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The Role of Crosswalks in the Smart City Concept Implementation from the "iGen" Perspective

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Abstract: In this article, the authors assumed that the "iGeneration" is the leading driving force for the SMART orientation of modern cities. Dynamic and multidirectional technical and technological processes introduce a new level of changes in urban space, adapting it to the present and future requirements of its inhabitants in a sustainable manner. An important infrastructure element of the urban space is the crosswalk, being an inseparable element of everyday life in the city. As part of a clear emphasis on the issue of vulnerable road users' protection, the aim of the article is to examine the perception of users regarding crosswalks in Poland, based on the example of Szczecin. The main aim of the article is to identify the dimensions of crosswalk perception. The specific objectives include the determination of the state of knowledge about the essence and typology of crosswalks and the identification of good practices in their designation. Literature analysis, questionnaire research, and a case study were used. In the adopted research methodology, the use of the questionnaire made it possible to identify key intersections (Five Stars), each different in their form, and to learn about the perception dimensions of this element of urban space. In the context of the Smart City concept implementation, the perception of crosswalks by young city residents, i.e., the "iGeneration", was examined. The obtained results allowed to perform a systematic analysis that focuses on individual behavioral aspects and subjectivism of the assessment of crosswalks in comparison with the commonly dominant architectural, engineering, and legal perspectives. The research allowed to assess the topology of intersections as well as the indication of safety improvement recommendation lists, taking into account intergenerational optics.

Keywords: crosswalk; smart city; VSS SN 640 241 standard

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1. Introduction

One of the five "megatrends" (macroeconomic force shaping the world) [1,2] is dominant in contemporary socio-economic development concerns "urbanization" [3,4]. It influences the dynamic development of modern cities, making them knowledge-based cities, digital cities, or eco-cities. The level of technological advancement predisposes the city to call itself "smart". The broader term "smart growth" is used in practice to define a new direction of urban development (especially in the operational dimension) [5,6], as a practical attempt to operationalize the broader idea of "sustainable development" being a desired direction of civilization development [7–9]. In its essence, sustainable development strongly emphasizes the idea of partnership (with a variety of goals and methods of action), by saving resources in a systemic way and using them rationally for the common good of city dwellers. The beginnings of the "smart city" concept date back to the 1990s. It was then that such terms as "city of bits" [10] or "cyber city" [11] emerged. One of the first attempts to define a "smart city" was made by N. Komninos [12], identifying it as a "territory" of creative population with high learning and innovation abilities, having effectively operating research and development institutions, higher education, digital infrastructure and communication technologies, as well as a high level of management efficiency with a

proven ability to innovate. However, in 2008, R. Holland [13] pointed to the lack of a clear definition of a smart city. Still, the idea of "smart growth" additionally strengthened the role of "smart city" [14]. The authors of the Mapping Smart Cities in the EU [15] report indicated that a smart city is a city where public issues are solved with the use of information and communication technologies (ICT), with the involvement of various stakeholders acting in partnership with city authorities. In a smart city, the quality of life improves, the environment becomes friendlier, and the prospects for economic development are stronger [16]. R.P. Dameri [17] analyzed the number of scientific articles on smart city (in title, abstract and keywords) indexed by Scopus in 1997–2008, finding one or several articles published. In 2009, it was 17, in 2011, 119, and in 2014 it reached 731 publications. The aforementioned R.P. Dameri [18] describes a "smart city" as "a precisely defined geographical area with advanced technologies (ICT, logistics, energy production, etc.) working together to create benefits for its inhabitants, contributing to increasing prosperity, integration and participation, improvement of the quality of the environment and intelligent development". Therefore, it is a common idea of all the city's stakeholders for its well-thought-out and long-term sustainable development based on the possessed potential, identified conditions and barriers as well as specific instruments supporting integrated economic, social, and environmental goals related to the improvement of the living conditions of the local community and widely accepted favorable sustainable development of the city.

The progressive socio-economic development is visible primarily in the dynamic urbanization. The growth of the urban population is becoming a key challenge for all decision-makers and stakeholders of the entire urban space. Since most people will soon live in urbanized spaces, measures should be taken now to ensure the highest quality of life within cities for different age and social groups. Therefore, cities need to provide all residents with a choice of alternative mobility options, all of which are equally fast, safe, sustainable, and tailored to their individual needs. They also need to expand access to transport services so that low-income people and seniors can also benefit from them. Thus, one of the main challenges is to make mobility more flexible and to coordinate the various modes of transport. This mobility is no longer treated as directly related to the possibilities of e.g., substitution of means of transport, but as a whole of comprehensive transport solutions (coordination of all types of mobility, from walking, cycling, through public transport, to driving a car) which should be fully adapted to the individual needs and preferences of every city resident. However, walking and cycling is to become an increasingly important aspect of mobility as most of the movement consists of walking (walking to the car and to final destination from the car). However, unlike people traveling by vehicles, pedestrians, cyclists, and motorcyclists do not have protection in the event of a road incident. That is why they are called unprotected road users (URU) [19]. In the ITS Directive, the unprotected road users are defined as non-motorized road users, such as pedestrians and cyclists, as well as motorcyclists and people with disabilities or reduced orientation and mobility [20]. Increasingly, cities tend to design friendlier environments for vulnerable road users. One example of solutions aimed at supporting the broader category of vulnerable road users (VRU) which includes unprotected road users in an urban environment is the creation of a common space for pedestrians and cyclists or shared with vehicle users. Shared space has been defined by the UK Department of Transport as a street or place designed to improve pedestrian traffic and comfort by reducing the dominance of motor vehicles [21].

This article presents the original concept of a holistic view of crosswalks from the perspective of both pedestrians and motorized vehicle drivers and cyclists (in the authors' opinion, they are an element that connects both perspectives). The aim set by the authors was to identify and organize into one whole (monoset), using an approach based on a hierarchical structure, all factors affecting the safety of vulnerable road users in the city of Szczecin (Szczecin Metropolitan Area). Pedestrians constitute the most numerous group of road users and are one of the most vulnerable groups, as they account for a large percentage of road victims. Therefore, diagnostic questions were focused primarily on

finding answers to the questions about the crosswalk. Representatives of the "iGen" were asked the following questions:

- What do you find dangerous?
- Why does the threat occur and what are their main causes?
- Who causes the greatest risk?
- What (what behavior) do you expect from others?
- What (what behavior) should others expect from you?
- What should be changed?
- What effects do you expect?

This approach determined the optics of the research procedure described and its construction. The assumption of the research is that a crosswalk is a key determinant defining urban mobility. Moreover, the article describes the methodology of reviewing the perception of crosswalks in the city, presents results of the survey, and summarizes the research implications as well as outlining the directions for further research.

2. Crosswalk as a Critical Element of the Urban Mobility Concept

The crosswalk is an inseparable element of living in the city. Its special role is growing in relation to the concept of "Smart City", although it is not only the technology itself. The actual level of pedestrian safety at crosswalks depends on the features and properties of this element of urban infrastructure, the characteristics of the set of all vehicles (psycho-motor characteristics of drivers and the technical condition of cars), and the parameters of the traffic they generate, as well as the behavioral characteristics of pedestrians and the traffic intensity they generate. The first considerations on crosswalks were initiated by B.F. Herms in 1972 [22]. On the basis of the quantitative research conducted, he came to the conclusion that about twice as many accidents involving pedestrians occur at marked crosswalks than at the suggested crosswalks. A full look at the problem of pedestrian in the city can be found in the "Pedestrian Safety, Urban Space and Health under the aegis of the Research Center of the International Transport Forum at the Organization for Economic Cooperation and Development (OECD)" report, according to which "/.../Walking is the most fundamental form of mobility. It is inexpensive, emission-free, uses human power rather than fossil fuel, offers important health benefits, is equally accessible for all—except those with substantially impaired mobility—regardless of income, and for many citizens is a source of great pleasure/.../" [23]. There is a common expectation that: "/.../current mobility strategies tend to pursue sustainable solutions with low environmental and economic impact/.../" [24]. N. Iranmanesh points to three important aspects for pedestrian traffic, i.e., environmental (pedestrianization can help to alleviate and reduce air and noise pollution, as there would be a reduction in the number of cars and reliance on motor vehicles), economic (for most large cities with heavy motor vehicle traffic, every year both the government and the private sector have to incur large economical losses in term of air pollution, costs of lost productivity and medical expenses. With less motor vehicle traffic and less pollution after pedestrianization, there can be a reduction in costs incurred, in addition to other social benefits (it helps to promote walking as a transport mode) [25].

The perfect road cross-section was presented at the First Road Congress in 1908 in Paris. For pedestrians and cyclists, M. H. Vaes, the engineer-architect in Brussels, proposed 43.3 percent of the street's cross-section (with a total length of 30 m) [26]. The current urban "priorities" reserved for pedestrians are less than 20% of the street's cross-section, the rest is designed for vehicles (e.g., Al. Jana Pawła II in Warsaw). It seems that despite the well-established view of the city's infrastructure through the prism of sustainable development, the issues regarding crosswalks are still mainly dominated by the architectural (crosswalk as an element of urban space), engineering (technical and technological design and modernizing existing crossings), and legal (introducing rules and restrictions for all road users) views. One should agree with the concept that the level of pedestrian safety at crosswalks depends on the features and properties of this element of infrastructure and the characteristics of the set of all vehicles and the parameters of traffic they generate, as well as

the set of behavioral characteristics of pedestrians and the level of traffic generated by them on a given crosswalk. Safety issues at crosswalks mainly concern behavioral aspects [27]. Only a few articles deal with the problem of pedestrian safety, but only in spatial (location) and time (time of day) terms. Most of them concern a hierarchical structure that allows for the development of indexes (according to the AHP method) that represent factors determining the safety status and priorities of the required intervention [28]. For example, J. Robin points to three specific points of view, i.e., speed reduction, increased visibility, and easier road crossing [29]. From a technical and technological point of view, such aspects as the elevation of the intersection above the road grade line or the characteristics of the sinusoidal cross-section of the contact surfaces minimize the situation when vehicles can jump without control, which improves the safety of pedestrians. In recent years, there has been an increase in investment in technological development in the city's transport system. This is mainly due to the large number of vehicles owned by city dwellers determining the increase in road traffic and the greater number of interactions between vehicle users and VRUs.

3. Materials and Methods

3.1. Respondents—"iGeneration"

Nowadays, the generation of young people is referred to as Generation Z or Gen Z, and this term applies to those born after 1995/1996. They are called "millennials" and constitute a group of people with little professional experience just entering the labor market. They are also known as "iGeneration" because they are the first "digital natives" growing up with smartphones and tablets with most of them having internet access at home [30]. The age difference between early and late millennials is significant. The second generation of "millenials" is made up of people born in the years 1995–2012 called "iGen", definitively embedding the next generation of digital natives in the digital world. Defining this group of populations results from the development of technologies that accompany them in everyday life as Internet access and smartphones reflect their lifestyle [31]. The development of sustainable cities and measures taken to limit climate change from the urban transport systems is the responsibility of the millennial and subsequent generations [32]. In modern cities striving to become a Smart City, an important role is played by the cooperation of public-private enterprises with city decision-makers, as well as residents. Developing cities that want to meet the needs of their inhabitants in accordance with the principles of sustainable development are called "Human Smart Cities" [33].

3.2. Study Sites and Investigation Design

The research process adopted in the article makes it possible to transform the theoretical assumptions into an empirical procedure, i.e., to conduct survey research. As the research is derived from the group of social methods, it is of a questioning nature, but thus allow to recognize the opinions and views of young people (respondents) in relation to the perception of crosswalks. The adopted scientific method of collecting research material allowed to obtain a conscious, logical and coherent set of answers. In the scientific proceedings, an assumption was made that the direct method should be used in order to assess the perception of respondents representing the "i" generation, i.e., to obtain an answer to the question to what extent the analyzed crosswalks are assessed as meeting the requirements of the VSS SN 640 241 standard (norm contains the general principles and requirements for crossing as well as the planning of crossing for non-motorized traffic), because the way crosswalks are perceived influence further behavior of the analyzed age group of respondents and the entire population of the city's inhabitants. This standard is part of the road and communication system. It regulates the requirements for modern pedestrian crossings. The "critical accident technique" was not thoroughly analyzed due to the fact that in Szczecin, with over 10,000 intersections, there were 14 fatal accidents (7 pedestrians and 7 drivers), in 2019, 10 fatal accidents (7 pedestrians and 3 drivers) in 2020 and only 4 fatal accidents (1 pedestrian and 3 drivers) in 2021 [34]. This statistic applies to the entire

population of the city, without a detailed analysis of the participation of "iGen" representatives in the events. This clearly declining trend was undoubtedly driven by three main reasons, i.e., the modernization of crosswalks, the deliberate reduction of their number in the city, and the lower level of mobility (the effect of the SARSCov-19 pandemic). The research was conducted using the questionnaire method (173 responses in total), and the sample was selected deliberately (young residents aged 19–26). The breakdown by gender was as follows: 80 respondents were men, 97 respondents were women. Most respondents (110 people) represented the age group 21–23, then 36 respondents were aged 19–21, and there were 31 respondents in the age group 24–26. According to the data of the Provincial Statistical Office, as of 31 December 2017, 116,255 people aged 19–24 lived in Szczecin. Compared to 2015, this age group decreased by over 10,000. There are five public universities and over a dozen private universities in Szczecin. Since the 2011/2012 academic year, there has been a decline in the number of candidates for higher education.

In total, information from 73 intersections was obtained (out of a total of estimated 10,000 intersections, regardless of their category), which allowed for the identification of five key representative intersections. The research was divided into two stages. In the first stage, the sample was selected using the convenience method, which is recommended in pilot studies when high flexibility and time saving are required. In the second stage, the sample was selected in a deliberate and in-depth manner, which allowed for the identification of 5 leading intersections (Five Stars) in the city center of the city (Figure 1).

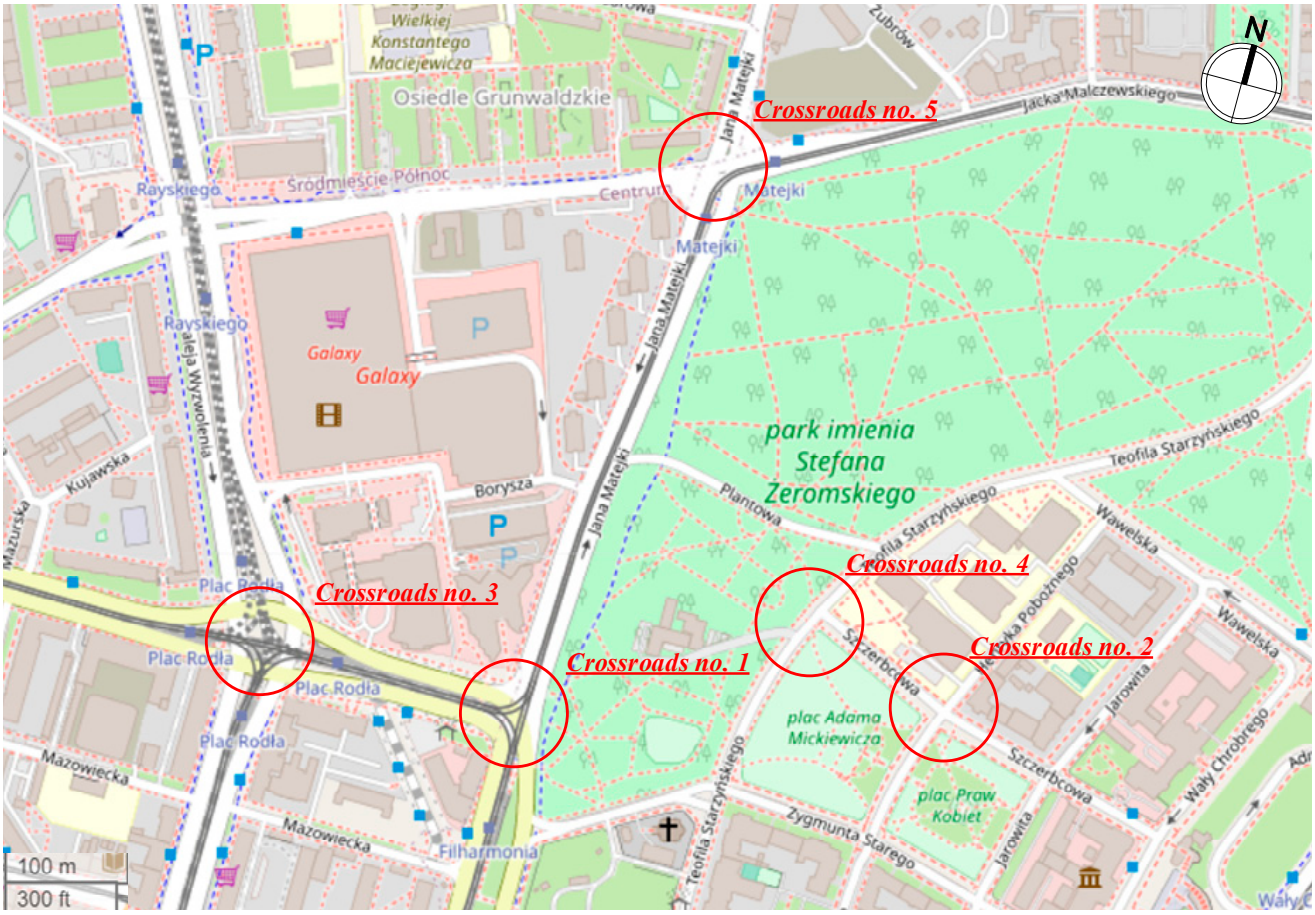
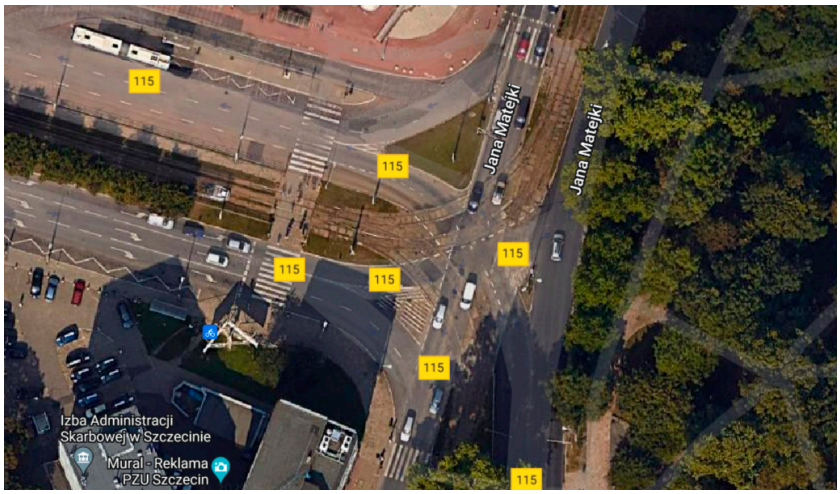
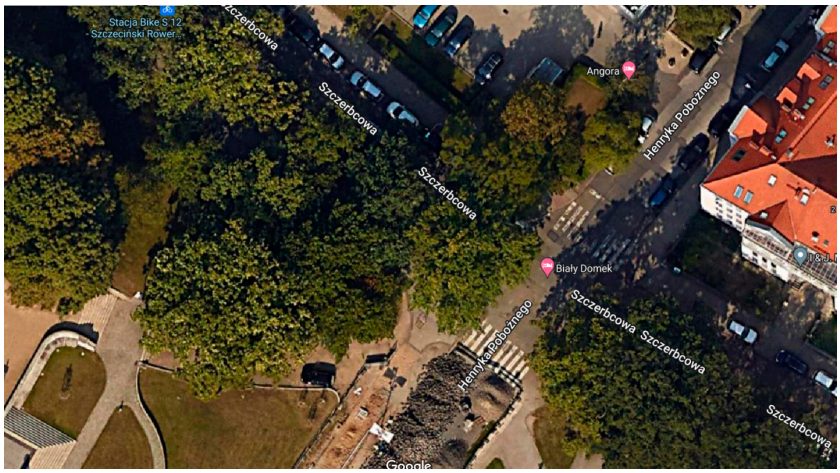


Figure 1. Location of key crosswalks (Five Stars).

A satellite view of each of the five identified crossings is presented below (Figure 2).



(**a**)



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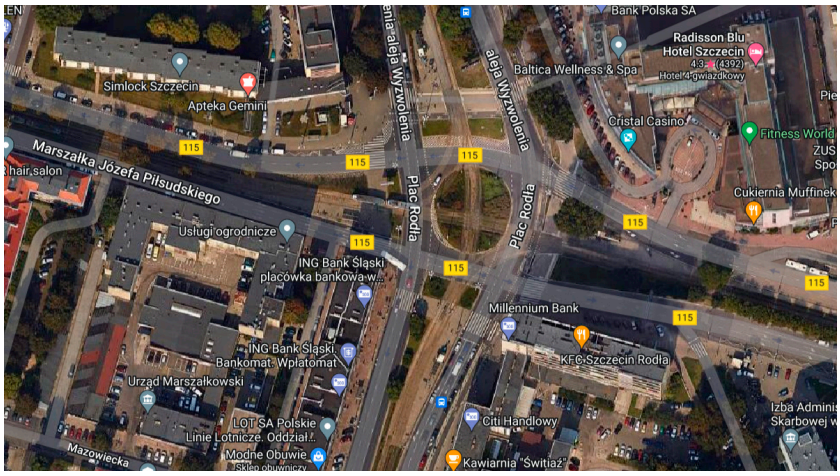
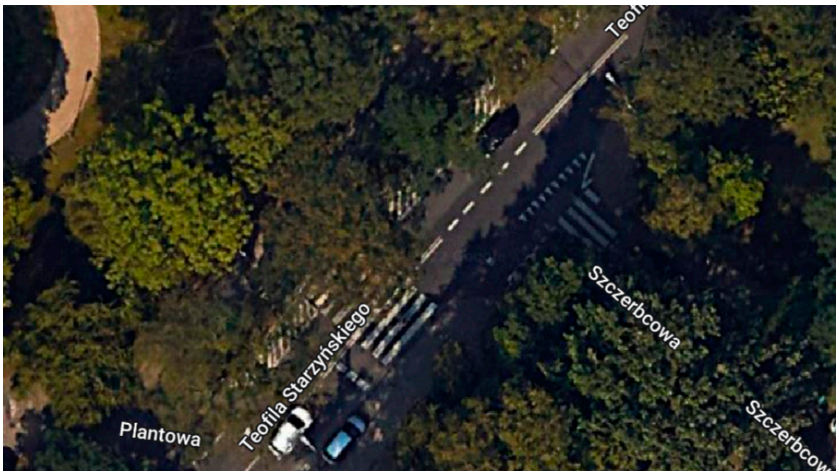


(**c**)

Figure 2. *Cont.*



(**d**)

(**e**)

Figure 2. Satellite view of the examined crosswalks. (**a**) Crossroads no. 1; (**b**) Crossroads no. 2; (**c**) Crossroads no. 3; (**d**) Crossroads no. 4; (**e**) Crossroads no. 5.

4. Results

Standard of the Swiss Association of Road and Transport Professionals (VSS) (VSS SN 640 241) (2016) "Crosswalks for pedestrians and light two-wheelers", indicates the requirements that must be met for crosswalks without the installation of traffic lights to ensure a safe crossing [35]. However, as the VSS organization points out, the question of its value as a legal basis is still under discussion. However, it indicates the viewing distance, i.e., the distance from which the driver is able to recognize a pedestrian and the other way around. Thus, it is the approach zone that is decisive, not just a fixed point (the necessary viewing distance corresponds to the minimum braking distance for vehicles). The effective speed of the vehicle is of key importance as the standard integrates primarily the "detection distance", that is, the distance from which the driver is able to recognize a crosswalk (it must be twice the required viewing distance). According to the standard, five main aspects of safety assessment at a crosswalk that can be adopted for further testing procedure include:

1. visibility (detection distance and viewing distance)
2. lighting
3. refuge island
4. single-lane road
5. traffic intensity.

The applied questionnaire made it possible to identify key factors related to the sense of safety when crossing a crosswalk and to determine their importance. This approach extends similar research including [28,36,37] and the initial assumptions regarding the systematics and assigned weights (W_i) are presented in Table 1. However, in the first research [36], the crash modification factor (CMF) of the pavement surface and the geometric design indicators for various types of crashes were developed (total, off-road and other), including road surface conditions (dry and wet) and lighting conditions (day and night), based on data from two-lane rural roads in Italy. The results of these research allowed for the effective integration of pavement management systems with safety management systems. On the other hand, the second research [28] examined 215 crosswalks in several European countries, but no questionnaires were used (it included the AHP method). Thus, the perceptions of users were not studied, but the transitions were objectively assessed in four categories (spatial design, visibility during the day, visibility at night and appropriate marking). The authors of other studies [38] draw attention to the fact that if a pedestrian considers a given crosswalk as unsafe, he will choose another one. This may lead to a distortion of the measurement result, because pedestrians who consider the crosswalk as unsafe will not answer the questions (500 respondents).

Table 1. Point weights of the main factors according to the adopted methodology.

No.	Factors	Weight (Wi)
1.	visibility (detection distance and viewing distance)	5
2.	lighting	4
3.	refuge island	3
4.	single-lane road	3
5.	traffic intensity	2

When analyzing the results of the survey, it can be stated that in general, seven out of 10 respondents replied that they felt safe at a given crosswalk. Interestingly, in the group of people who feel unsafe, 66% were women (two out of three respondents). However, this subjective feeling is disturbed by the perception of witnessing unsafe behavior at crosswalks (Figure 3) as most respondents very often encounter unsafe behavior from other pedestrians.

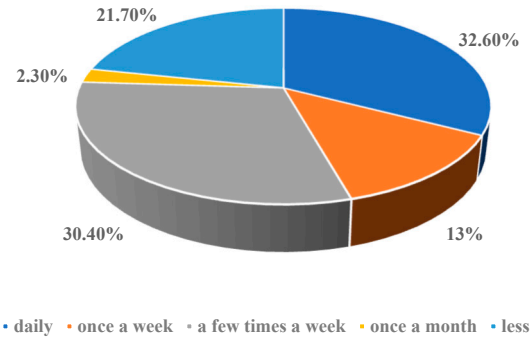


Figure 3. The frequency of witnessing dangerous situations at crosswalks.

According to the respondents (Figure 4), the most dangerous situations are created by young people (with a comparable share of adults and the elderly (25% and 29%, respectively), and the least number by kids (4%). Therefore, it seems reasonable to study perceptions and expectations of the youth, which constitute the contemporary "iGeneration". Thanks to this (answering the research questions posed as a problem), it will be possible to identify those elements and situations that young people themselves consider dangerous, and at the same time to determine their perception of potential threats and their possible causes (obtaining answers to previously formulated research questions).

However, in general (Figure 5), in relation to all analyzed crosswalks at all 73 intersections, the respondents considered the "spatial design" of the crosswalk as well-thought-out and thus safe for pedestrians (68% of responses in total). Responses to the thoughtful spatial design of intersections is proportional for the respondents in different age groups and broken down by gender. Interestingly, the spatial design of intersections is well thought out for the majority of respondents who use a given intersection regularly/often/quite often.

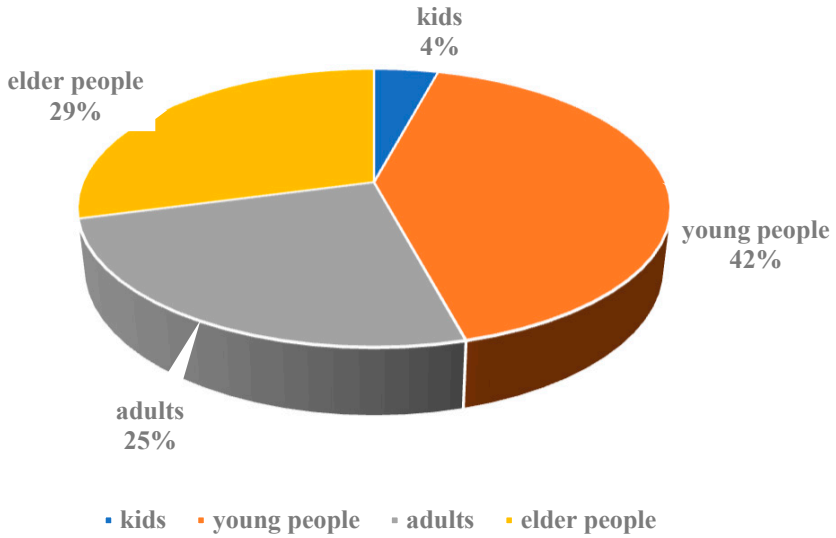


Figure 4. People who create the most dangerous situations by age group.

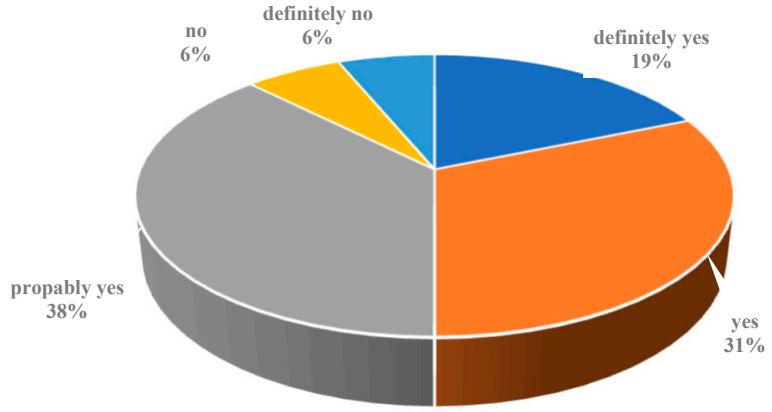


Figure 5. Assessment of the spatial design of the crosswalk in terms of safety.

The five-star intersections have been characterized in terms of the factors specified in the standard, as shown in Table 2. At the busiest intersections (average result of respondents' answers), street lighting was included in the Intelligent Lighting system implemented in Szczecin. In the case of intersections with two-lane, two-way roads, islands separating the lanes (and sometimes tram tracks) are used. According to the respondents, the visibility at selected intersections is not satisfactory during the day, while at night better visibility was at intersections 2–4.

Table 2. Five star details by factors.

	Intersection 1	**Intersection 2**	**Intersection 3**	**Intersection 4**	**Intersection 5**
Visibility (detection distance and viewing distance)	During the day: 31% of respondents said it was rather poor, 31%—poor, and 38%—very poor; At night: 44% of respondents said it was rather poor, 25%—poor, and 31%—very poor;	During the day: 30% of respondents said it was rather poor, 30%—poor, and 40%—very poor; At night: 40% of respondents said it was good, 30%—rather poor, 20%—poor, and 10%—very poor;	During the day: 30% of respondents said it was rather poor, 30%—poor, and 40%—very poor; At night: 40% of respondents said it was rather good, 30%—rather poor, 20%—poor, and 10% -very poor;	During the day: 11% of respondents said it was very good and good, 22%—rather poor, 33%—poor and 22%—very poor; At night: 22% of respondents said it was very good, 33% -good, 11%—rather poor, 33%—poor	During the day: 14% of re-respondents said it was rather poor, 71%—poor and 14% very poor; Responses at night coincide with responses during the day
Lighting	Intersection lighting included in the Smart Lighting system	Sodium street lights	Intersection lighting included in the Smart Lighting system	Sodium street lights	Intersection lighting included in the Smart Lighting system
Refuge island	YES, the refuge island separates the road and the tram crossing	NO	YES, the refuge island separates the road and the tram crossing	NO	YES, the refuge island separates the road and the tram crossing
Single-lane road	NO, intersection with road without right of way, two-way two-lane roads	YES, uncontrolled intersection, single-lane roads	NO, intersection with road without right of way, two-way two-lane roads	YES, intersection with road without right of way, single-lane roads	NO, intersection with road without right of way, two-way two-lane roads
Traffic intensity	Average 239 people/h per 24 h	Average 108 people/h per 24 h	Average 356 people/h per 24 h	Average 145 people/h per 24 h	Average 127 people/h per 24 h

The point weights identified in Table 1 (1 ÷ 5, respectively) were assigned to the selected main groups of factors. By far, the highest priority was given to good visibility (pedestrian/car detection distance and viewing distance). There are many obstacles that can disrupt the driver (or pedestrian's) awareness or reduce reaction time. It depends on the location of the crosswalk (topography, not obstructed by parking vehicles; this value depends, among others, on the presence of a green belt or devices preventing parking of vehicles). The occurrence of other permanent obstacles, e.g., in the form of billboards, is also inadvisable. The second place was taken by "good lighting", which is directly related to the distance from the streetlamp and its parameters of light intensity, in particular adjusted to changing weather conditions. In the opinion of the respondents, apart from street lighting, an important role is played by additional lighting illuminating the crosswalk. According to the respondents, the "refuge island" is important, above all, in the case of two-lane roads, in order to be able to pass the crosswalk in two stages. Hence, with heavy traffic, it is necessary to organize a safe space between the road lanes and, for example, the sidewalk on an island between the road and the tram track. The feeling of safety also depends on the "structure" of the road itself (the time spent by a pedestrian on the road depends on the presence of one or more road lanes). The shorter the walk, the safer it is for pedestrians. Finally, the fifth factor is the level of traffic intensity. The pedestrian flow was selected based on the respondents' direct observation and is related to the location of individual crosswalks. Research focusing on pedestrian flow sheds light on the need to model VRU facilities adapted to the road traffic intensity.

With regard to representatives of "iGeneration", the most frequent opinions were formulated (with the possibility of multiple choice) that the reason for their dangerous behavior at crosswalks include: "looking at the phone while crossing" (76%), "not paying attention to other traffic participants "(74%), the belief that" no one will hit me anyway"(68%)," haste "(72%), walk with RED/DON'T WALK sign on (59%),"bad habits" (51%). The obtained answers allowed for the verification of subsequent research questions, i.e., the identification of those dangerous behaviors (and their causes) of the representatives of "iGen", the cessation of which is expected by other users of pedestrian crossings. Behavior such as "carelessness" (looking at the phone while crossing a pedestrian crossing), "cult of youth" (lack of empathy towards other users and artificial rush), "excessive bravado" (disregarding red light and the belief that no one will hit me), should not take place for the sake of respect for all co-users of pedestrian crossings.

Figure 6 presents in a synthetic way the actions proposed by the respondents which, in their opinion, could reduce dangerous situations occurring at crosswalks.

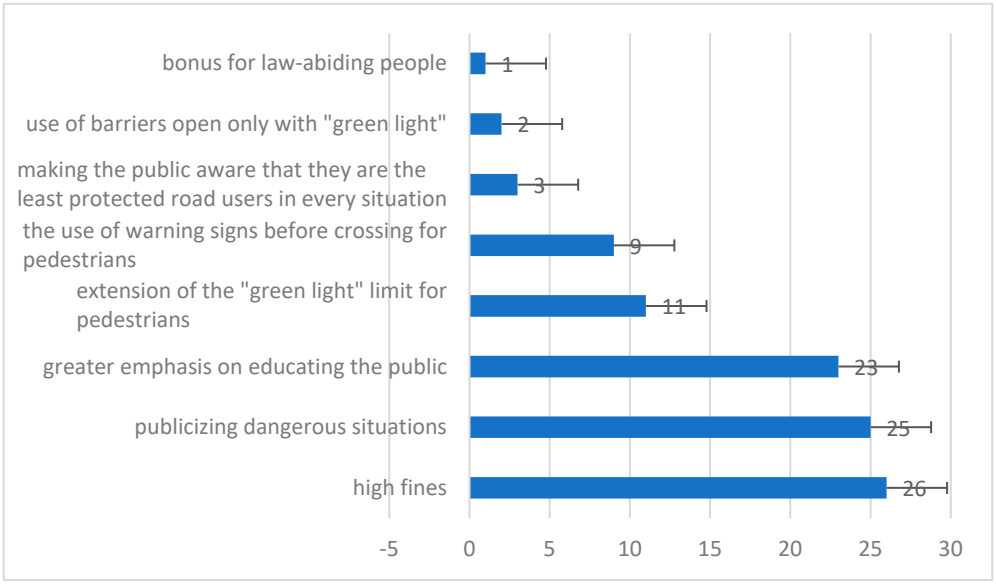


Figure 6. Factors limiting dangerous situations occurring at crosswalks.

Representatives of "iGen" primarily pointed to the "personalization" of actions through the use of strong sanctioning instruments, i.e., severe financial penalties for offenders (26%) and publicizing individual offenses, which would result in immediate criticism of the offense by the society as a whole (25%). At the same time, the necessity to take "group" actions was indicated to put more emphasis on educating the society in a systematic and continuous manner in the field of road traffic regulations, customs and practices of safe behavior at pedestrian crossings (23%). The conducted research allowed to identify and systematize the key factors related to (1) technical conditions, (2) technological conditions, (3) organizational conditions, and (4) behavioral factors contributing to the increase of safety at crosswalks. Table 3 presents these results in a synthetic way. Each of the respondents mentioned 3 factors. The percentage distribution of the individual factors is shown in Figure 7.

Table 3. Solutions influencing safety at pedestrian crossings according to identified types of factors.

Type of Factor	Factor	Number of Responses
Technical (physical) solutions	vertical marking,	81
	horizontal marking,	104
	sidewalk,	3
	appropriate curb profile	11
	an island dividing the road and a crosswalk,	4
	speed bumps,	1
	wide sidewalk,	3
	bicycle paths and crossings,	4
	technical condition of road surfaces	4
Technological solutions	traffic lights,	77
	sound signaling,	11
	collision-free traffic lights,	3
	signaling informing about an approaching tram,	1
	countdown timers,	3
	street lights,	35
	illumination of crosswalks,	7
	illuminated information sign "crosswalk",	2
	marking of crosswalks with LED strips/points	2
Organizational solutions	good visibility,	78
	location of a crosswalk (applies to road geometry),	13
	road traffic,	19
	speed limit zone,	10
	location of crosswalks,	14
	a crossing guard	1
Behavioral conditions	behavior of road users,	10
	vehicle speed	5

Frequently, a traffic user is forced to stop as a result of violations made by others, e.g., failing to yield the right of way. The human factor is mainly responsible for the occurrence of undesirable situations in road traffic. According to E. Petridou, behavioral factors contributing to road collisions can be divided into those reducing the ability from the long-term and short-term perspectives [39]. Nevertheless, human errors are a frequent phenomenon, and their identification allows the implementation of preventive changes. The data presented above show that crosswalks, as perceived by the respondents, are not safe when vehicles are moving at too high speed and when the behavior of road users raises concerns about compliance with road traffic regulations and the culture of road users. Behavioral behaviors influence the way public space is organized. The increase in the number of vehicles in cities determines the implementation of technical solutions to increase the safety of vulnerable road users [40]. According to the respondents, one of the most important factors influencing the safety of crosswalks is the correct vertical and horizontal marking and the appropriate curb profile. Curb ramps are used where there is a difference in levels between a pedestrian and bicycle path and road [41]. Designing urban space accessible to people with disabilities, the elderly and other groups is becoming a topic of discussion for various city stakeholders. Providing adequate access for pedestrians to the infrastructure adapted to their movement, supporting their mobility, and the choice of means of transport has a decisive influence on the quality of life in the city. Organizational and technological solutions are key in creating a pedestrian-friendly space. According to the research results presented above, good visibility at the intersection, street lighting, and

traffic lights have an impact on the safety of crosswalks. Currently, thanks to the collection of data, the creation of urban big data, and the possibilities offered by information and communications technology, it is possible to adjust the urban space to the needs and expectations of the society [42]. These solutions support the management of traffic flow in order to influence the safety of road users.

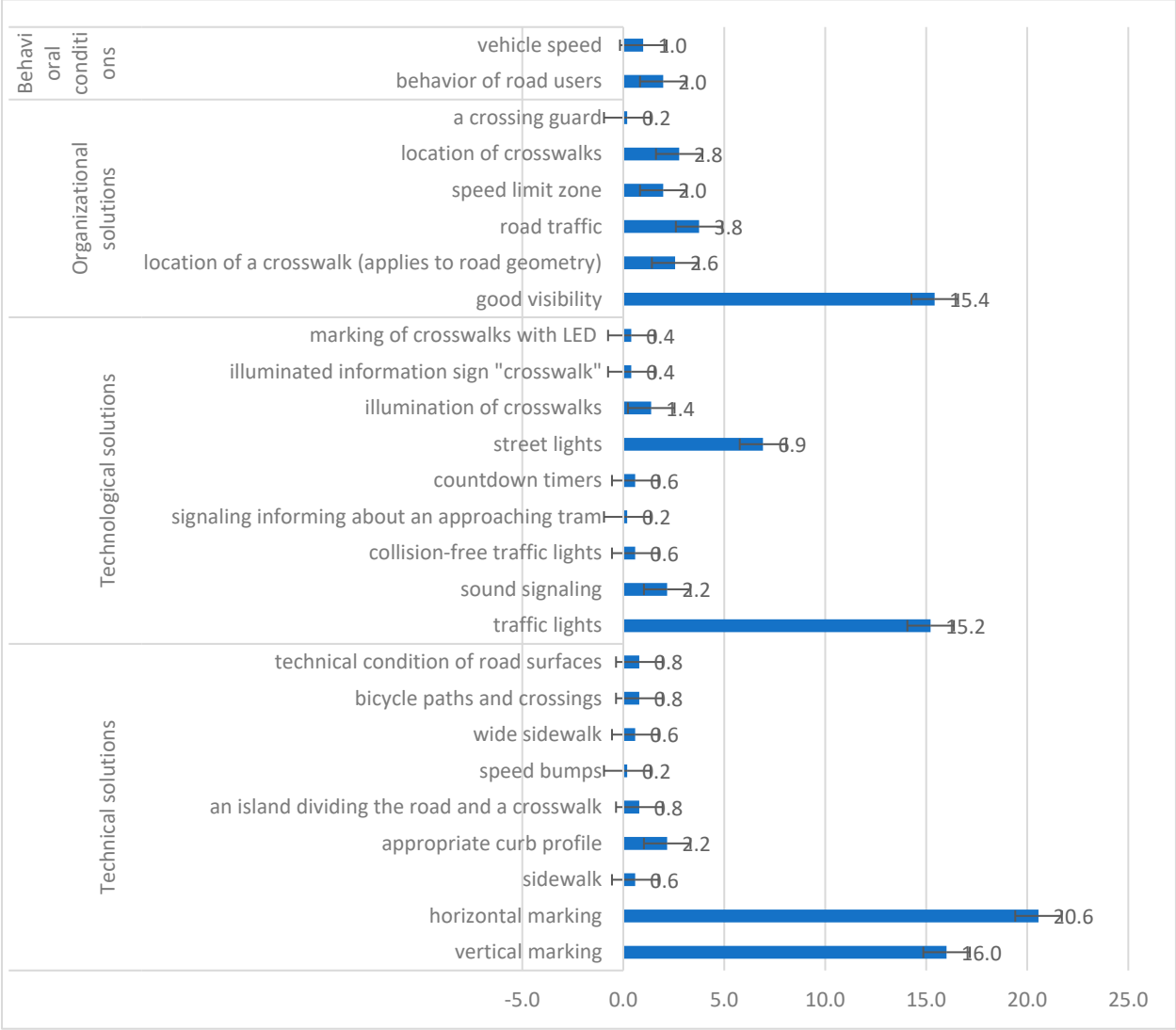


Figure 7. Factors influencing the safety of crosswalks.

5. Conclusions and Recommendation

Many city designers emphasize the need to orientate the city's development and adapt solutions to the expectations of pedestrians [43]. Marked crosswalks are usually located at signalized intersections, unmarked intersections, school zones and locations in the middle of the block [44]. The most common markings are standard parallel lines, ladders or continental stripes and diagonal stripes [45]. Intersections are those specific places where many pedestrians must cross the road despite the risks involved. Therefore, a safe layout and thoughtful sharing of road space with signs, markings, and distinctive surfaces can positively influence the behavior of pedestrians and cyclists at intersections and thus reduce the potential number of accidents. As a rule, crosswalks are viewed as safe places to cross a road, although this is not necessarily true. While the intersections themselves offer some protection, especially for young and old passers-by, many accidents occur in their vicinity: it is particularly dangerous within 50 m on both sides of the crossing.

Hence, such an important role is played by solutions such as: lowered curbs at intersections (especially important for people with physical disabilities) or detectable warning surfaces for people with visual impairments. Additionally, solutions, such as refuge islands, provide additional assistance in crossing the road.

The respondents (non-probabilistically selected pedestrians representing the "iGen") indicated that the most important factors determining a safe crosswalk are traffic lights and appropriate marking (mainly horizontal). In Szczecin, there are 19 roundabouts (classified according to the proper name) and approximately 15 roundabouts classified as a specific road traffic system. Summarizing the conducted research, it should be noted that the research and analytical procedure provided answers to the research questions, i.e., factors perceived as dangerous were identified, their source was identified (also by identifying age groups), and activities desired by other users were identified (in the list with side effects).

The priority procedure of the City Authorities is the introduction of the so-called "Tempo 30" (permanent restriction in the zone; irrevocable at the next intersection), construction of "mini roundabouts", elimination of typical crosswalks, increasing visibility via the restrictive removal of vehicles, and punishing drivers for parking too close to intersections, as well as installing poles, preventing parking, until the narrowing of the road (the width of the road lanes). At the same time, pedestrians are expected to use all their senses when crossing the road.

Certainly, some studies have shown a greater risk of accidents involving pedestrians at marked crosswalks in comparison to unmarked crosswalks [22,46–49], and other studies showed a lower risk of collision with pedestrians at marked crosswalks than at unmarked crossings [50]. However, the case of Szczecin proves that the views represented by the first group are more accurate.

In the authors' opinion, the article allowed to fill the existing scientific and cognitive gaps in looking at a crosswalk as a critical point in urban logistics. It indicates the key role of cooperation between academic centers and Police Headquarters as a government administration body in creating a holistic view of the urban safety issue (Szczecin agglomeration). The Maritime University of Szczecin, on 23 May 2018, signed a letter of intent with the Provincial Police Headquarters in Szczecin regarding cooperation, within which an important and ongoing process is the "exchange of information and experiences regarding activities carried out by each of the institutions and/or organizations that affect the improvement of road safety".

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References

1. PWC. Five Megatrends and Possible Implications. 2014. Available online: www.pwc.com/us/CenterforBoardGovernance (accessed on 12 April 2022).
2. Eagar, R.; Boulton, C.; Demyttenaere, C. The Most Important Megatrends and How to Monitor Them. The Trends in Megatrends. Prism No. 2. 2014. Available online: https://www.adlittle.com/sites/default/files/prism/The_Trends_in_Megatrends_9.pdf (accessed on 15 April 2022).

3. Seto, K.S.; Reenberg, A.; Boone, C.C.; Fragkias, M.; Haase, D.; Langanke, T.; Marcotullio, P.; Munroe, D.K.; Olah, B.; Simon, D. Teleconnections and Sustainability: New Conceptualizations of Global Urbanization and Land Change. *Proc. Natl. Acad. Sci. USA* **2012**. Available online: www.pnas.org/cgi/doi/10.1073/pnas.1117622109 (accessed on 12 April 2022). [CrossRef] [PubMed]
4. ESPAS. *2030 Global Trends to 2030: Can the EU Meet Challenges Ahead?* ESPAS: Brussels, Belgium, 2015.
5. Calafati, A. *The 'Smart Growth' Paradigm and the European Urban System*; Cities in the European Project; GSSI: Laquila, Italy, 2014.
6. Johnson, W. *Smart Growth How to Grow Your People to Grow Your Company*; Harvard Business Review Press: Boston, MA, USA, 2022.
7. Brodhag, C.; Taliere, S. Sustainable development strategies: Tools for policy coherence. *Nat. Resour. Forum* **2006**, *30*, 136–145. [CrossRef]
8. OECD. *OECD Work on Sustainable Development*; OECD Publications: Paris, France, 2011.
9. UNESCO. Education for Sustainable Development: Sourcebook. In *Learning & Training Tools N°4*; United Nations Educational, Scientific and Cultural Organization: Paris, France, 2012.
10. Mitchell, W.J. *City of Bits. Space, Place, and the Infobahn*; MIT Press: Cambridge, MA, USA, 1996.
11. Graham, S.; Marvin, S. Planning Cyber-Cities? Integrating Telecommunications into Urban Planning. *Town Plan. Rev.* **1999**, *70*, 89–114. [CrossRef]
12. Komninos, N. *Intelligent Cities: Innovation, Knowledge Systems and Digital Spaces*; Spon Press: London, UK, 2002.
13. Hollands, R. Will the Smart City Please Stand Up? Intelligent, Progressive or Entrepreneurial? *City* **2008**, *12*, 303–320. [CrossRef]
14. Allwinkle, S. Cruickshank P. Creating Smart-er Cities: An Overview. *J. Urban Technol.* **2011**, *18*, 1–16. [CrossRef]
15. Manville, C.; Cochrane, G.; Cave, J.; Millard, J.; Pederson, J.K.; Thaarup, R.K.; Liebe, A.; Wissner, M.; Massink, R.; Kotterink, B. *Mapping Smart Cities in the EU, Study, Directorate General for Internal Policies, Policy Department A: Economic and Scientific Policy*; European Parliament: Brussels, Belgium, 2014.
16. Lee, J.H.; Gong Hancock, M.; Hu, M.-C. Towards an Effective Framework for Building Smart Cities: Lessons from Seoul and San Francisco. *Technol. Forecast. Soc. Change* **2014**, *89*, 80–99. [CrossRef]
17. Dameri, R.P. *Smart City Implementation*; Springer International Publishing: Cham, Switzerland, 2017. [CrossRef]
18. Dameri, R.P. Searching for smart city definition: A comprehensive proposal. *Int. J. Comput. Technol.* **2013**, *11*, 2544–2551. [CrossRef]
19. Vanlaar, W.; Hing, M.; Brown, S.; McAteer, H.; Crain, J.; McFaull, S. Fatal and serious injuries related to vulnerable road users in Canada. *J. Saf. Res.* **2016**, *58*, 67–77. [CrossRef] [PubMed]
20. European Commission. Mobility and Transport. Available online: https://ec.europa.eu/transport/themes/its/road/action_plan/its_and_vulnerable_road_users_en (accessed on 18 August 2021).
21. Kaparias, K.; Bell, M.; Miri, A.; Chan, C.; Mount, B. Analyzing the perceptions of pedestrians and drivers to shared space. *Transp. Res. Part F Traffic Psychol. Behav.* **2012**, *15*, 297–310. [CrossRef]
22. Herms, B.F. Pedestrian Crosswalk Study: Accidents in Painted and Unpainted Crosswalks. In Proceedings of the 51st Annual Meeting of the Highway Research Board, Washington, DC, USA, 17–21 January 1972; National Research Council: Washington, DC, USA, 1972.
23. OECD/International Transport Forum. *Report Pedestrian Safety*; Urban Space and Health: Paris, France, 2011; p. 7.
24. Campisi, T.; Basbas, S.; Tesoriere, G.; Trouva, M.; Papas, T.; Mrak, I. How to Create Walking Friendly Cities. A Multi-Criteria Analysis of the Central Open Market Area of Rijeka. *Sustainability* **2020**, *12*, 9470. [CrossRef]
25. Iranmanesh, N. Pedestrianisation a great necessity in urban designing to create a sustainable city in developing countries. In Proceedings of the 44th ISOCARP Congress, Dalian, China, 19–23 September 2008.
26. *1er Congrès International de La Route-Compte Rendu des Travaux du Congrès*; Lahure: Paris, France, 1908; p. 3.
27. Jain, A.; Gupta, A.; Rastogi, R. Crosswalk behavior analysis at intersections. *J. Traffic Transp. Eng.* **2014**, *4*, 105–110. [CrossRef]
28. Basile, O.; Persia, L.; Usami, D.S. A methodology to assess crosswalk safety. *Eur. Transp. Res. Rev.* **2010**, 129–137. [CrossRef]
29. Robin, J. Assurer la Sécurité des Passages Piétons. 2019. Available online: www.securite-routiere-plus.com (accessed on 20 March 2022).
30. European Union. *Next Generation or Lost Generation? Children, Young People and the Pandemic*; Briefing European Parliament: Brussels, Belgium, 2020.
31. Gabrielova, K.; Buchko, A.A. Here comes Generation Z: Millennials as managers. *Bus. Horiz.* **2021**, *64*, 489–499. [CrossRef]
32. Giachino, C.; Bollani, L.; Truant, L.; Bonadonna, A. Urban area and nature-based solution: Is this an attractive solution for Generation Z? *Land Use Policy* **2022**, *112*, 105828. [CrossRef]
33. McBride, K.; Cingolani, L.; Hammerschmid, G. *Human Centric Smart Cities Redefining the Smart City*; Hertie School: Berlin, Germany, 2022.
34. Police Headquarters in Szczecin, Road Accidents—Annual Reports. 2022. Available online: https://statystyka.policja.pl/st/ruch-drogowy/76562,wypadki-drogowe-raporty-roczne.html (accessed on 15 May 2022).
35. *SN 640 241:2000*; Querungen für den Fussgänger—Und leichten Zweiradverkher; Fussgangärstreifen. Forschung, VSS: Zürich, Switzerland, 2016. Available online: https://www.vss.ch/de/ (accessed on 25 March 2022).
36. Cafiso, S.; Montella, A.; Mauriello, F.; Pappalardo, G.; Cavarra, R. Valutazione dei fattori di rischio degli attraversamenti pedonali mediante analisi di sicurezza e analisi dei conflitti. In Proceedings of the 17° Convegno Nazionale; 2008. Available online: http://www.siiv.net/site/sites/default/files/Documenti/enna/63_2848_20080919100028.pdf (accessed on 16 March 2022).
37. Montella, A.; Mauriello, F. Pedestrian crosswalks safety inspections: Safety assessment procedure. In Proceedings of the 4th International Symposium on Highway Geometric Design, TRB, Valencia, Spain, 2–5 June 2010.

38. Rankavat, S.; Tiwari, G. Pedestrians perceptions for utilization of pedestrian facilities—Delhi, India. *Transp. Res.* **2016**, *42*, 495–499. [CrossRef]
39. Petridou, E.; Moustaki, M. Human factors in the causation of road traffic crashes. *Eur. J. Epidemiol.* **2000**, *16*, 819–826. [CrossRef] [PubMed]
40. Movahed, S.; Azad, S.P.; Zakeri, H. A safe Pedestrian Walkway; Creation a Safe Public Space Based on Pedestrian Safety. *Procedia—Soc. Behav. Sci.* **2012**, *35*, 572–585. [CrossRef]
41. United Nations. Department of Economics and Social Affairs Disability. Available online: https://www.un.org/esa/socdev/enable/designm/AD1-05.htm (accessed on 10 June 2022).
42. Brezina, T.; Graser, A.; Leth, U. Geometric methods for estimating representative sidewalk widths applied to Vienna's streetscape surfaces database. *J. Geogr. Syst.* **2017**, *19*, 157–174. [CrossRef]
43. Mosharraf, H.M.; Teimourimanesh, M. The Importance of Pedestrian Ways in Universities Campuses Design. *Iber. J. Soc. Sci.* **2021**, *1*.
44. Mead, J.; Zegeer, C.; Bushell, M. *Evaluation of Pedestrian-Related Roadway Measures: A Summary of Available Research*; Federal Highway Administration DTFH61-11-H-00024; 2014; pp. 1–126. Available online: https://www.pedbikeinfo.org/cms/downloads/PedestrianLitReview_April2014.pdf (accessed on 16 March 2022).
45. Federal Highway Administration. *Manual on Uniform Traffic Control Devices for Streets and Highways*; U.S. Department of Transportation Federal Highway Administration: Washington, DC, USA, 2009; pp. 1–864.
46. Campbell, B.J.; Zegeer, C.V.; Huang, H.H.; Cynecki, M.J. *A Review of Pedestrian Safety Research in the United States and Abroad*; Final Report (November 2003), FHWA-RD-03-042; Federal Highway Administration Research and Technology: Washington, DC, USA, 2003.
47. Hanley, K.; Gibby, A.; Ferrara, T. Analysis of Accident-Reduction Factors on California State Highways. *Transp. Research Rec.* **2000**, *1717*, 37–45. [CrossRef]
48. Jones, P.; Anciaes, P. A comprehensive approach for the appraisal of the barrier effect of roads on pedestrians. *Transp. Res. Part A Policy Pract.* **2000**, *134*, 227–250.
49. Koepsell, T.; McCloskey, L.; Wolf, M.; Moudon, A.V.; Kraus, J.; Patterson, M. Crosswalk markings and risk of pedestrian-motor vehicle collisions in older pedestrians. *JAMA* **2002**, *288*, 2136–2143. [CrossRef] [PubMed]
50. Tobey, H.N.; Shunaman, E.M.; Knoblauch, R.L. Pedestrian Characteristics and Exposure Measures. *Transp. Res. Record* **1983**, 31–45.