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IDENTIFICATION AND ASSESSMENT OF BARRIERS TO THE IMPLEMENTATION OF SMART INFRASTRUCTURE LOGISTICS PROJECTS[8]

Urbanisation in the era of Industry 4.0 is characterised by the rapid development of smart cities, in the management system of which SMART logistics infrastructure plays a special role. The main hypothesis of the study is to identify critical barriers that impede the implementation of SMART infrastructure logistics projects in smart city management systems, which, combined with the use of the fuzzy set method to build a comprehensive model for assessing such barriers, will allow for the timely development of an effective mitigation strategy. Based on the generalisation of the results of theoretical research and an expert survey on the barriers to the implementation of logistics SMART infrastructure projects, 12 of the most significant barriers were identified, and it was proposed to conditionally combine them into 4 groups: organisational, political, financial and technological. The feasibility of using the fuzzy set method for modelling the integral indicator of barrier assessment for the implementation of SMART infrastructure logistics projects is substantiated, taking into account the high degree of uncertainty of the decision-making process

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at the early stage of planning these projects. It is proven that the use of a fuzzy model of an integral barrier assessment indicator for the implementation of SMART logistics infrastructure projects ensures their scientifically based prioritisation and will contribute to the development of optimal scenarios for the development of smart cities.
Keywords: smart city; smart city management; logistics SMART infrastructure; barriers to infrastructure project implementation; fuzzy sets method; Ukrainian logistics infrastructure
JEL: D81; L98; O30; R58

1. Introduction

Urbanisation in the era of Industry 4.0 is accompanied by the emergence and dynamic development of smart cities, whose management processes differ significantly from those of traditional cities. A radical distinction in the management processes of a smart city is its digitisation and intellectualisation based on the extensive use of modern SMART technologies. The 'backbone' of this radical renewal in smart city management processes is the SMART infrastructure, without which the concept of a smart city cannot be realised. In the smart city management system, SMART logistics plays a crucial role because managing urban transportation, waste and recycling, distribution and use of urban resources (energy and water consumption, construction of smart buildings and offices, efficient land use, street lighting, etc.), and providing services to the population (healthcare, administrative and financial services, libraries, etc.) can be optimised through the application of a logistical approach (Korczak, Kijewska, 2019).

SMART logistics is based on the 3P+I concept: planning, people, policy, and infrastructure, and assumes synchronised interaction among these four key domains (Woensel, 2012). Among the main strategic initiatives of SMART logistics, researchers highlight: ensuring transparency and real-time tracking of management processes; demand-orientated supply chain planning; implementation of stream logistics concepts; providing logistic services with high reliability and adherence to SLA (Service Level Agreement) conditions; forming resilient and, at the same time, adaptive supply chains; creating a unique value proposition for customers (Szymczak, 2019). The effective formation of logistics SMART infrastructure in smart cities is a necessary condition for their sustainable development, which necessitates the further development of modern methods of monitoring, analysis and assessment of barriers to the implementation of logistics SMART infrastructure projects.

2. Literature Overview

The literature review is aimed at a systematic analysis of research on SMART infrastructure as an important component of the smart city management system. Special attention is paid to the development of SMART infrastructure through the implementation of SMART infrastructure projects. A comprehensive review aims to understand the problems of logistics infrastructure development in the context of the presence of certain barriers to its renewal through the implementation of logistics smart infrastructure projects. Methodical approaches for assessing the level of such barriers are highlighted, which will make it possible to determine priorities and risks in the management of logistics infrastructure.

2.1. SMART infrastructure is an important component of the smart city management system

The term "Smart City" refers to a modern concept of urban strategic management, which involves the broad implementation of cutting-edge SMART technologies to create conditions and ensure a high quality of life for citizens and to achieve economic and social goals of cities. These goals include improving service quality, reducing costs, optimising resource consumption, and enhancing interaction between citizens and government, among others. The smart city management system is built on the synergy of goals, tasks, functions, principles, structural elements, levels, tools, and methods for managing the development of modern cities (Attaran et al., 2022; Carboni, 2024; Stofkova, Janošková, 2021).

A smart city requires the formation of a multi-branch and multi-departmental intellectual business information management system that serves government administration, enterprises, and public life. In the smart city management system, subsystems for outcome planning, coordination planning, and project supervision are formed, along with a unified, complete, and standardised comprehensive database (Huang et al., 2022).

An intelligent smart city management system is characterised by:

1) goals: smart infrastructure, convenient municipal services, excellent social management, livable environment, reliable information security network, and modern industrial development (Fang, Shan, 2022);
2) strategy: smart cities should be built based on pre-developed strategies aimed at achieving specific effects in urban/economic/social development (Trincă, 2023);
3) hierarchical organisation: the hierarchical organisation of certain dimensions and sub-dimensions, components, domains, levels, elements, and characteristics. Researchers (Athiyatul et al., 2024; Sharif, R. A., Pokharel, S., 2022) highlight seven main dimensions: people, government, economy, environment, infrastructure, mobility, and quality of life. At the same time, Trincă (2023) identifies six main components of a smart city: economy, infrastructure/mobility/transport, environment/resilience, citizens/people, life/lifestyle/safety and health, government/management. Fang et al. (2021) identify three levels of hierarchical structure for smart city development from bottom to top: smart infrastructure, smart management or “brain”, and smart applications. According to Jakub (2018), a smart city includes 16 hierarchically organised components, which form four levels: organisational level, smart city community level, infrastructure level, and quality of life and city attractiveness level.
4) management entities: Jakub (2018) identifies political and strategic stakeholder levels (consultants, expert groups, research organisations, universities, etc.); business community (investors, technology suppliers, service providers, financial resources); operational stakeholder level (urban service operators and providers, components of integrated rescue systems); and smart city service users (citizens, institutions).

SMART infrastructure is an important component/level/dimension of the smart city management system, as highlighted by Jakub (2018); Fang et al. (2021); Trincă (2024); Athiyatul et al. (2024); Sharif, Pokharel (2022). Mitchell (2022) defines it as the result of combining traditional (physical) infrastructure with technological (digital) infrastructure.

Adding digital solutions to physical infrastructure provides the latter with information about its condition and operation, which, in turn, allows for more effective and accurate decision-making regarding infrastructure design, maintenance, and current operations. This effectively makes physical infrastructure "smart", enabling it to synthesise important information and, using SMART technologies, communicate with other SMART objects and personnel. Key digital technologies include: Internet of Things, Big Data, autonomous vehicles, RFID, car and ride sharing, autonomous robots, augmented (virtual) reality and digital space, Bitcoin, blockchain, 3D printing, cloud computing, drones, Vehicle-to-Everything (V2X) communication, artificial intelligence, machine learning, deep learning, 5G technology, wireless network technology, sensors, and others.

The development of SMART infrastructure is carried out through the implementation of SMART infrastructure projects. Jakub (2018) distinguishes between investment projects and development projects:

- investment projects: involve the acquisition and operation of assets such as vehicles and information;
- development projects (also known as "demonstration" or "innovation" projects): in which the city acts as a "living laboratory" for modern technologies used in the project, and only covers costs directly related to their operation. Technology manufacturers receive data to test their technical solutions for further commercialisation.

Both types of SMART infrastructure projects are characterised by complex and costly implementation processes, necessitating the assessment of relevant barriers and risks (Stanislawski, Szymonik, 2021), considering political factors (government and international support, etc.); financial factors (private and public investments, project profitability); human factors (psychological and mental readiness for implementation); and the availability of solutions (Markevych, 2021).

2.2. Analysis of the properties of SMART logistics infrastructure projects from the point of view of barriers to their implementation

Analysing the properties of logistics SMART infrastructure projects in terms of barriers to their implementation reveals the varied nature of these barriers, which span many areas of public life, economics, politics, and technical and technological development (Table A.1, Appendix A). The large number and diverse nature of these barriers necessitate their systematisation for comprehensive and integrated consideration in assessing the prospects for SMART project implementation.

To identify the main barriers to infrastructure projects, researchers suggest using an initial questionnaire based on literature review results in the first stage, followed by the use of three rounds of Delphi study and distributing a semi-structured questionnaire (containing open-ended questions) among experts to determine the final barriers and risks for projects (Tamosaitiene et al., 2020).

2.3. Methods of assessing barriers, priorities and risks in logistics infrastructure management

Among the methods for assessing priorities and risks in infrastructure management, multi-criteria analysis (MCA) and multi-criteria decision-making (MCDM) methods hold significant importance due to the complexity of managing the construction and maintenance of infrastructure objects and the need to simultaneously consider many different aspects (technical, economic, social). Bošnjak, Jajac (2023) propose using the two-phase Analytical Hierarchy Process (AHP) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) methods to determine the importance of criteria and rank infrastructure management priorities. At the same time, the high degree of uncertainty inherent in decision-making processes suggests the usefulness of the fuzzy sets method (Kolodizieva et al., 2022; Omelchenko et al., 2018).

Kaczorek, Jacyna (2022) justify the use of the fuzzy sets method to support decision-making regarding the prioritisation of transport infrastructure projects, identifying three groups of criteria: economic, social, and environmental impact. The advantages of the proposed method include the ability to align input data requirements with information available at early planning stages; ease of use of the Toolbox available in MATLAB; the ability to use natural language in decision support systems; and the usefulness of fuzzy logic for supporting decision-making in strategic planning of logistics infrastructure development.

Tabatabai et al. (2023) proposes using expert methods to assess risk levels (very low, low, medium, high, and very high) for infrastructure construction projects, with subsequent conversion of certain expert assessments into fuzzy linguistic values using a defined scale (from 0 to 10): from 0 to 2.5 – very low risk, from 2.5 to 5 – low risk, and so on up to 10.

Salimian et al. (2022) proposes using a hybrid model to evaluate alternative infrastructure projects, combining three approaches: interval-valued intuitionistic fuzzy set (IVIFS), relative preference alternative (RPR) method, and multi-attributive border approximation area comparison (MABAC) method.

The frequency of use of methods in this literature review and the characteristics of the models are given in Table 1.

Table 1. Evaluation Methods used to assess barriers in logistics infrastructure management (literature review for 2022-2023 years)

Methods used to assess barriers in logistics infrastructure management	Frequency of use of methods, %	Authors	Model characteristics
Two-phase Analytical Hierarchy Process (AHP)	12,5	Bosniak, Jajac (2023)	Hybrid
Order of preference by similarity to the ideal solution (TOPSIS)	12,5	Bosniak, Jajac (2023)	Hybrid
Fuzzy set method	25,0	Kaczorek, Jacyna (2022) Tabatabai and al (2023)	Fuzzy model, hybrid model
Expert methods	12,5	Tabatabai and al (2023)	Hybrid
Multi-Attribute Boundary Approximation Area Comparison (MABAC) method.	12,5	Salimyan et al. (2022)	Hybrid
Interval-valued intuitionistic fuzzy set (IVIFS),	12,5	Salimyan et al. (2022)	Hybrid
Alternative Relative Preferential Pricing (RPR) Method	12,5	Salimyan et al. (2022)	Hybrid

Thus, to assess barriers to the implementation of logistics SMART infrastructure projects, it is advisable to use a combination of different methods and approaches that meet the requirements for establishing the significance and level (materiality) of barriers, for further ranking of these barriers and integrating their partial assessments into a comprehensive integral assessment. Among the mentioned methods, those based on fuzzy sets theory deserve special attention due to the significant level of uncertainty at the project planning stage, such as:

- the lack of precise information regarding the final cost and timeline of the project, availability of financial resources, investments, etc.;
- uncertainty regarding the behaviour of key project stakeholders, including government officials and local authorities during project implementation, and limitations in government policy and strategic vision for smart city development at the national level;
- the presence of alternative projects based on one or more SMART technologies, which may be at different stages of implementation;
- different expert opinions on the list and assessment of main barriers to infrastructure project implementation;
- limited access to complete information about technical specifications and contractors of infrastructure projects.

Using linguistic evaluations based on trapezoidal numbers for linguistic variables within the specified method will help avoid issues related to low certainty in evaluating barriers to SMART logistics infrastructure projects, enabling assessments in linguistic terms (e.g., "high level" of barrier, "medium," "low"), making the evaluation process more understandable and flexible.

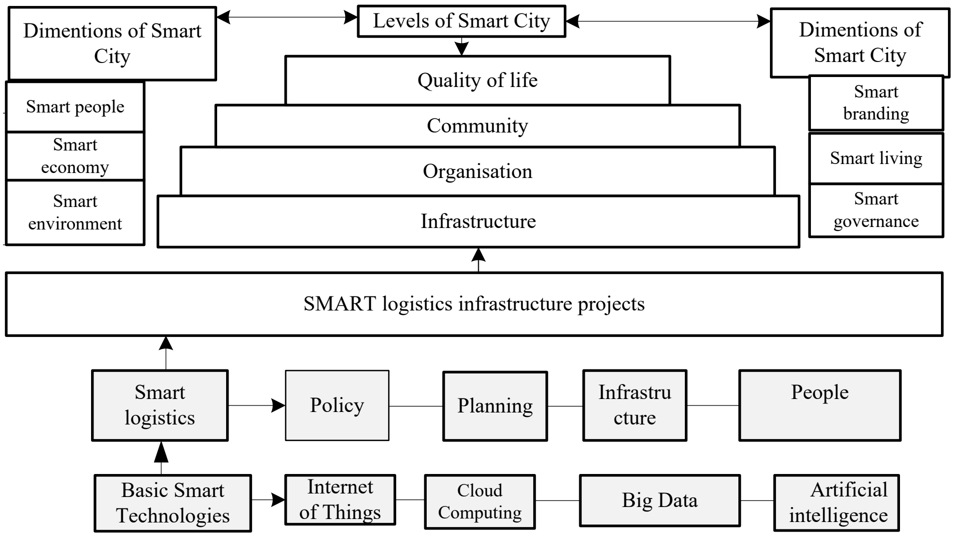
Methodological approaches to assessing the prospects for implementing logistics SMART projects should be considered as a structural element in the smart city management mechanism, which (Fang, 2022) ensures overall coordination between systems and improves investment and financing mechanisms. Alongside the mentioned methods, among the methods for monitoring, analysing, and evaluating smart cities, researchers (Jakub, 2018) highlight the formation of various indicators of urban services and quality of life, which can include up to 100 different indicators, including statistical ones.

Hypothesis (H1): Identification of critical barriers that hinder the implementation of SMART infrastructure logistics projects in smart city management systems, and assessment of these barriers based on the construction of a comprehensive assessment model using the fuzzy set method.

3. Materials and Methods

The generalisation of literary sources on the smart city system, its levels, dimensions, components, the impact of SMART logistics and the basis of smart cities – basic SMART technologies – made it possible to determine the place of SMART logistics infrastructure projects within the framework of the smart city management system (see Figure 1).

Figure 1. SMART logistics infrastructure projects within the smart city system



Source: (developed based on Woensel, 2012; Jakub, 2018; Sharif, 2022; Athiyatul et al., 2024; Yermachenko et al., 2023)

Considering that most management processes occurring in a smart city fall under the category of logistics and involve digital transformation of flows (material, financial, informational, service, economic, etc.), the impact of SMART logistics on the functioning of a smart city is undeniable. On the other hand, the smart city concept itself is built upon the implementation of SMART technologies in urban management, with four technologies considered fundamental (see Fig. 1). Thus, the management, functioning, and development of a smart city occur under the influence of SMART logistics and SMART technologies.

The review and generalisation of literary sources regarding the barriers to the implementation of logistics infrastructure development projects in the system of smart cities (Appendix A, Table A.1) made it possible to identify and single out separate groups of barriers: organisational, political, financial and technological.

The first group is organisational barriers, which include:

1. "Lack of effective anti-corruption policy and transparency of financial flows." The presence of this barrier is due to the lack of a clear definition of financial flows regarding financing, risk insurance and profit from the project, which leads to demotivation of civil servants who are more interested in corrupt “opaque” schemes with guaranteed income (points № 12, 14, Appendix A, Table A.1).
2. "Lack of decentralisation and autonomy of decisions" This barrier is associated with existing bureaucracy and centralisation in institutions and enterprises, while infrastructure

projects require decentralisation and autonomy in decision-making. The bureaucratic system resists the implementation of logistics infrastructure projects in Ukraine due to its closed nature towards cooperation with partners, reluctance to exchange information about new solutions in the environment, and reluctance to make changes within the organisation (enterprise), which require significant effort (points № 3, 7, Appendix A, Table A.1).

3. "Insufficient number of highly qualified personnel" The implementation of SMART logistics infrastructure projects requires a certain strategic orientation of decisions, government strategic plans for sustainable development of territories, which are often absent and create obstacles for implementing specific infrastructure projects. Moreover, the implementation of SMART projects significantly depends on SMART managers who represent management institutions and can prioritise certain activities depending on goals, constraints, and potential trade-offs between creating, maintaining, and disrupting the operation of SMART infrastructure in the long term (points № 1, 13 Appendix A, Table A.1).

The second group is political barriers, which include:

1. "Insufficient level of political will of the central and local authorities". This obstacle is due to the lack of government efforts, political will of central authorities, and political will of local authorities (point № 10, Appendix A, Table A.1).
2. "Insufficient involvement of stakeholders in public initiatives and events" This barrier is caused by the lack of political will from local authorities for the implementation of specific SMART infrastructure projects and ensuring local authorities' support for the stakeholder engagement process (points № 8, 10, Appendix A, Table A.1).
3. "Lack of an investment road map of the development of SMART technologies" The successful implementation of SMART infrastructure projects is only possible under a rational investment strategy and the development of an investment roadmap (point № 16, Appendix A, Table A.1). The absence of this creates certain obstacles for the implementation of SMART logistics infrastructure projects.

The third group is financial barriers, which include:

1. "Lack of financial resources". Scholars note the significance of this barrier, pointing out the lack of financial resources for many logistics SMART infrastructure projects (points № 2, 6, Appendix A, Table A.1).
2. "Excessively high investment costs". This barrier is highlighted by authors, emphasising the excessively high investment costs of logistics SMART infrastructure projects (point № 6, Appendix A, Table A.1).
3. "Lack of methodology for assessing the effectiveness of SMART projects during and after the construction of a smart city". A significant obstacle to the implementation of logistics SMART infrastructure projects is often the lack of methodological support for measuring the effectiveness of building a smart city, which is critically important for its further sustainable development. In addition, when measuring the effectiveness of SMART projects, one should also take into account their perception by citizens even

before the projects are implemented, since the source of income from the projects will be their consumers, that is, citizens of the smart city. After the implementation of the projects, it is advisable to include business models that determine their profitability in the post-evaluation mechanism for their support and further improvement (points № 15, 19, 20, Appendix A, Table A.1).

The fourth group is technological barriers, which include:

1. "Technical and technological barriers". Infrastructure development is constrained by the presence of technical and technological barriers (point №2, Appendix A, Table A.1).
2. "Low level of skills in society (local innovative communities) in the field of information technology" The presence of this barrier is explained by the fact that implementing logistics SMART infrastructure projects requires all project participants to not only integrate new technologies but also utilise new knowledge, engagement highly qualified personnel, develop skills in information technology and modern information systems, including safety rules, ensure complete security of stored data. Integrating SMART technologies into existing urban planning requires focusing on creating a sustainable and smart city logistics environment, designing service support and utilising the resource potential of local innovative communities within pilot infrastructure and service projects. The passive participation of citizens in urban SMART projects, who often prefer top-down service delivery rather than expressing opinions bottom-up, is also a reason for this barrier (points № 1, 4, 5, 8, 9, 19, Appendix A, Table A.1).
3. "Inadequacy of state and non-state drivers of the development of smart technologies”. Slow development of the SMART technology market is largely explained by insufficient administrative capacity and legal framework that are unsuitable for implementing new technologies; the lack of a motivation system for specialists to use ICT knowledge for the successful implementation of SMART technologies in logistics infrastructure; the lack of education for employees, accountability, as well as standardisation and compatibility of SMART technologies. The low level of SMART technology market development in Ukraine is also associated with low societal skills in information technology and the use of modern systems, and inadequate accessibility of SMART technologies to the average user. An important solution for this problem in Ukraine is to create expert consortia at the national (regional, local, enterprise/organisation) level encompassing various disciplines: economics, sociology, engineering, information and communication technologies (ICT), policy, and management to assess the feasibility of implementing various technologies (points № 4, 11, 16, 17, 18, Appendix A, Table A.1).

The further study and evaluation of barriers to the implementation of SMART infrastructure projects using expert methods (using the example of Ukraine) was based on results of expert assessment (Delphi method), which assessed the intensity of barriers (organisational, political, financial and technological) to the construction of SMART infrastructure in Ukrainian cities. The experts included 30 representatives from each group: representatives of local authorities (group No. 1); from higher education institutions and research institutes (group No. 2); business representatives (regarding the implementation of logistics smart infrastructure projects) (group No. 3) – who provided their assessments of the level of barriers to the development of SMART infrastructure in Ukrainian cities.

The expert assessment questionnaire contained questions to determine the levels of certain barriers: high, moderate, or low, according to the defined scale (from -5 to 15), shown in Table 2. The presence of three expert groups allowed for a comprehensive assessment of the intensity of each barrier and the determination of the range of expert assessments (minimum and maximum assessment according to the assessment scale), since it is this range that determines whether such a barrier as a whole (taking into account the opinions of experts from all 3 groups) is defined as high, moderate or low.

Table 2. Scale of Values for Linguistic Evaluation

Linguistic Evaluation	Values for Linguistic Variable (scores)
Low barrier	Negative value (range from "-5" to "0")
Moderate Barrier	Positive value (range from "0" to "5")
High Barrier	Positive value (range from "5" to "10")

Source: compiled by the authors.

It is proposed to base the integral assessment of barriers for SMART logistics infrastructure projects on the integral indicator, the structure of which is shown in Figure 2.

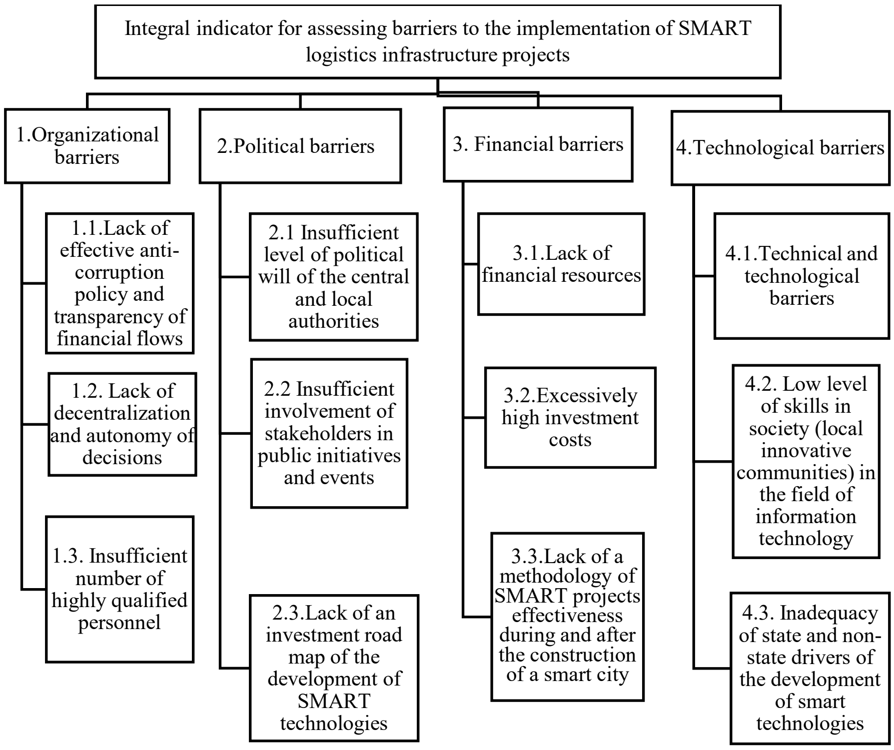
The integral indicator includes assessments of barriers, which were evaluated by experts in the process of an expert survey using the Delphi method.

To construct the fuzzy model for the integral indicator of barriers to the implementation of SMART logistics infrastructure projects, a specialised module from the Fuzzy Logic Toolbox in Matlab software was used.

Based on the identified barriers to the implementation of SMART logistics infrastructure projects, a fuzzy model for integrated assessment is proposed by forming an integral indicator of barriers to the implementation of SMART logistics infrastructure projects (I). This indicator is formed as a result of a three-level aggregation of input indicators – the assessment of the level of each individual barrier (a11, a12,…, d33) followed by their combination into aggregate indicators for each group of barriers (A, B, C, D), which, in turn, produce the integrated resulting indicator. Input indicators and aggregate indicators of barrier groups receive corresponding linguistic assessments to determine the integral indicator of barriers for the implementation of SMART logistics infrastructure projects.

The resulting indicator of the developed model – the integral indicator of barriers for the implementation of SMART logistics infrastructure projects (I) can vary within the interval values established according to the three gradations of the Harrington scale, corresponding to the linguistic categories "low" (0.00 - 0.37), "moderate" (0.37 - 0.69), "high" (0.69 - 1.00) (Samokhvalov, 2018). Interval values of the aggregate indicators for each barrier group (A, B, C, D) are formed as a result of calculations in the Fuzzy Logic Toolbox module of the Matlab software (Figures A.1. - A.4, Appendix A).

Figure 2. Structure of the integral indicator for assessing barriers to the implementation of SMART logistics infrastructure projects



Source: compiled by the authors.

Table 3. Integral and aggregate indicators for assessing barriers to the implementation of SMART logistics infrastructure projects

Symbol	Indicator Name	Symbol	Linguistic Evaluation	Trapezoidal Numbers for Linguistic Variable Values				Interval
I	Barrier Levels for the Implementation of SMART Logistics Infrastructure Projects	I_1	Low Barrier	0	0.13	0.25	0.37	From 0 to 0.37
		I_2	Moderate Barrier	0.35	0.46	0.57	0.69	From 0.37 to 0.69
		I_2	High Barrier	0.67	0.78	0.89	1.00	From 0.69 to 1.00
A	Level of Organizational Barriers	A_1, B_1, C_1, D_1	Low Barrier	0	0.17	0.335	0.505	From 0 to 0.505
B *C*	Level of Political Barriers Level of Financial Barriers	A_2, B_2, C_2, D_2	Moderate Barrier	0.5	0.585	0.67	0.755	From 0.5 to 0.755
D	Level of Technological Barriers	A_3, B_3, C_3, D_3	High Barrier	0.75	0.835	0.92	1	From 0.75 to 1

Source: compiled by the authors.

According to the structure of the integral indicator for assessing barriers to the implementation of SMART logistics infrastructure projects in Ukraine (Fig. 2), each aggregate indicator for assessing a group of barriers is formed as a result of the aggregation of input indicators of the model – evaluations of each individual barrier. The structure of each aggregate indicator and the interval values of the input indicators are defined based on the expert survey and are provided in Appendix A, Tables A.2–A.5.

The intervals for the input indicators of the level of each separate barrier are determined on the basis of the collective assessment of experts who have specific judgements regarding the level of certain barriers (Table 2).

To obtain the aggregate indicators for barrier groups, which form the integral indicator for assessing barriers to the implementation of SMART logistics infrastructure projects, and the integral indicator itself, the model employs rules formulated with the involvement of experts in SMART logistics infrastructure design (Tables A6-A7 in Appendix A).

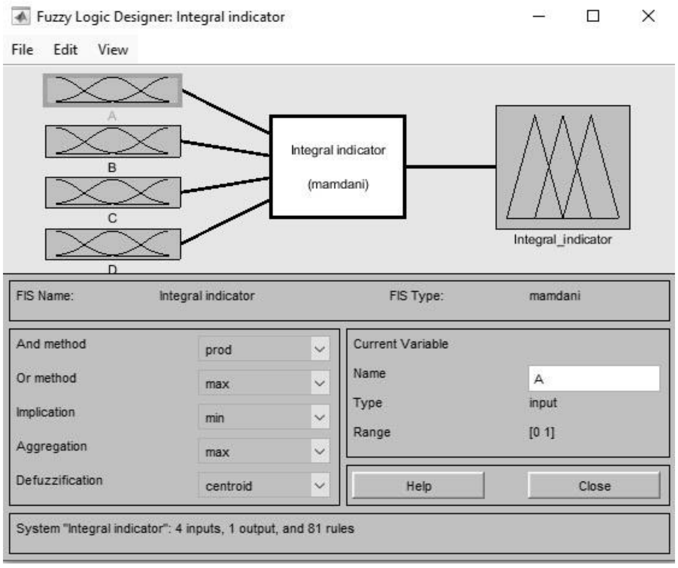
The model is constructed using fuzzy set theory with the help of the Fuzzy Logic Toolbox module in Matlab software.

The input indicators (Tables A.2–A.5 in Appendix A) and the rule base (the rules are given in Table A.6, Appendix A for indicator A, for indicators B, C, B they are compiled similarly) have allowed for obtaining the aggregate indicators of the fuzzy model: A – "Level of Organisational Barriers", B – "Level of Political Barriers", C – "Level of Financial Barriers", D – "Level of Technological Barriers". The obtained aggregate indicators of the fuzzy model, in the form of membership function editors, are implemented in Matlab software and are shown in Appendix A, Figures A.1–A.4.

The structure of the integral indicator for assessing barriers to the implementation of SMART logistics infrastructure projects, in triangular representation, is shown in Fig. 3.

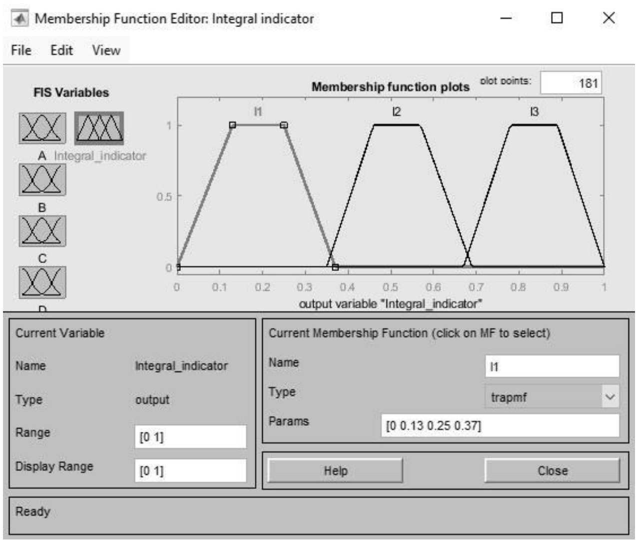
The integral indicator for assessing barriers to the implementation of SMART logistics infrastructure projects (I), as a result of the fuzzy inference function editor modelling, is presented in Figure 4.

Figure 3. Aggregate indicators of barrier groups (A, B, C, D) and resulting integral indicator for assessing barriers to the implementation of SMART logistics infrastructure projects in trapezoidal form (obtained in Matlab environment)



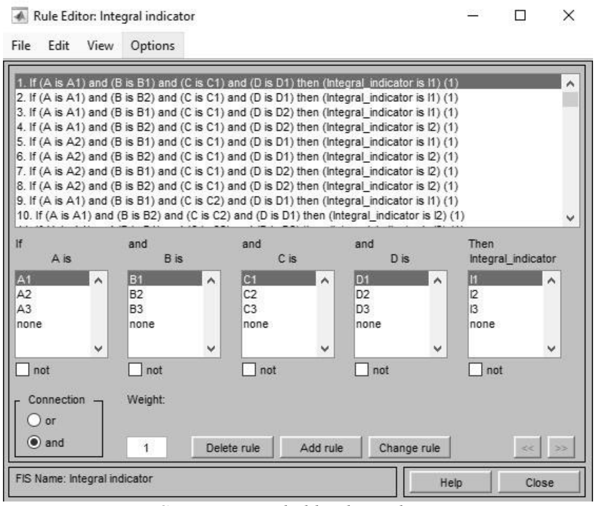
Source: compiled by the authors.

Figure 4. Resulting Integral Indicator for assessing barriers to the implementation of SMART logistics infrastructure projects in the form of membership functions of the Fuzzy inference system (obtained in Matlab environment).



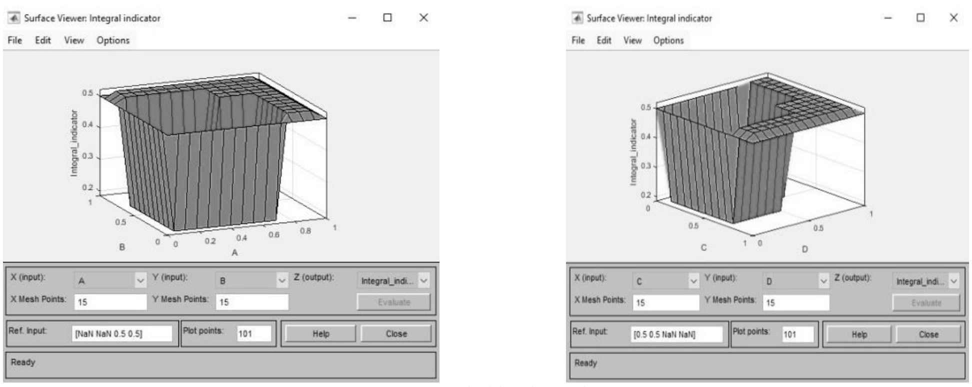
Source: compiled by the authors.

Figure 5. Fragment of rule input for obtaining the integral indicator of barriers to the implementation of SMART logistics infrastructure projects in Matlab software



Source: compiled by the authors.

Figure 6. Graphical representation of the integral indicator for assessing barriers to the implementation of SMART logistics infrastructure projects (obtained in Matlab software environment)



Source: compiled by the authors.

Fig. 6 shows the graphical interpretation of the integral indicator for assessing barriers to the implementation of SMART logistics infrastructure projects in the Matlab environment. Depending on the combination of aggregate indicators A, B, C, D, a total of 6 such integrated indicator surfaces can be obtained. Projects (obtained in Matlab software environment).

The model of comprehensive assessment of barriers to the implementation of SMART logistics infrastructure projects is based on the results of an expert survey and includes the most relevant barriers to the implementation of SMART logistics infrastructure projects in Ukraine.

Thus, the structure of the integral indicator for assessing barriers to the implementation of SMART logistics infrastructure projects may change. Additionally, the model is specifically designed for Ukrainian realities, and the structure of the integral indicator may vary significantly depending on the conditions of each specific country.

The developed model was tested for the integrated assessment of barriers to the implementation of two projects:

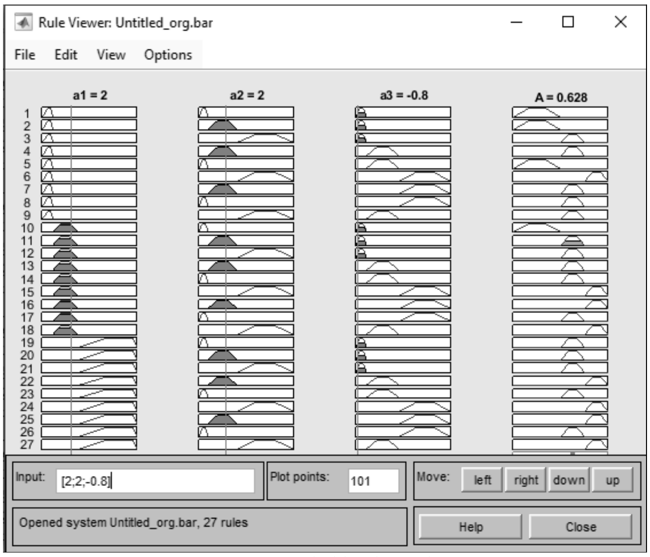
№1. Project "Smart Energy Consumption, Use of Renewable and Alternative Energy Sources".

№2. Project "Smart Parking".

The values of input indicators were obtained based on the analysis of secondary information regarding expert surveys (Removing Barriers to Increase Investment in Energy Efficiency in Public Buildings in Ukraine through the ESCO Modality in Small and Medium-Sized Cities, 2021).

The integrated indicator for assessing the barriers to the implementation of these projects was obtained using the developed fuzzy model. The defuzzification of intermediate modules to the final level of the developed fuzzy model is shown in Fig. 7 for Project No. 1 and in Appendix A, Fig. A.5 for Project No. 2.

Figure 7. Defuzzification of data to the final level of the developed Fuzzy model – Integral indicator for assessing barriers to the implementation of SMART logistics infrastructure projects for project № 1 (fragment)



Source: compiled by the authors.

The results of the calculation of the integral indicator for assessing barriers to the implementation of two SMART logistics infrastructure projects are presented in Table 4. For Project No. 1, the indicator value was 0.835, corresponding to the linguistic evaluation of "high level of barriers." For Project No. 2, the indicator value was 0.518, corresponding to the linguistic evaluation of "moderate level of barriers".

Table 4. Input, generalised indicators, and resulting integral indicator for assessing barriers to the implementation of SMART logistics infrastructure projects

Project, Expert rating range		Assessment of Barriers to the Implementation of SMART Logistics Infrastructure Projects																
		Organizational Barriers Level (A)				Political Barriers Level (B)				Financial Barriers Level (C)				Technological Barriers Level (D)				
		.Lack of effective anti-corruption policy and transparency of financial flows (a1)	Lack of decentralization and autonomy of decisions (a2)	Insufficient number of highly qualified personnel (a3)	Organizational Barriers Level (A)	La Insufficient level of political will of the central and local authorities (b1)	Insufficient involvement of stakeholders in public initiatives and events (b2)	Lack of an investment road map of the development of SMART technologies (b3)	Political Barriers Level (B)	Lack of financial resources (c1)	Excessively high investment costs (c2)	Lack of a methodology of SMART projects effectiveness during and after the construction of a smart city (c3)	Financial Barriers Level (C)	Technical and technological barriers (d1)	Low level of skills in society (local innovative communities) in the field of information technology (d2)	Inadequacy of state and non-state drivers of the development of smart technologies (d3)	Technological Barriers Level (D)	Integral Indicator for Assessing Barriers to the Implementation of SMART Logistics Infrastructure Projects
Expert rating range	min	-1,1	-0,9	-1	0	-0,9	-1,1	-1,3	0	-1,1	-0,9	-1,1	0	-1	-1,4	-2,3	0	0
	max	9	9,2	8,8	1	9,2	8,1	8,8	1	5,8	5,1	8,1	1	9	8,8	7,6	1	1
Project 1		2	2	-0,8	0,628	9	4,3	8,5	0,875	5,5	4,5	6	0,875	8,5	2	-1	0,628	0,835
Barrier level for Project 1		moderate	moderate	low	moderate	high	moderate	high	high	high	moderate	high	high	high	moderate	low	moderate	high
Project 2		1,8	2.8	-0,2	0,628	2	2	1	0,628	1	2,5	2,5	0,628	2,2	1,5	-0,5	0,628	0,518
Barrier level for Project 2		moderate	moderate	low	moderate	moderate	moderate	moderate	moderate	moderate	moderate	moderate	moderate	moderate	moderate	low	moderate	moderate

Source: compiled by the authors.

According to Table 3, the high level of barriers for Project 1 is due to the high values of the summary indicators "Political Barriers Level" (B) and "Financial Barriers Level" (C), which correspond to the linguistic assessment of a "high level" and are 0.875. Thus, Project 1 faces significant obstacles to implementation, primarily related to the lack of an appropriate strategy and political will at both the national and regional/local levels. Regarding financial barriers, the main issues include insufficient financial resources in both state and local budgets, lack of investment, and the absence of clear quantitative and qualitative indicators of SMART logistics infrastructure projects' effectiveness.

For Project 2, all summary indicators correspond to a "moderate level," which indicates a higher priority for the implementation of this project compared to Project 1. This project could lead to better economic performance for cities (territories), improved parking process productivity, reduced service prices, and better local budget revenues.

The developed fuzzy model for assessing barriers for SMART logistics infrastructure projects, as part of the smart city management system, combines a large number of barriers into a single indicator that allows determining the overall level of barriers and riskiness of certain urban logistics infrastructure modernisation projects.

The relevance of integrated assessment of barriers and priorities for infrastructure projects based on hybrid models is supported by many researchers, including Kaczorek, Jacyna (2022), Bošnjak, Jajac (2023), Tabatabai et al. (2023), and Salimian et al. (2022), with nearly all emphasising the advantages of fuzzy set theory.

At the same time, the identification and establishment of barrier levels for infrastructure projects can only be achieved through expert surveys, which require determining the composition and number of experts, selecting possible barriers, conducting surveys, and processing results. The composition of experts can significantly influence the results. Expert subjectivity and the composition of expert groups can significantly influence the results of expert surveys, which explain the appropriateness of using hybrid models and employing several methods to obtain more reliable results for the prospects of SMART logistics infrastructure development projects.

The developed fuzzy model for assessing barriers to SMART logistics infrastructure projects has certain application limitations, as it is based on expert survey results conducted in Ukraine. At the same time, the list of barriers for the formation of an integral indicator of their assessment was formed on the basis of a literature review of world literature, which expands the geography of possible application of the obtained fuzzy model.

This model is not static and requires further refinement concerning the list and significance of barriers, depending on the stage of SMART technology implementation in urban infrastructure, the pace, and issues of economic development of countries, and Industry 4.0 trends. Therefore, future research could focus on refining the composition and significance of barriers, risks, and priorities for the implementation of SMART logistics infrastructure projects worldwide.

Conclusion

The study aimed to identify critical obstacles that hinder the implementation of SMART infrastructure logistics projects in smart city management systems and to develop a model for a comprehensive assessment of barriers to the implementation of such projects.

The generalisation of theoretical sources allowed for the justification of the importance of assessing barriers to SMART logistics infrastructure projects as a structural element in the smart city management system; the development of a fuzzy model for this assessment can be considered a contribution to the methodological support of smart city management.

The developed fuzzy model for assessing barriers to the implementation of SMART logistics infrastructure projects encompassed four groups of barriers: organisational, political, financial, and technological barriers, covering the 12 most significant obstacles to the realisation of SMART logistics infrastructure projects.

The results of testing this model for the integrated assessment of barriers to the implementation of two projects: "Smart Energy Consumption, Use of Renewable and Alternative Energy Sources" and "Smart Parking," confirmed the potential for practical application in establishing project prioritization, identifying the most significant obstacles hindering the intellectualisation of logistics infrastructure, and addressing these obstacles through the most effective methods.

The advantage of the obtained model is its objectivity and informativeness, thanks to the use of the results of an expert survey in Ukraine and practical application in the assessment of barriers and prioritisation of individual SMART logistics infrastructure projects.

Systematic assessment of barriers for SMART logistics infrastructure projects, taking into account the rapid development of smart cities and deep intellectualization of smart city management systems based on SMART technologies, is a dynamic process that requires theoretical justification and consideration of modern key concepts, methods and trends, depends on changes in many factors, and also requires the use of appropriate mathematical tools. This can be considered as a direction for further scientific research.

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APPENDIX A

Table A.1 Properties of SMART logistics infrastructure projects in the context of barriers to their implementation

№	Author	Properties of logistics SMART infrastructure projects	Barriers
1	Malagon-Su´arez, Orjuela-Castro (2023)	High implementation costs; use of new technologies requires highly qualified personnel; a specific strategic orientation is necessary; companies must not only ensure integration of new technologies but also acquire new knowledge.	Insufficient number of highly qualified personnel (a3) Low level of skills in society (local innovative communities) in the field of information technology (d2)
2	Ozturk, Yildizbasi (2020)	Barriers to digitisation: technical, technological, and security; resources (human and financial); organisational-social; environmental and cultural.	Lack of financial resources (c1) Technical and technological barriers (d1)
3	Ozturk, Yildizbasi (2020)	Organisational barriers, including: bureaucracy and centralisation in enterprises; rigid control systems leading to reluctance to collaborate with partners, reluctance to share information about new solutions due to the need to protect market competitiveness; unwillingness to make internal changes that require significant effort and allocation of specific resources.	Lack of decentralisation and autonomy of decisions (a2)
4	Vasek et al. (2014)	Low level of skills in society in the field of information technology and use of modern systems, including security rules; lack of complete data security despite the use of cryptographic protection methods.	Low level of skills in society (local innovative communities) in the field of information technology (d2) Inadequacy of state and non-state drivers of the development of smart technologies (d3)
5	Swan (2015)	Low level of accessibility in the field of information technology to the average user.	Low level of skills in society (local innovative communities) in the field of information technology (d2)
6	Bohme et al. (2015)	Lack of financial resources and excessively high investment costs.	Lack of financial resources (c1) Excessively high investment costs (c2)
7	Hülsmann, Windt (2007)	Need to ensure decentralisation and autonomy of decisions.	Lack of decentralisation and autonomy of decisions (a2)
8	Xenou et al. (2022)	Need for the city administration to provide general resources to create a more sustainable and smart logistics environment; promoting the process of stakeholder engagement, which is essential for the viability of public initiatives and activities.	Insufficient involvement of stakeholders in public initiatives and events (b2) Low level of skills in society (local innovative communities) in the field of information technology (d2)
9	Omelyanenko,Omelianenko (2023)	Need for national strategic plans for sustainable development of territories through service provision design and use	Low level of skills in society (local innovative

№	Author	Properties of logistics SMART infrastructure projects	Barriers
		of local innovative community resource potential within pilot infrastructure and service projects.	communities) in the field of information technology (d2)
10	Myeong et al. (2018)	Government efforts to build a smart city correlate with the political will of the central government. Government policy should always be considered alongside the political will of local authorities.	Insufficient level of political will of the central and local authorities (b1) Insufficient involvement of stakeholders in public initiatives and events (b2)
11	Mitchell (2022)	In many cases, administrative capacity and legal framework are inadequate for implementing new technologies, especially when projects cross jurisdictional boundaries between local and national authorities. Effective partnerships and collaboration among various stakeholders are necessary for successful project implementation.	Inadequacy of state and non-state drivers of the development of smart technologies (d3)
12	Mitchell (2022)	A comprehensive anti-corruption policy is needed, particularly relevant for parties involved in physical infrastructure projects. Their integrity departments should be able to use advanced artificial intelligence tools to detect (and possibly predict) signs of corruption (i.e., red flags) in construction projects through access to data from electronic procurement systems and building information/modelling management software. This will, in turn, lead to better economic performance and productivity, reduced costs, and decreased poverty.	Lack of effective anti-corruption policy and transparency of financial flows (a1)
13	1. Guenduez et al. (2024)	Implementation of SMART projects depends on SMART managers (who represent specific management institutions) who can prioritise certain activities based on objectives, constraints, and potential trade-offs between creating, maintaining, and disrupting SMART infrastructure operations.	Insufficient number of highly qualified personnel (a3)
14	Flynn et al. (2018)	Infrastructure projects require clear definitions of funding flows; the business model for an infrastructure project determines who will fund the project and bear risks, who will pay for infrastructure services, and who will generate revenue from the project.	Lack of effective anti-corruption policy and transparency of financial flows (a1)
15	1. Li et al (2018)	Measuring the effectiveness of smart city construction is a fundamental and long-term task for the sustainable development of cities	Lack of methodology for assessing the effectiveness of SMART projects during and after the construction of a smart city (c3)

№	Author	Properties of logistics SMART infrastructure projects	Barriers
16	Fang et al (2022)	It is necessary to comprehensively evaluate the potential consequences of the investment strategy and rationally decide on the investment roadmap. Particularly for cities with limited budgets, priority should be given to areas with the highest expected cost-to-benefit ratios.	Lack of an investment road map for the development of SMART technologies (b3) Inadequacy of state and non-state drivers of the development of smart technologies (d3)
17	Almaqashi (2019)	A consortium of experts covering various disciplines is crucial for the strategic definition and implementation of SMART city initiatives. This interdisciplinary assembly includes professionals from economics, sociology, engineering, information and communication technologies (ICT), politics, and management.	Inadequacy of state and non-state drivers of the development of smart technologies (d3)
18	1. Washburn et al. (2009)	IT directors in the era of smart cities must demonstrate leadership by showcasing ICT knowledge for the successful development of smart cities, including long-term funding skills, proper distribution of experience, employee education, staff responsibilities, and system standardisation and compatibility.	Inadequacy of state and non-state drivers of the development of smart technologies (d3)
19	Fang, Shan (2022)	In SMART projects, citizens often passively accept top-down services rather than expressing bottom-up opinions. As citizens are the most critical users of SMART infrastructure, high citizen satisfaction should be one of the primary goals of its construction. Citizen perception should be fully considered not only when measuring the effectiveness of smart city construction but also before, during, and after the construction of the smart city.	Lack of methodology for assessing the effectiveness of SMART projects during and after the construction of a smart city (c3) Low level of skills in society (local innovative communities) in the field of information technology (d2)
20	Fang, Shan (2022)	The city government should enhance the analysis of project requirements using surveys or other methods during the smart city design phase. After the implementation of smart city projects, a post-evaluation mechanism can support ongoing improvement of the projects.	Lack of methodology for assessing the effectiveness of SMART projects during and after the construction of a smart city (c3)

Source: compiled by the authors.

Table A.2 Input Indicators of Organisational Barriers Level (A)

Symbol	Indicator Name	Symbol	Linguistic Rating	Trapezoidal Numbers for Linguistic Variable Values				Experts' Opinion on Barrier Significance
a1	Lack of effective anti-corruption policy and transparency of financial flows	a_{11}	Low Barrier	-1,1	-0,45	-0,2	0,1	Score up to -1,1 from interviewed experts of group No. 1
		a_{12}	Moderate Barrier	0	0,9	1,8	2,8	Score up to 2,8 from interviewed experts of group No. 2
		a_{13}	High Barrier	2,7	5,63	8,56	9	Score up to 9,0 from interviewed experts of group No. 3
a2	Lack of decentralisation and autonomy of decisions	a_{21}	Low Barrier	-0,9	-0,56	-0,23	0,1	Score up to -0,9 from interviewed experts of group No. 3
		a_{22}	Moderate Barrier	0	1,07	2,14	3,2	Score up to 3,2 from interviewed experts of group No. 2
		a_{23}	High Barrier	3,1	5,13	7,16	9,2	Score up to 9,2 from interviewed experts of group No. 1
a3	Insufficient number of highly qualified personnel	a_{31}	Low Barrier	-1	-0,63	-0,26	0,1	Score up to -1,0 from interviewed experts of group No. 1
		a_{32}	Moderate Barrier	0	1,17	2,34	3,5	Score up to 3,5 from interviewed experts of group No. 2
		a_{33}	High Barrier	3,4	5,2	7,0	8,8	Score up to 8,8 from interviewed experts of group No. 3

Source: compiled by the authors.

Table A.3. Input Indicators of Political Barrier Levels (B)

Symbol	Indicator Name	Symbol	Linguistic Rating	Triangular and for Linguistic Variable Values				Experts' Opinion on Barrier Significance
b1	Insufficient level of political will of the central and local authorities	b_{11}	Low Barrier	-0,9	-0,56	-0,23	0,1	Score up to -0,9 from interviewed experts of group No. 1
		b_{12}	Moderate Barrier	0	1,1	2,2	3,3	Score up to 3,3 from interviewed experts of group No. 2
		b_{13}	High Barrier	3,2	5,2	7,2	9,2	Score up to 9,2 from interviewed experts of group No. 3
b2	Insufficient involvement of stakeholders in public initiatives and events	b_{21}	Low Barrier	-1,8	-1,17	-0,54	0,1	Score up to -1,8 from interviewed experts of group No. 1
		b_{22}	Moderate Barrier	0	0,83	1,66	2,5	Score up to 2,5 from interviewed experts of group No. 2
		b_{23}	High Barrier	2,4	4,3	6,2	8,1	Score up to 8,1 from interviewed experts of group No. 3
b3	Lack of an investment road map of the development of SMART technologies	b_{31}	Low Barrier	-1,3	-0,83	-0,36	0,1	Score up to -1,3 from interviewed experts of group No. 3
		b_{32}	Moderate Barrier	0	1,13	2,26	3,4	Score up to 3,4 from interviewed experts of group No. 2
		b_{33}	High Barrier	3,3	5,13	6,96	8,8	Score up to 8,8 from interviewed experts of group No. 1

Source: compiled by the authors.

Table A.4. Input Indicators of Financial Barriers Level (C)

Symbol	Indicator Name	Symbol	Linguistic Rating	Trapezoidal Numbers for Linguistic Variable Values				Experts' Opinion on Barrier Significance
c1	Lack of financial resources	c_{11}	Low Barrier	-1,1	-0,7	-0,3	0,1	Score up to – 1,1 from interviewed experts of group No. 2
		c_{12}	Moderate Barrier	0	1,05	2,1	3,2	Score up to 3,2 from interviewed experts of group No. 1
		c_{13}	High Barrier	3,1	4,0	4,9	5,8	Score up to 5,8 from interviewed experts of group No. 3
c2	Excessively high investment costs	c_{21}	Low Barrier	-0,9	-0,55	-0,21	0,13	Score up to -0,9 from interviewed experts of group No. 2
		c_{22}	Moderate Barrier	0	1,41	2,78	4,2	Score up to 4,2 from interviewed experts of group No. 3
		c_{23}	High Barrier	4,1	4,41	4,75	5,1	Score up to 5,1 from interviewed experts of group No. 1
c3	Lack of a methodology of SMART projects effectiveness during and after the construction of a smart city	c_{31}	Low Barrier	-1,7	-1,1	-0,5	0,1	Score up to -1,7 from interviewed experts of group No. 3
		c_{32}	Moderate Barrier	0	1,37	2,74	4,1	Score up to 4,1 from interviewed experts of group No. 1
		c_{33}	High Barrier	4	5,37	6,74	8,1	Score up to 8,1 from interviewed experts of group No. 2

Source: compiled by the authors.

Table A.5. Input Indicators of Technological Barriers Level (D)

Symbol	Indicator Name	Symbol	Linguistic Rating	Trapezoidal Numbers for Linguistic Variable Values				Experts' Opinion on Barrier Significance
d1	Technical and technological barriers	d_{11}	Low Barrier	-1	-0,63	-0,26	0,1	Score up to -1,0 from interviewed experts of group No. 1
		d_{12}	Moderate Barrier	0	1,1	2,2	3,3	Score up to 3,3 from interviewed experts of group No. 2
		d_{13}	High Barrier	3,2	5,13	7,06	9	Score up to 9,0 from interviewed experts of group No. 3
d2	Low level of skills in society (local innovative communities) in the field of information technology	d_{21}	Low Barrier	-1,4	-0,8	-0,2	0,36	Score up to -1,4 from interviewed experts of group No. 3
		d_{22}	Moderate Barrier	0,18	2,52	4,86	7,22	Score up to 7,22 from interviewed experts of group No. 1
		d_{23}	High Barrier	7,04	7,62	8,2	8,8	Score up to 8,8 from interviewed experts of group No. 2
d3	Inadequacy of state and non-state drivers of the development of smart technologies	d_{31}	Low Barrier	-2,3	-1,7	-1,1	-0,48	Score up to -2,3 from interviewed experts of group No. 1
		d_{32}	Moderate Barrier	-0,58	0,8	2,19	3,56	Score up to 3,56 from interviewed experts of group No. 2
		d_{33}	High Barrier	3,46	4,84	6,23	7,6	Score up to 7,6 from interviewed experts of group No. 3

Source: compiled by the authors.

Table A.6. Rules for Assessing the Level of Organisational Barriers (A)
(A_1 Low Barrier; A_2 Moderate Barrier; A_3 High Barrier)

No.	Component Combinations			Component Combinations (or/and)	Organizational Barriers A
1	a_{11}	a_{21}	a_{31}	and	A_1
2	a_{11}	a_{22}	a_{31}	and	A_1
3	a_{11}	a_{23}	a_{31}	and	A_2
4	a_{11}	a_{22}	a_{32}	and	A_2
5	a_{11}	a_{21}	a_{32}	and	A_1
6	a_{11}	a_{23}	a_{33}	and	A_2
7	a_{11}	a_{22}	a_{33}	and	A_2
8	a_{11}	a_{21}	a_{33}	and	A_2
9	a_{11}	a_{23}	a_{32}	and	A_2
10	a_{12}	a_{21}	a_{31}	and	A_1
11	a_{12}	a_{22}	a_{31}	and	A_2
12	a_{12}	a_{23}	a_{31}	and	A_2
13	a_{12}	a_{22}	a_{32}	and	A_2
14	a_{12}	a_{21}	a_{32}	and	A_2
15	a_{12}	a_{23}	a_{33}	and	A_3
16	a_{12}	a_{22}	a_{33}	and	A_2
17	a_{12}	a_{21}	a_{33}	and	A_2
18	a_{12}	a_{23}	a_{32}	and	A_2
19	a_{13}	a_{21}	a_{31}	and	A_2
20	a_{13}	a_{22}	a_{31}	and	A_2
21	a_{13}	a_{23}	a_{31}	and	A_2
22	a_{13}	a_{22}	a_{32}	and	A_2
23	a_{13}	a_{21}	a_{32}	and	A_2
24	a_{13}	a_{23}	a_{33}	and	A_3
25	a_{13}	a_{22}	a_{33}	and	A_3
26	a_{13}	a_{21}	a_{33}	and	A_2
27	a_{13}	a_{23}	a_{32}	and	A_3

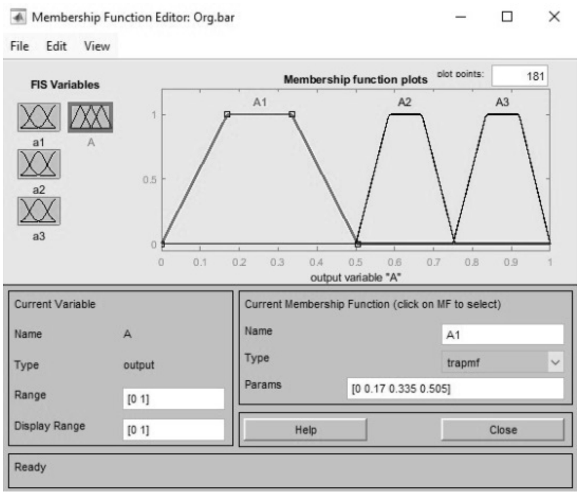
Source: compiled by the authors.

Table A.7 Rules for Forming the Integral Indicator of Barriers Assessment for SMART Logistics Infrastructure Projects (I)
(I_1 Low Barriers; I_2 Moderate Barriers; I_3 High Barriers) (fragment)

No.	Component Combinations				Component Combinations (or/and)	Integral Indicator of Barriers Assessment for SMART Logistics Infrastructure Projects
1	A_1	B_1	C_1	D_1	and	I_1
2	A_1	B_2	C_1	D_1	and	I_1
3	A_1	B_1	C_1	D_2	and	I_1
4	A_1	B_2	C_1	D_2	and	I_2
5	A_2	B_1	C_1	D_1	and	I_1
6	A_2	B_2	C_1	D_1	and	I_2
7	A_2	B_1	C_1	D_2	and	I_2
	…..	……	….	…..	…..	…..
73	A_3	B_2	C_1	D_2	and	I_2
74	A_3	B_2	C_1	D_3	and	I_2
75	A_3	B_2	C_2	D_1	and	I_2
76	A_3	B_2	C_2	D_2	and	I_2
77	A_3	B_2	C_2	D_3	and	I_3
78	A_3	B_3	C_1	D_1	and	I_2
79	A_3	B_3	C_2	D_1	and	I_2
80	A_3	B_3	C_2	D_2	and	I_3
81	A_3	B_3	C_2	D_3	and	I_3

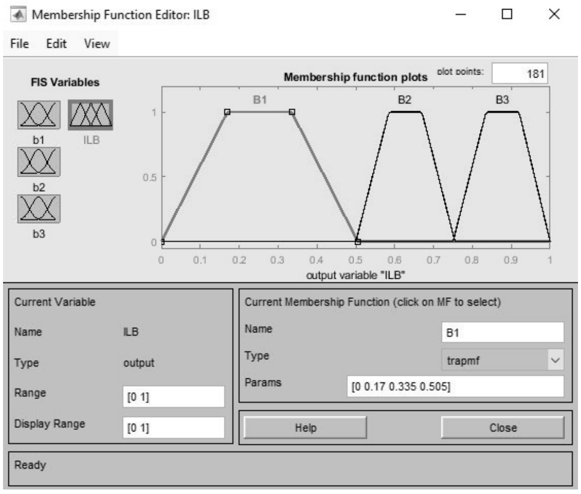
Source: compiled by the authors.

Figure A.1. General Indicator of Organisational Barriers Assessment (A1) in the Form of a Membership Function Editor (obtained using Matlab software)



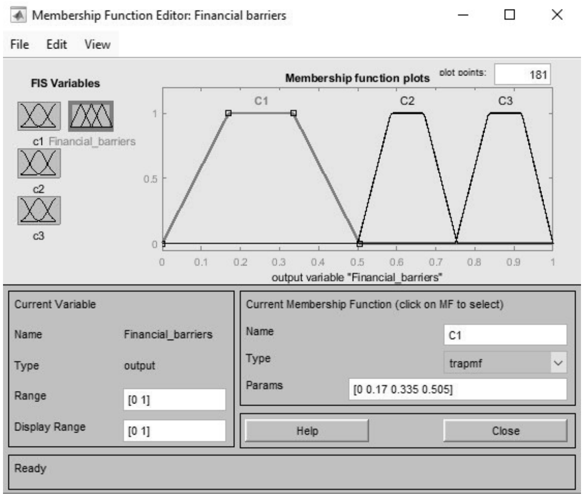
Source: compiled by the authors.

Figure A.2. General Indicator of Political Barriers Assessment (B1) in the Form of a Membership Function Editor (obtained using Matlab software)



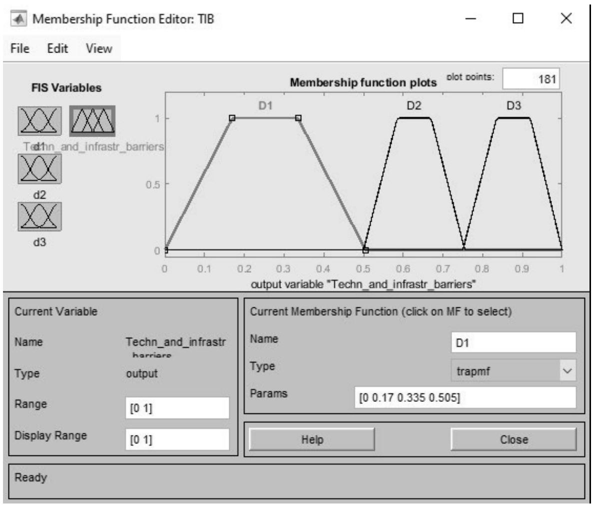
Source: compiled by the authors.

Figure A.3. General Indicator of Financial Barriers Assessment (C1) in the Form of a Membership Function Editor (obtained using Matlab software)



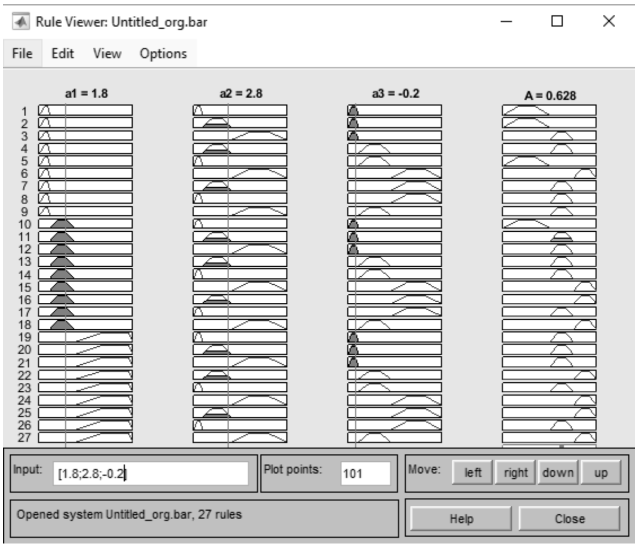
Source: compiled by the authors.

Figure A.4. General Indicator of Technological Barriers Assessment (D1) in the Form of a Membership Function Editor (obtained using Matlab software)



Source: compiled by the authors.

Figure A.5. Defuzzification of Data to the Final Level of the Developed Fuzzy Model – Integral Indicator of Barriers Assessment for SMART Logistics Infrastructure Projects for Project No. 2. (fragment)



Source: compiled by the authors.