tram stops. The most common answers include the following:

a) Separating stops from other traffic participants, i.e., vehicular, bicycle, and pedestrian traffic. Experts also paid attention to the users of personal transport devices.
b) Lighting of the stop platform.
c) Adjusting the geometric parameters of the platform to the rolling stock and the passenger flow, i.e., the appropriate height of the platform edge as well as its length and width.
d) Monitoring of the stop in terms of the personal safety of people waiting for the tram.
e) Using warning stripes at the edges of the platform and designating a waiting area for people with disabilities.
f) Provision of access to the platforms, access from both sides of the platform, and lighting of these passages were often emphasized.

Experts interpreted the issue of traffic lights both in terms of their positive impact on safety and their negative impact. Among the few answers, there were doubts about its legitimacy and the possibility of provoking illegal behavior in situations of incorrect operation of traffic light programs, as well as the possibility of ignoring the indications of traffic lights at crossings of tram tracks, which has its arguments in the literature (Rydlewski & Skupień, 2020).

For the interviews, the authors listed 23 criteria that are integral elements related to the infrastructure of stops. The justification for selecting these criteria factors for the study is based on the literature review on methods of assessing stops and transfer nodes and on the authors' previous research results. The prepared list was presented to experts for evaluation on a five-point scale, illustrated in Figure 7.

Since the research was of the nature of preliminary qualitative research, it was left to the experts to determine the importance attributed to a given criterion. The assessment carried out by experts referred to their knowledge resulting from experience and the standards in force in a given city. A 5-point scale was deliberately chosen to not limit the experts in their opinion assessing the level of impact. In our

further research, elements regarding boundary parameters will be determined, allowing for such an assessment concerning specific quantities.
The average results obtained by each of these criteria in terms of assessing its impact on safety are presented in Table 2.

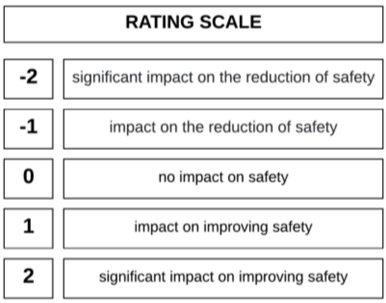

Fig. 7. Tram stops rating scale

Based on the obtained results, several factors can be distinguished that significantly impact the safety of the stop. These are the factors marked with the symbols K8, K6, K1, K7, K2, K3, and K5. Each received an average score higher than 1.20 in the overall assessment of their impact on safety. The results from this question are consistent with those indicated by the respondents under the safety critical factors. They refer to the presence of warning fields, lighting, and technical parameters of the stop (length, width, and height). A detailed analysis of the experts' answers regarding the indicated criteria shows that, in most cases, these answers are consistent across a broad group of experts. The calculated standard deviation value evidences this among all the answers given. Among all criteria, the values of standard deviations range from 0.52 (criterion K8) to 1.13 (criterion K16).
It is also essential to pay attention to points K13, K16, and K11, which have a high overall score on the deterioration of stop safety. These criteria relate primarily (K13 and K16) to the issue related to the separation of the waiting and passenger exchange space at the stop, with the parts of the road intended for the movement of other road users, in this case, primarily cyclists. However, it should be noted that there is a certain lack of unanimity among experts on this topic. The standard deviation values for these criteria are, respectively, for K13 and K16: 0.99 and 1.13. The high value of this deviation may indicate that in some cities, the problem of separating bicycle traffic from stops is not as big a problem as in other cities. This may also be influenced by the issues of creating transport policy, and thus the ways of organizing traffic in the city, which can be diversified. This affects how potential conflicts between traffic participants are interpreted. In this case, conditions related to, e.g., the density of the bicycle road network in cities, may also have an impact. Table 3 presents the average response results and the values resulting from the obtained standard deviations for the five towns characterized by the most significant number of experts participating in the study, i.e., the Upper Silesian Conurbation, Poznań, Warsaw, Wrocław, and Olsztyn. In each city, seven or more experts in the area of stop infrastructure took part in the study.
Apart from the Upper Silesian Conurbation experts, in most cases, there is a reasonably high consistency in the answers given. It occurs, with one exception, in all other cities in the area assessing the impact of criterions K13 and K16 on safety. The coherence of experts' answers, assessed by the standard deviation value, varies from 0.50 to 0.74. The only exception is the assessment of the K16 criterion by experts from Poznań. Here, a significant lack of consistency was observed, the standard deviation takes the value of 1.23, and the detailed answers fluctuate in the full range of the five-point weighting. The high response consistency of the experts in the area of the analyzed cities, with the simultaneous significant differences in the results of the impact on the safety between the selected cities, confirms the different assessment perspectives on a global scale. It can also be observed that in larger cities such as Warsaw, Wrocław or Poznań, the presence of a bicycle path without a fence in the vicinity of a tram stop is interpreted as less safe than in a significantly smaller city, such as Olsztyn.
Among the three criterions characterized by the most significant lack of consistency of answers among experts, one was also related to the presence of trees (criterion K11). The standard deviation, in this case, is 0.80. This indicates that from the point of view of safety, it is not reasonable to place trees at tram stops. Their presence can affect many criteria, from limiting visibility to creating local bottlenecks, and can lead to dangerous situations. In extreme conditions, trees near the tram traction system can also damage it, e.g., during intense winds or storms.

Table 2. Assessment of the safety of selected criteria in the area of tram stops

No.	Criteria	Average rating	Standard deviation
K8	Presence of guidance path for the blind	1,61	0,52
K6	The lighting of the entire stop zone	1,50	0,59
K1	Adjusting the platform width to the passenger flow	1,45	0,59
K7	Presence of a detectable warning lane along the entire edge of the platform	1,44	0,59
K2	Adjusting the platform length to the serviced tram	1,34	0,70
K3	Raising the platform to a height adapted to the serviced tram	1,27	0,71
K5	Presence of the lighting of the stop shelter	1,21	0,66
K17	The stop area is fenced off with a barrier	1,15	0,60
K9	Presence of a waiting place for people with disabilities	1,05	0,84
K4	Presence of a stop shelter	0,42	0,92
K18	Separating the stop from the pedestrian route using a different surface type	0,37	0,79
K20	Separating the stop from the bicycle path by using a different type of surface	0,32	0,94
K19	Separating the stop from the pedestrian route by painting a line	0,23	0,89
K21	Separating the stop from the bicycle path by painting a line	0,11	0,94
K14	Direct vicinity of a bicycle path with a fence	0,1	0,90
K10	Presence of a bench in the stop area	0,03	0,77
K15	Sharing the stop area with the pavement	-0,24	0,94
K22	Presence of the passenger information board in the stop area	-0,26	0,97
K12	Presence of greenery in the pots in the stop area	-0,45	0,80
K23	Presence of the services point in the stop area. Adjusting the platform width to the passenger flow	-0,50	0,90
K11	Presence of trees in the stop area	-0,82	0,80
K16	Sharing the stop area with the pedestrian and bicycle path	-0,85	1,13
K13	Direct vicinity of a bicycle path without its fencing	-1,06	0,99

Table 3. The results of the assessment of the impact of criteria related to cycling in or through the stop area (criterions K13 and K16)

City	Number of experts participating in the study	The average score for criterion K13 (with standard deviation)	The average score for criterion K16 (with standard deviation)
Upper Silesian Conurbation	14	-0,36 (1,23)	-0,29 (1,33)
Poznań	11	-1,55 (0,66)	-0,64 (1,23)
Warszawa	9	-1,22 (0,63)	-1,11 (0,74)
Wrocław	8	-1,50 (0,50)	-1,25 (0,66)
Olsztyn	7	-1,00 (0,53)	-1,14 (0,64)

Tram stops are a critical element of infrastructure in cities. They are an integral part of the transport system, which enables the connection of tram traffic with pedestrian traffic, often preceded by car or bicycle traffic, e.g., using Park&Ride car parks. They also play a crucial role by enabling transfers between different public transport lines. They are characterized by the need to reach the waiting and passenger exchange zones, which have different characters and parameters depending on the stop type. The multitude of design possibilities, their widespread use by public transport passengers, and the direct impact on other traffic users play a crucial role in ensuring a high level of safety for users of stops. Providing comfortable conditions for using stops must result from knowing the criteria and the scale of their impact on their safety level. This applies to both bus stops (A. A. Tubis et al., 2021) and tram stops (Rydlewski & Tubis, 2022).

The presented results allowed to conclude that the critical elements from the point of view of safety are those related to technical aspects (i.e., the length, width, and height of platforms), which are adapted to the type of rolling stock and the size of passenger flows. The average result of the level of impact of these criteria on safety ranges from 1.27 to 1.45, which places them at the forefront of the most important elements affecting safety at tram stops. Another significant group of criteria, which determines the stop safety, is equipping them with elements supporting use by people with disabilities (i.e., placing warning fields at the edges of the platform, designating a waiting area for people with reduced mobility, or using guidance path for blind). The element of the stop equipment, which is a convenience for people with disabilities guidance path for the blind, was assessed by experts as having the highest impact on safety among all the analyzed criteria. This criterion reached the value of 1.61. It is also crucial to maintain appropriate separation of traffic between its various participants so that other traffic participants do not use the waiting and passenger exchange area. The criterion related to the provision of lighting of the entire stop zone was ranked second in importance for the impact on safety. This criterion provides increasing the visibility of stop users among other traffic participants, also affects the assessment of the sense of security by travelers waiting at the stop.

In most cases, the tram stop infrastructure in Poland is assessed by experts as good or very good. However, since this assessment is not unanimous, it indicates that a high level of safety does not characterize all stops. This allows us to assume that certain irregularities require corrective action in each city. Therefore, it is essential to carry out continuous inventory or audits of the stop infrastructure. Such monitoring identifies existing threats and irregularities for public transport users.

The conducted research allows for a detailed interpretation of the results related to the impact of selected criterions on the safety of the tram stop infrastructure. The literature review indicates the wide use of methods for assessing tram stops in terms of safety in the global literature. However, it should be noted that certain conditions are specific to the area (tram system) for which the analyses are carried out. These differences can occur even in the area of cities located within the territory of one country. This is confirmed by the fact that each of the examined cities has its own standards regarding the infrastructure of stops, which differ significantly in selected elements. Therefore, internationally widely-used methods of assessing the safety of tram stops should be adopted regarding their adaptation to the conditions in which they are to be used.

The results obtained as part of the analysis will be the basis for further research. They will constitute an essential input for developing a precise method of evaluating tram stops in Poland in terms of their safety. Such a method will be both scientific and practical. It will be able to be used by operators of stop infrastructure to conduct periodic audits and develop directions for implemented improvements. At the same time, the obtained results will be the basis for determining the level of significance of selected criteria in terms of their impact on the safety of the stop. On this basis, it will be possible to estimate the weights of individual elements in the weighted approach to assessing the safety of stops and as a guide to improving the design of tram stops depending on the circulation conditions, city population, user behavior, etc.

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