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FACTORS DRIVING THE ACCEPTANCE OF IOT TECHNOLOGY FOR UNIVERSAL DESIGN PURPOSES IN THE CITY OF PŁOCK

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Purpose: In Poland, it is necessary to take care of accessibility in urban infrastructure. The possibility of using Internet of Things (IoT) sensors is an opportunity for smart cities to help the public and design urban spaces according to universal design principles. Using the data generated by IoT sensors makes it possible to develop applications that use them for smartphones and wearables. IoT sensors will identify places and objects unsuitable for people with disabilities and provide personalized information based on analyzing the situation near the sensors. However, using IoT in towns raises many concerns and controversies. Investigating residents' attitudes toward IoT sensors is necessary before deploying them in the city.
Design/methodology/approach: Survey data collected from 149 residents of Plock was used for the factor analysis. Additionally, descriptive statistics and reliability analysis were used.
Findings: The paper identifies key dimensions regarding using IoT devices in Płock. The factors determining the acceptance of IoT technology are indicated. Most respondents support introducing facilities for the disabled, although trust in the city authorities and the belief that technology will be used for a good purpose is average. People trust new technologies when they are used for universal design and are anonymous. Residents of Płock support IoT sensors for ecology applications and universal design, and they support facial recognition.
Research limitations/implications: The research was conducted through an online questionnaire in Plock. It is necessary to survey by a polling company to reach a representative sample of the public.
Practical implications: The research results will be helpful for the authorities of Płock when implementing IoT in the city.
Social implications: Using IoT sensors for universal design will adapt urban spaces for people with mobility problems.
Originality/value: Typically, IoT sensor data is sent to the cloud and can be captured. The acceptance of IoT technology in Edge Computing mode has not been evaluated yet. Using IoT sensors in Edge Computing mode, where data is processed in the vicinity of the sensors and is anonymized, can affect social acceptance.

Keywords: Internet of Things, smart city, universal design, edge computing, social acceptance.

Category of the paper: Research paper.

1. Introduction

Today, most of the world's population lives in cities, and this trend is becoming more pronounced. By 2050, 70% of the population will live in cities (United Nations, 2019). It is estimated that the world's population will grow from 7 to 9.3 trillion, and the number of people living in cities will increase to 6.2 trillion. By 2050, the population living in cities will double (Verma et al., 2020). The United Nations highlights city inequalities (United Nations, 2018). Urban dwellers will be concentrated on only 3% of the earth's surface, yet they will consume 80% of the world's energy. They will also produce 75% of the world's CO_2 emissions (Calvo, 2020). By 2050, there will be 1.3 billion blind people globally, 75 million wheelchair users, and 500 million people with hearing disabilities. Everyone who uses a baby carriage or shopping cart, the elderly also needs a better-designed city. Legal regulations force the adaptation of urban spaces to the needs of all users: people with mobility impairments, the blind, the elderly, people with small children, with luggage, and tourists.

On June 11, 2019, the European Union Directive on the accessibility requirements for products and services (European Accessibility Act, 2019) concerning the unification of the European market in terms of accessibility by all social groups, including people with special needs and people with disabilities. Following this, Poland introduced the Accessibility Act (2019), which requires public entities and cooperating organizations to adapt their services to the needs of all stakeholders. The Act addresses architectural, digital, and information and communication accessibility. The Act mandates universal design, signed in New York on December 13, 2006 (*The Convention on the Rights of Persons with Disabilities of 13.12.2006*, 2006). The Act also introduced amendments to the Building Act (Building Act, 1995) and the Act on spatial planning and development (Act on spatial planning and development, 2003). It defines minimum architectural requirements that buildings should meet in their use by people with disabilities. New requirements have also been introduced for regional development. The Polish government has launched the Accessibility Plus program to ensure free access to goods, services, and participation in social and public life for people with special needs (Ministry of Health, 2022). The program funds projects that adapt public space, architecture, transportation, and products to the requirements of all people. The Polish government provides loans and grants to adapt buildings and urban areas to the needs of the Accessibility Act. Universal design is not only the goodwill of organizations and government and local administration but an obligation.

The literature draws attention to the necessity of adapting cities to the needs of all inhabitants, creating inclusive cities through good urban management policies, adapting urban architecture to the needs of all inhabitants, and using modern technologies for the needs of dwellers. Inclusive cities involve many scientific disciplines and specialists from different fields: architects and urban planners, surveyors, sociologists, computer scientists, environmental engineers responsible for sustainable development, engineers of various disciplines and artists, philosophers, economists, politicians, and others. Modern, inclusive cities should be tailored to the requirements of the inhabitants, and all services should be consulted with the inhabitants to offer them what is needed and accepted. Creating an inclusive city requires a combination of many areas, including understanding the place being designed, proper city management, technological innovation, and listening to the public's voice (Ahad et al., 2020). Hambleton (2014) believes that the above areas need to be expanded and suggests the following determinants of an inclusive city: paying attention to the inclusion of all social groups in city life, paying attention to social inequalities and lack of accessibility to urban spaces, assessing particular areas of cities, adapting certain urban areas to the needs of residents, promoting inclusive urban development, linking urban development to the environment (Hambleton, 2014).

The ambition of the authorities of the city of Płock is to increase the accessibility of people with special needs to urban spaces, offices, and public transport. Good practices of universal design are being implemented. Unfortunately, currently in the metropolitan area of Płock, many places are not adjusted to the needs of those people. Not all sidewalks and streets are prepared for people with special needs. Not all public buildings meet the conditions of new regulations. City authorities strive to adapt urban spaces to the needs of all residents. Squares and streets are being redesigned, a strategy for greening and decontaminating the city is being prepared, and authorities care about people with disabilities and their ability to use city infrastructure. Sidewalks are adjusted to the residents' needs. Enclaves of places to rest, to escape from the hustle and bustle of city traffic are being created. City lighting is continuously improved. Pedestrian crossings and intersections are also being improved. Curbs are improved, and traffic lights are equipped with rapid tick sound signals. Pedestrian crossings are moved slightly away from crossroads to protect pedestrians. Car traffic in front of intersections and pedestrian crossings is slowed down using horizontal obstacles on the roadway. Like the rest of Poland, Plock is considering removing car traffic from the city center or creating pedestrian-only routes where pedestrians prioritize cars.

It is impossible to manage increasing agglomerations without using information technology. Optimizing energy consumption, provisioning, transportation, health care, and logistics require IoT usage. Data from networked IoT sensors make it possible to learn about city dwellers' needs, habits and expectations and, as a result, design a friendly city for everyone. Using IoT devices, residents with special needs can receive personalized information on their phone apps and wearables. Users can receive customized information that allows them to take advantage of city systems at a particular location (Erten, Turan, 2017; Lopes, 2020; Rakshit et al., 2021).

IoT technology being new and distributed, is vulnerable to cyber-attacks and data takeover. Users of IoT devices and related applications may be concerned about the security of their phones, wearables, and computers (IoT Inspector, 2022; ITwiz., 2022; Tarabasz, 2016). The critical infrastructure of cities may be at risk. Attacks on IoT devices are in their infancy because the market for IoT devices is only growing. An increasing number of devices will be connected to 5G networks. Attacks currently focused on individuals will focus on industry and the infrastructure of cities and states. Data on the city's life is needed to manage it and make the changes its inhabitants expect. An alternative is Edge Computing. With the number of IoT devices increasing yearly, processing all data in the cloud becomes impossible. Edge Computing is becoming an alternative that will relieve network traffic and allow for secure data processing. Devices not connected to the network, or connected to it intermittently, are less likely to be taken over by criminals (Liu et al., 2019). Plock, like other cities in Poland, is equipped with city monitoring. In addition to the monitoring system, the city has air quality sensors connected to the international monitoring system. Universal design requires collecting data from more devices. In addition to cameras, the city needs noise monitoring, pedestrian and vehicle traffic volume, the ability to recognize people, monitor light intensity and moisture in the air and the soil, test soil salinity around the street, and much more. If the data is processed at the sensors and anonymized, the aggregated data will be sent to the decision-makers. Such monitoring would comply with the General Data Protection Regulation (Official Journal of the European Union, 2016).

Warsaw University of Technology assessed residents' attitudes towards IoT technology operating in Edge Computing mode used in Plock for Universal Design purposes. This study aims to identify the factors and variables that influence the residents' perspectives. The triangulation method was used in this study. Based on the literature analysis, questionnaires were prepared for a survey conducted among the residents of Płock. Additionally, interviews with the inhabitants of Plock were performed to confirm the content of the study.

The article discusses the survey questionnaire and presents preliminary analyses of the results. Respondents support the introduction of IoT sensors to make life easier for people with disabilities and mobility problems. Residents of Plock, even though they do not know what the effects of using the new technology might be and have no objectives of using it. Trust in the city government is average. Surveyed respondents are not interested in city affairs. A small percentage read the local press and city portals or listen to local radio. Residents support the use of IoT sensors to improve environmental activities. They also support the use of IoT sensors for better city design for the needs of all residents.

2. Literature Review

The evaluation of the use of IoT sensors in smart cities operating in Edge Computing mode has not been analyzed in the literature. The literature evaluating the acceptance of IoT technologies, especially their application in smart cities, was used to prepare the research tool. General technology acceptance models have often assessed the acceptance of IoT technologies. These methods have evolved to include more and more factors.

The early models: Theory of Reasoned Action (TRA) and Theory of Planned Behavior (TPB), are derived from psychology and consider factors like attitudes, social norms, and behavioral intention. Technology Acceptance Model (TAM) was the first model where "technology" was highlighted. Davis (1989) combined TRA and TPB models to evaluate attitudes toward technology usage (Davis, 1989). Initially, the model was prepared to explain the resistance toward technology. Attitude toward technology was explained by perceived usefulness and perceived ease of use. Perceived usefulness is the degree to which a person believes that using a particular technology would enhance their job performance, whether it might be helpful in everyday life. Perceived ease of use is a degree to which a person believes they should not use much effort when learning how to operate new technology and how much training will be needed. Following the model's assumptions, people will likely use a technology when both factors are in place. City decision-makers may create a smart city technologies version of a questionnaire to hold, among others, Edge Computing acceptance.

An extension of the TAM model is the Value-based Adoption Model (VAM), which considers the intended utility of the technology, satisfaction with its use, perceived technical maturity, and cost. All these factors influence the customer's perceived value of the technology, affecting its acceptance (Davis, 1989; Davis et al., 1992; Kim et al., 2007).

TAM2 model (Venkatesh, Davis, 2000) includes additional variables and incredibly subjective norms that helped capture social influence. The model considers whether technology is helpful for a person, what kind of image the user will have in their head while using technology, and whether the technology is relevant for their job. The model includes the user's prior experience and voluntariness of use – whether the user is forced to use a technology or whether it is their choice.

The unified Theory of Acceptance and Use of Technology (UTAUT) model includes features like performance expectancy, effort expectancy, social influence and facilitating conditions, and other moderating variables like gender, experience, and voluntariness of use. The UTAUT model is the most frequently used for technology acceptance evaluation. The critical components affecting technology acceptance and use are performance expectancy, effort expectancy, social influence, and facilitating conditions. UTAUT model is a revision of TAM and captures the characteristics of technology users. Four mediating factors were included in the model: age, gender, prior experience, and voluntariness to use technology. Those variables impact behavioral intentions and usage behavior (Venkatesh et al., 2003).

The UTAUT2 model is the newest model that incorporates primary relationships from the UTAUT model and adds new constructs and relationships that extend the applicability of the original one taking into consideration organizational and consumer contexts. Here, new facilitating and moderating conditions are taken into account. Observable variables explain all constructs, usually checked by questionnaires. Structural Equation Modelling (SEM) must be applied to solve such models (Venkatesh et al., 2012).

There are multiple technology adoption models (Hartman, 2020): Decomposed Theory of Planned Behaviour (DTPB), Diffusion of Innovations Theory (DIT), Innovation Diffusion Theory (IDT), Social Cognitive Theory (SCT), Motivational Model (MM), Model of PC Utilization (MPCU), Matching Person and Technology (MPT). All instruments are intended to assess how likely individuals, professionals, and organizations will use technology, predict user intentions and prepare a method of informing about technology (La Torres, 2020; Wright, 2017).

Technology adoption models became more complicated and, thus, more comprehensive to tackle all circumstances that technology designers should consider. While evaluating the acceptance of used technologies, smart city planners, for instance, Edge Computing, will benefit from the models above. They are natural aid in better planning and designing smart city services as all concepts and permutations of technology acceptance problems are already listed and tested.

Leong et al. (2017) evaluated the acceptance of IoT technology in the aspect of smart cities in Malaysia. The authors conducted an online survey where they used the UTAUT2 method. The intention to use IoT technology is influenced by performance expectancy, effort expectancy, hedonic motivation, cost of the equipment, and trust in the technology. The moderator in the structural model turned out to be the experience of technology users—the greater the background, the greater the motivation to use IoT devices. The influence of societal pressures, habits, and facilitating factors on willingness to use and accept technology was not confirmed. However, the authors emphasized that these factors may become necessary once the technology becomes widespread (Leong et al., 2017).

Grandhi (2021) presents an extensive literature analysis on IoT use in smart cities. Their study used the sec-UTAUT model to evaluate IoT technologies' security in smart cities. They used factors such as performance expectancy, effort expectancy, social influence, facilitating conditions, attitude, adoption intention, and behavioral intention. Age, gender, experience, and voluntariness were used as moderators. Survey research was supplemented with qualitative research to detail the findings (Grandhi et al., 2021). The authors found that technology functionality and reliability did not affect trust in technology in further research. Predicted usability and data security were found to influence trust in IoT technology. Data security does not explicitly affect users' trust. A sense of self-efficacy certainly affects trust in IoT technology. The authors have prepared tips for city officials on implementing IoT technology in terms of technology security (Neupane et al., 2021).

Bestepe et al. (2019) also provide a literature review on the use of IoT in smart cities. The authors highlighted the acceptance of city services such as city WiFi, smart city cards, and city and government phone apps. They identified 50 factors used in the literature to assess smart city residents' attitudes toward technology. According to the commonly used TAM model, the most important were perceived usefulness and perceived ease of use of the technology, which the authors found to be the most widely used model for assessing technology in smart cities. According to the authors, the TRA model is also frequently used because it captures privacy. Other factors noted were security, cost, trust in technology, control over technology, and satisfaction with technology use. The authors pointed out that the use of technology by residents is keyed by its acceptance. They also noted that literature on the acceptance of IoT devices in smart homes and healthcare is abundant. Still, there are not as many research papers on the acceptance of IoT technology in smart cities. Most of the work appears in Asia, and SEM is the most commonly used tool to evaluate the technology (Bestepe, Yildirim, 2019).

Pal et al. (2020) used four models to evaluate the acceptance of voice-controlled IoT devices: TAM, TPB, UTAUT, and VAM. They included enough variables in the survey to test all models using SEM. The UTAUT and VAM models explained the highest percentage of variance at 60-70% (Pal et al., 2020).

It is also important to note the safety of the technology. Choo et al. (2021) identified many factors that influence smart city residents' assessment of the security of IoT devices. These include cybersecurity, privacy, and secure data processing factors, such as Edge Computing (Choo et al., 2021).

The models presented below used to assess technology acceptance mainly included factors that were found to have a significant impact on the acceptance and willingness to use IoT devices:

Theory of Reasoned Action (TRA), (Fishbein, Ajzen, 1975):

- Subjective norm.
- Attitude toward behawior.

Theory of Planned Behaviour (TPB) (Ajzen, 1985):

- Attitude.
- Subjective norm.
- Perceived behavioral control.

Technology Acceptance Model (TAM) (Davis, 1989):

- Perceived usefulness.
- Perceived ease of use.
- Subjective norm.

Technology Acceptance Model 2 (TAM2) (Venkatesh, Davis, 2000):

- Perceived usefulness.
- Perceived ease of use.
- Subjective norm.
- Image.
- Job relevance.
- Output quality.
- Result demonstrability.

Value-based Adoption Model (VAM) (Davis, 1989; Davis et al., 1992; Kim et al., 2007):

- Perceived usefulness.
- Enjoyment.
- Perceived technicality.
- Perceived fee.
- Perceived value.

Unified Theory of Acceptance and Use of Technology (UTAUT), (Ahmad, 2014; Alwahaishi, Snášel, 2013; Venkatesh et al., 2003):

- Performance expectation.
- Effort expectancy.
- Social influence.
- Facilitating conditions.

Unified Theory of Acceptance and Use of Technology 2 (UTATA2) (Venkatesh et al., 2012):

- Performance expectation.
- Effort expectancy.
- Social influence.
- Facilitating conditions.
- Hedonic motivation.
- Price value.
- Habit.

It has been recognized that the acceptance of IoT technology for universal design purposes can be significantly influenced by empathy towards people with special needs. Of the many variables presented in the literature measuring cognitive empathy, emotional empathy, and emotional disengagement (Gerdes et al., 2011; Herrera-López et al., 2017; Lietz et al., 2011), variables measuring cognitive empathy, or the ability to put oneself in the place of another person, were selected. This factor was not considered in general and smart city technology acceptance models, but Horton (2021) tested such a relationship. However, he found that the effect of empathy towards people with disabilities on the acceptance of IoT technologies was insignificant (Horton, 2021).

3. Methodology

Based on the literature analysis, the key dimensions characterizing the acceptance of the use of IoT technology by the residents of the city of Plock in terms of universal design were identified. The most frequently used dimensions in the literature in models for assessing the acceptance of IoT devices in smart cities were selected. The questionnaire is presented in the Appendix. Respondents' attitudes towards the technologies used by the city government were assessed. The dimensions were evaluated using a five-point Likert scale: 1 – Strongly disagree, 2 – Disagree, 3 – Undecided, 4 – Agree, 5 – Strongly Agree. The dimensions' symbols and the number of variables are shown in parentheses:

- Empathy (ETD – 6 variables).
- Perceived usefulness (PU – 6 variables).
- Trust to city authorities (TG – 6 variables).
- The general acceptance of using data retrieved from IoT sensors (AC – 6 variables).
- Trust to technology (TT – 6 variables).
- Safety of people with mobility problems (PS – 5 variables).
- Pro-environmental behavior (PB – 4 variables).
- City activity (CA – 8 variables).
- Acceptance of the eco-friendly functionality of IoT applications (PA – 6 variables).

Respondents were informed that the purpose of the survey was to assess the IoT technology used for universal design purposes and that the data would be processed in Edge Computing mode. At the same time, the results in anonymized form would be forwarded. Further, respondents were asked about age, gender, education, economic and moral views, and family household income.

The sample for analysis was collected using the snowball method. An invitation to complete the survey was posted on city portals and Warsaw University of Technology websites. The invitation was also sent to interested city organizations. Over 200 people completed the survey in January and February 2022, but 149 complete data records were analyzed. Only full records were used because the primary method of analysis planned for assessing the acceptance of IoT by Plock residents would be Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), and SEM. Those statistical methods require complete data. The median age of respondents is between 41 and 50 years. The questionnaires were completed by a comparable number of women, K = 75, and men, M = 74. The respondents' education was divided into ranges corresponding to the structure of Polish education: primary, secondary, bachelor/engineer, master, doctor, and higher. There were no respondents of primary education. The structure of respondents by gender and age and gender and education are presented in Fig. 1.

The analysis was conducted using the SPSS v. 27 statistical package, IBM AMOS v. 27, and Microsoft Excel 365.

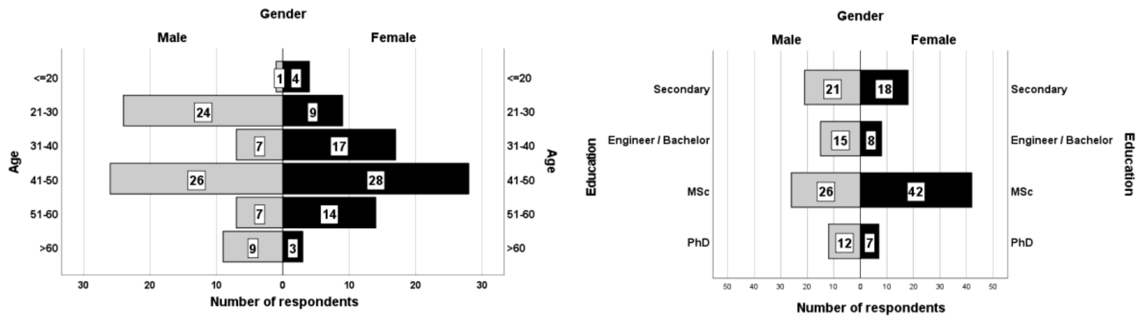

Figure 1. Structure of survey respondents by gender and age (left) and gender and education (right).

Source: Authors' research.

4. Results

In the survey, respondents were primarily optimistic about all presented statements. Each IoT acceptance dimension consisted of multiple variables (all variables are shown in the Appendix). Figure 1. illustrates the averaged results of respondents' answers. Descriptive statistics of the dimensions are presented in Table 1.

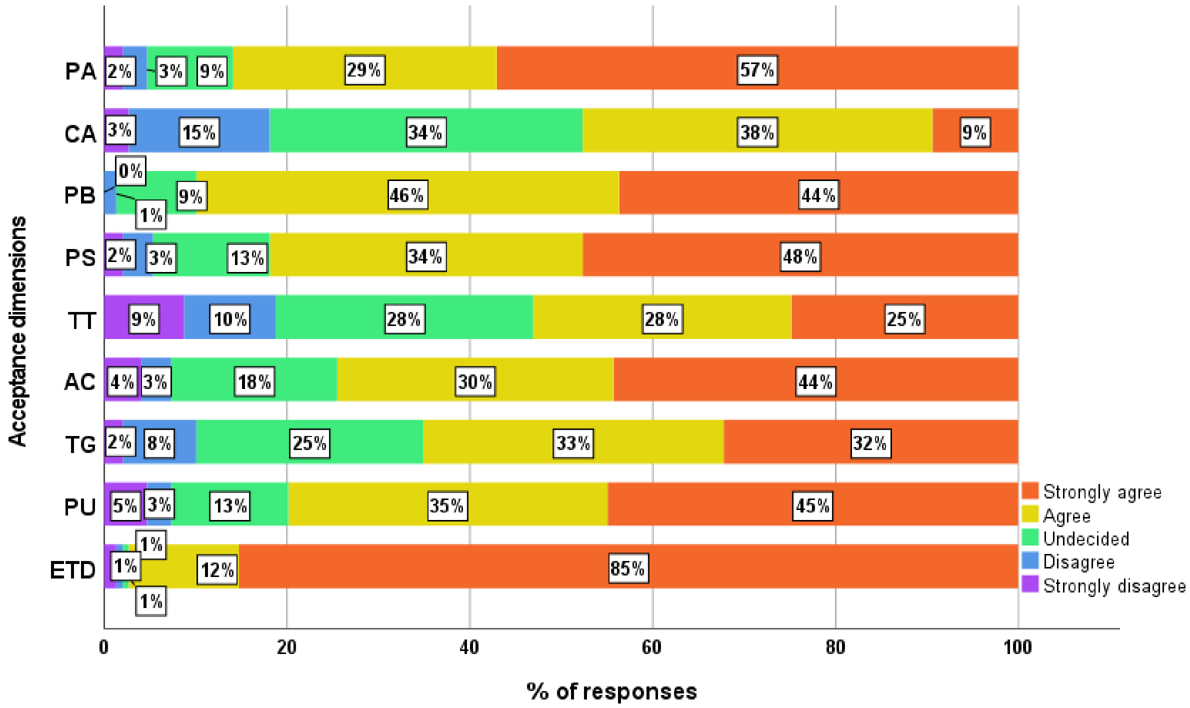

Figure 2. Distributions of survey responses.

Source: Authors' research.

Table 1.
Descriptive statistics for analyzed dimensions

Dimension	Mean	Median	Std. Deviation	Variance	Skewness	Kurtosis
ETD	4.79	5.00	0.62	0.382	-4.186	20.645
PU	4.13	4.00	1.05	1.098	-1.401	1.727
TG	3.85	4.00	1.03	1.059	-0.604	-0.285
AC	4.07	4.00	1.06	1.123	-1.150	0.915
TT	3.50	4.00	1.22	1.481	-0.498	-0.567
PS	4.22	4.00	0.94	0.876	-1.309	1.642
PB	4.32	4.00	0.69	0.477	-0.773	0.418
CA	3.36	3.00	0.95	0.895	-0.300	-0.295
PA	4.36	5.00	0.91	0.827	-1.659	2.810

Note. Dimensions' acronyms are explained in Table 1.

Source: Authors' research.

Most respondents state that they have positive attitudes toward the vulnerable and people with disabilities. 93% of respondents believe that sidewalks and streets should be adapted for people with special needs. 95% see the need to adjust city spaces to accommodate wheelchair users. 96% believe that the city should be adapted to the needs of blind people. 96% think that city authorities should make it easier for people with disabilities to get around. 93% of respondents say they understand the needs of people with disabilities. The average empathy score on a scale of 1 to 5 was 4.75. 90% of respondents rated their empathy score above 4; the distribution is left-skewed. The results indicate that the residents of Płock identify with people with special needs and feel they deserve help and assistance.

The perceived usefulness of technology for universal design was rated high. The mean value of the factor was higher than 4. 60% of respondents placed this dimension above 4. The distribution is left-skewed. More than 75% of respondents believe that the analysis of city surveillance will enable better design of streets to meet the needs of wheelchair users and the blind. 77% of respondents believe that analyzing data from IoT sensors can offer new services to residents. 73% believe that data from urban IoT devices can help design green spaces in the city according to residents' needs.

Trust in city authorities is not as unambiguous as in the previous dimensions. Overall, trust in the authorities at the highest level is declared by 62% of residents, 15% do not trust the city leaders, and 20% have no opinion on this issue. 45% of respondents do not think that the city's procedures for processing IoT sensor data are appropriate, but 65% of residents believe that the authorities can bring these procedures up to the proper standards, and 67% of respondents believe that the highest priority of the authorities is to safeguard the interests of residents. The average trust in the city government was rated at 3.8. 50% of the residents rated their faith in the government above 4. More than 90% of the residents believe that the government should introduce IoT technology in the city as long as it is secure and the data is processed locally and only after anonymization is used for design purposes.

Confidence in technology is evenly distributed among respondents. The average value of the factor is 3.5. A rating of 4 and above 4 was given by 30% of the respondents, and a rating of 2 and below 2 by 25%. The remaining respondents had no opinion on whether or not technology should be trusted. Half of the respondents believe that the city will adequately secure residents' data and be safe, and has proper procedures to ensure such data. At the same time, 23% of people do not share this opinion. As many as 25% of respondents do not know if the data is adequately secured. 58% of respondents believe that IoT technology will be used to meet the needs of people with disabilities. 70% of respondents believe that people with disabilities will feel safe through IoT sensors. The average factor value was 4.22.

Regarding ecology, 86% of people admit that they segregate waste, 90% of respondents declare that they care about energy saving, 80% save water, and 62% buy food, checking if it contains ecological products. The average value of the factor was rated at 4.2 by respondents. A value above 4 was given by 70% of respondents. 70% of people support using IoT sensors to collect data for urban green maintenance, and 77% support using this data for green design.

Urban activity is the most diverse category. 55% of people read the local press, 27% do not read anything. 65% of respondents follow regional portals, 15% do not check anything, local radio is listened to by 42% of respondents, 38% of people do not listen to the radio at all, 40% of people participate in events organized in the city, 24% of people do not participate in any events. 40% of people spend their free time in the city, 20% do not. The average rating for this dimension is 3.28, and an average value above 4 was given by 20% of respondents. 70% of people support IoT sensor data for better waste disposal management. 80% of people support IoT sensor data for greener city design, and 85% support pro-environmental changes in the city to make urban space easier to use. The average approval value for the pro-environmental use of IoT sensors is 4.3. On average, 70% of people gave a value of 4 to this factor.

The overall acceptance of Edge Computing IoT sensor data collection for universal design is high at 4.03, with a value above 4 given by 60% of respondents. 79% of respondents believe using IoT sensors for universal design is a good idea. 82% of people support city surveillance for this purpose, 77% agree with facial recognition, assuming the processed data will be anonymous, 85% support non-anonymous data processing, such as drone delivery of medicine to residents. 67% of people support non-anonymous facial recognition to assess whether someone is breaking the law, and 70% of respondents support observing the movement of people in a city to design it for people with disabilities better.

5. Discussion

The research objective of this study was to identify factors measuring dimensions that assess the acceptance of IoT technology in the city of Płock. Based on the results of the survey, an analysis of the EFA was conducted. The validity of combining the variables into assumed dimensions was confirmed using this method. The full model with all variables failed to extract the factors initially assumed. Not all variables entered the model. Those included are summarized in Table 2, where factor loadings for each variable are stated; all of them are greater than 0.5, and the average values of factor loadings are greater than 0.7, which allows for confirmed convergent validity of the model. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) and Bartlett's test of sphericity (BA coefficient) were calculated to confirm the adequacy of the model. For the model, KMO = 0.915 > 0.6, BA = 8216, significance, p-value, $p < 0.0001$. The coefficient values indicate that the variables in the model are properly correlated. Additionally, the communalities for all variables should be greater than 0.3. All model variables meet this requirement. Both conditions: KMO, BA, p-value, and communalities values, allowed to confirm the adequacy of the model. Discriminant validity of the model was also confirmed since all variables load clearly on each factor, which means that the factors measure different dimensions (Table 2). Additionally, the reliability of the model was confirmed. Cronbach's Alpha coefficient was calculated for each dimension. The higher the coefficient, the higher the reliability value, which should be greater than 0.6 (Table 3) (Tabachnick, Fidell, 2018). Although the dimensions tested separately meet the criteria for each factor evaluation (Table 3), combined into a single model does not allow its full validation. Dimensions PS, AC, TT, and PA were not included in the model. The survey statements inadequately measure them. To assess these dimensions, it is necessary to change the survey statements. The model explains 73% of the variance. The criterion for accepting the number of dimensions in the model is the value of total eigenvaluses > 1 (Table 4).

Table 2.
Factor analysis results

Variables	Dimension				
	TG	**PU**	**CA**	**ETD**	**PB**
ETD1				0.812	
ETD2				0.810	
ETD3				0.882	
ETD4				0.832	
ETD5				0.703	
PU1		0.821			
PU2		0.844			
PU3		0.809			
PU5		0.705			
PU6		0.742			
TG1	0.744				

Cont. table 2.

TG2	0.780				
TG3	0.744				
TG4	0.871				
TG6	0.681				
AC1		0.768			
AC2		0.718			
AC4		0.577			
AC6		0.649			
TT1	0.847				
TT2	0.814				
TT3	0.809				
TT4	0.879				
TT5	0.859				
TT6	0.883				
PB1					0.690
PB2					0.813
PB3					0.832
PB4					0.630
CA1			0.756		
CA2			0.779		
CA3			0.676		
CA4			0.835		
CA5			0.737		
CA6			0.693		
CA7			0.648		
CA8			0.571		

Note. Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

Source: Authors' research.

Table 3.

Adequacy and reliability indicators

Dimension	KMO	BA	p-value	Cronbach's Alpha
Empathy, ETD	0.887	496	<0.001	0.905
Perceived Usefulness, PU	0.863	835	<0.001	0.952
Trust to City Authorities, TG	0.882	752	<0.001	0.940
IoT Acceptance, AC	0.862	666	<0.001	0.909
Trust to Technology, TT	0.897	1257	<0.001	0.972
Security, PS	0.879	557	<0.001	0.923
Environmental Behavior, PB	0.733	202	<0.001	0.776
City Activity, CA	0.874	607	<0.001	0.876
IoT Environmental Acceptance, PA	0.870	891	<0.001	0.930

Note. KMO - Kaiser-Meyer-Olkin Measure of Sampling Adequacy, BA - the coefficient of Bartlett's Test of Sphericity. Cronbach's Alpha coefficient should be higher than 0.6 (Tabachnick, Fidell, 2018).

Source: Authors' research.

Table 4.
Total variance explained

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	total	% of variance	cumulative %	total	% of variance	cumulative %	total	% of variance	cumulative %
1	16.407	44.344	44.344	16.407	44.344	44.344	9.024	24.389	24.389
2	3.868	10.453	54.796	3.868	10.453	54.796	6.343	17.144	41.533
3	3.069	8.294	63.090	3.069	8.294	63.090	4.874	13.173	54.706
4	1.921	5.193	68.284	1.921	5.193	68.284	4.036	10.909	65.615
5	1.661	4.489	72.773	1.661	4.489	72.773	2.648	7.158	72.773
6	0.910	2.460	75.233						
7	0.864	2.334	77.567						

Note. Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

Source: Authors' research.

There is a lack of models in the literature assessing the impact of Edge Computing based IoT applications in smart cities for universal design purposes. The variables used in the present paper were compared with studies on the application of IoT in smart cities, smart homes, education, healthcare, and industry (Economides, 2017).

The use of IoT sensors in smart cities is increasing year by year, and acceptance models for this technology in various areas have been developed. Many different acceptance models are used, along with more than 50 technology evaluation variables. The most commonly used variables are perceived usefulness, perceived ease of use, and technology acceptance. Respective variables PU and AC used in this study correctly measure the assumed dimensions (Bestepe, Yildirim, 2019). It is noted that there are many people with disabilities and mobility problems in cities, so the use of IoT technology is necessary so that urban infrastructure is friendly and safe for residents (Gafner, 2019). Most often, the use of IoT in smart cities has been evaluated in terms of personal use of the technology. As in the case of the present study, users were very positive about the technology (AC dimension), and their overall acceptance depended on the perceived usefulness and ease of use of IoT devices. Attention was also paid to the security of IoT sensor applications (Tsourela, Nerantzaki, 2020). Not only for the safety of the devices in which such sensors are used but also for the security of the people observed by these sensors. Audience trust is affected by data security, data transmission security, security of devices used by users, and user security (Khan et al., 2016). In the present study, different results were obtained, as users judged that sensors operating in Edge Computing mode to observe urban spaces to assist the disabled were trustworthy (PS dimension).

The ecological aspect of using IoT sensors was included in the model, as they are often used for this purpose. In surveys evaluating the use of IoT sensors in smart homes, respondents positively assessed the possibility of using this technology to improve ecological functions, primarily the goal of saving energy. A study in Plock confirmed the positive assessment of the use of IoT sensors in smart Plock (PB and PA dimensions) (Bernsdorf, Hasreiter, Kranz, Sommer, Rossmann, 2016).

In many models, the social aspect is taken into account. In smart homes, it's the influence of the environment on the use of appliances and wearables (Gao, Bai, 2014). In smart cities, residents are involved in social issues (Habib et al., 2020). In both cases, the social aspect was significant, so the dimension of city engagement (CA) was introduced into the analysis in this study. The dimension was positively validated and can be used in its current form in further analyses.

An essential aspect of technology acceptance is empathy for people with disabilities and mobility problems. IoT technology has been assessed in terms of its use at home (Guillaume, 2020). Still, it is also worth considering this dimension when evaluating the use of IoT in smart cities (ETD variable). The dimension was positively validated and, as presented, can be used in further research.

One of the most critical dimensions of technology acceptance is trust in the technology and the organization using it. Trust influences the assessment of security and, consequently, technology acceptance. This is particularly important in using IoT sensors for people with disabilities (Ogonji et al., 2020). The survey conducted in Plock concerned the evaluation of citizen-watching IoT sensors, but the data from these sensors are sensitive. Hence, the Płock survey included TT and TG dimensions, which were positively validated and can be used in subsequent analyses.

6. Summary

Information and communication technologies are excellent tools to help design smart cities for all residents. The use of IoT technology involves a violation of privacy, and the town of Płock authorities decided to survey the level of acceptance of Plock residents. Based on the literature analysis, the survey was prepared and conducted among inhabitants.

The study found that in the area of empathy, respondents were almost unanimous in declaring favoritism toward people with disabilities. The vast majority of respondents, more than 90%, believe that the city should be adapted to the needs of people with disabilities - people with mobility problems, blind people, or people with young children. More than 70% of respondents believe that using IoT sensor data can be helpful to better design the city for the needs of people with disabilities and consider it a good idea. Even the facial recognition option is acceptable to more than 70%, and 66% think it is acceptable to use facial recognition with IoT sensors to check if someone is breaking the law. More than half of respondents trust the Plock city government, but a quarter has no opinion. 52% of respondents trust IoT technology, while 28% have no idea. More than 80% of respondents believe that IoT technology will make all city residents feel safe in Płock. It was assumed that attitudes toward the use of IoT technology in the city, among other things, to improve urban ecological functions, could be used to assess the mutual impact of the dimensions on each other. When asked about environmental behavior, 82% of respondents answered positively. On average, 47% of residents are interested in Płock issues. More than 80% support using sensors to improve the city's ecology (watering plants, taking out waste, better design of green areas. 82% believe that the city government should fund the use of IoT technology in Plock to adapt it to the needs of all residents.

In the analysis, dimensions of acceptance were selected and validated. Those factors will be later used to build structural models of acceptance assessment and evaluate the impact of individual variables on overall acceptance. The city authorities, using the results of the analysis, seeing what the concerns and expectations of residents are, will be able to conduct an information campaign among society.

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Appendix

Questionnaire statements

Below, the questionnaire statements used in the Plock survey are presented.

Dimension: Empathy - ETD

ETD1 I believe that pavements and streets should be adapted to the needs of people with mobility impairments

ETD2 Urban spaces should be friendly for people with wheelchairs

ETD3 Pavements and streets should be adapted to the needs of wheelchair users

ETD4 The city should be adapted to the needs of blind people

ETD5 I believe that city authorities should make it easier for people with disabilities to get around the city

ETD9 I understand the needs of people with disabilities

Dimension: Perceived usefulness - PU

PU1 I think that city surveillance images can be helpful in better designing the city for the needs of people with wheelchairs

PU2 Using data from city cameras will help to better design my city to the needs of people in wheelchairs

PU3 Data from city cameras could be helpful to better design streets for the needs of blind people

PU5 Data from the city's IoT sensors will allow many new services to be offered to residents

PU6 Observing the movement of residents using Internet of Things sensors will enable the city to introduce more greenery in places where it is convenient for residents

Dimension: Trust to city authorities - TG

TG1 I trust the city government to use data from the city's Internet of Things sensors and cameras to improve city infrastructure

TG2 I trust the city's capabilities in developing secure smart city services

TG3 I trust that the city's top priority in terms of using the Internet of Things in the city is to safeguard the interests of residents

TG4 I believe that city procedures will protect the data of people observed by city surveillance and Internet of Things sensors

TG5 I think that the city authorities should finance the development of smart technologies in the city

TG6 In general, I trust my city authorities

Dimension: General acceptance of using data retrieved from IoT sensors - AC

AC1 I think that better designing the city based on monitoring records and data from IoT sensors for the needs of people with mobility problems is a good idea

AC2 I support the use of city surveillance data and Internet of Things sensors to adapt the city to the needs of people with disabilities

AC3 I support the use of facial recognition in city surveillance cameras operating in Edge Computing mode to search for missing persons

AC4 I support the use of drones delivering medical products and other goods to people with disabilities who cannot leave their homes

AC5 I support the use of facial recognition in Edge Computing city surveillance cameras to check whether someone is breaking the law

AC6 I support the collection of data on how people move around the city using Edge Computing IoT sensors to redesign the city for people with mobility problems

Dimension: Trust to technology - TT

TT1 I believe that the monitoring systems used by the city that collect data to adapt the city's infrastructure to the needs of people with disabilities will be sufficiently protected

TT2 I trust Internet of Things devices and city applications that collect and process data from urban spaces to adapt the city to the needs of people with mobility problems

TT3 I can count on the IoT sensors collecting data for adapting the city to the needs of people with disabilities to have this data adequately secured

TT4 I believe the city has a firm policy to protect sensitive data processed by the city's monitoring system to improve the city's infrastructure to accommodate people with disabilities

TT5 I believe that the city's privacy policy for city monitoring (aimed at improving the functioning of people with disabilities) protects their privacy

TT6 I believe that the policy on using Internet of Things sensors to adapt the city to the needs of people with disabilities certainly protects their data

Dimension: Trust to city authorities - TG

PS1 I believe that IoT sensors will make people with disabilities feel safe in the city

PS2 I believe that city monitoring devices that warn pedestrians of oncoming bicycles and scooters will allow pedestrians to feel safe

PS3 I believe that using additional devices at intersections to warn of oncoming vehicles or traffic light changes will help people with disabilities feel safe

PS4 I believe that using specific city apps to find the best route for people with different disabilities will allow them to feel safe

PS5 I believe that the city needs a specific application that will allow blind people to move around the city safely

Dimension: Safety of people with mobility problems - PB

PB1 I separate my rubbish carefully, so it is easier to recycle

PB2 I reduce my energy consumption (electricity, gas, heating oil)

PB3 I save water and, where possible, try to recycle it

PB4 I buy food with consideration for the environment

Dimension: City activity - CA

CA1 I read the local municipal press

CA2 I browse the city's web portals or the city's social media

CA3 Listen to the local radio

CA4 I participate in city events

CA5 I use leisure facilities in my city

CA6 I am interested in the redevelopment plans for my city

CA7 I use an app or website to monitor air quality in my city

CA8 I take part in participatory budget voting

Dimension: Acceptance of the eco-friendly functionality of IoT applications - PA

PA1 I support using city surveillance data to design more green spaces where it is convenient for residents

PA2 I support using urban sensor data for proper watering of urban greenery

PA3 I support using city sensor data to collect and separate waste in the city in a more convenient way

PA4 I support using urban sensor data to design the city in an eco-friendly way

PA5 I accept environmentally-friendly changes to the city that take into account convenient use of the city

PA6 I agree with an urban design that makes it easier for residents to care for the environment

Additional questions

AGE – what is your age

GENDER – what is your gender

Education What is your education level

- Primary
- Secondary
- Engineer / Bachelor
- Master of science (M.Sc.)
- Doctor of Philosophy (Ph.D.)

City authorities should finance the development of IoT technologies to adapt the city for people with special needs
Range from 0 – No to 10 – Yes