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INNOVATIVE PRO-ENVIRONMENTAL TECHNOLOGIES AND THE MODEL OF PUBLIC MANAGEMENT IN SUBURBAN ZONES IN POLAND

INNOWACYJNE ROZWIĄZANIA PROŚRODOWISKOWE A MODEL ZARZĄDZANIA PUBLICZNEGO W STREFACH PODMIEJSKICH W POLSCE

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Abstract

Research on suburban zones, which has been carried out for many years, allows us to assume that, as in the case of urban space, suburban zones are predestined to become smart spaces. The smart city, as proposed by Komninos (2019), is understood broadly as an urban region, of which the suburban zone is the second component next to the large city. However, while new technologies are present in cities as innovation centres, their diffusion may be much slower and more diverse in suburban zones, which have been developing in Poland since as late as the system transition.

This paper addresses the presence of innovative pro-environmental technologies (IPTs) in suburban zones in Poland in the light of social research. The presence of these solutions was considered in the context of the public management model. The primary data source was a nationwide survey conducted on a representative sample of 939 respondents.

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The survey showed that innovative pro-environmental solutions developed in suburban communes strongly depend on the governance model. The more traditional the management model, the less innovative commune. The most valuable public management model involves all users of space. Research indicates that the closer it is to a participatory approach, the more effectively innovative pro-environmental solutions are implemented.

Keywords: pro-environmental innovation, innovative pro-environmental technology, public management model, smart governance, suburban zone.

Streszczenie

Prowadzone od wielu lat badania nad strefami podmiejskimi pozwalają przyjąć, że podobnie jak w przypadku przestrzeni miejskiej, strefy podmiejskie są predestynowane do stania się przestrzeniami inteligentnymi. Inteligentne miasto, zgodnie z propozycją Komninosa (2019), rozumiane jest szeroko, również jako region miejski, którego drugim – obok dużego miasta – komponentem jest strefa podmiejska. O ile jednak nowe technologie są obecne w miastach jako centrach innowacji, o tyle ich rozprzestrzenianie się może być znacznie wolniejsze i bardziej zróżnicowane w strefach podmiejskich, które rozwijają się w Polsce dopiero od czasu transformacji ustrojowej.

W niniejszym artykule podjęto problematykę obecności innowacyjnych rozwiązań prośrodowiskowych (IPT) w strefach podmiejskich w Polsce w świetle badań społecznych. Obecność tych rozwiązań rozpatrzono w kontekście modelu zarządzania publicznego. Głównym źródłem danych był ogólnopolski sondaż przeprowadzony na reprezentatywnej próbie 939 respondentów.

W badaniu wykazano, że innowacyjne rozwiązania prośrodowiskowe w gminach podmiejskich są silnie uzależnione od modelu zarządzania. Im bardziej tradycyjny model zarządzania, tym mniej innowacyjna gmina. Należy podkreślić, że najbardziej wartościowy model zarządzania publicznego, to model angażujący wszystkich użytkowników przestrzeni. Jak wskazują badania, im jest on bliższy partycypacyjnemu założeniu, tym skuteczniej implementowane są innowacyjne rozwiązania prośrodowiskowe w myśl zasady zrównoważonego rozwoju.

Słowa kluczowe: innowacje prośrodowiskowe, model zarządzania publicznego, smart governance, strefa podmiejska.

INTRODUCTION

In the face of ongoing urbanisation processes, suburban zones are being transformed, becoming an extension of urban spaces and autonomous areas with the potential to implement smart solutions. This is an important issue because, in the light of ongoing research (Komninos, 2019), the suburban zone is a vital component of an innovative urban region that co-creates with the city that produces it. However, while new solutions are present in cities as innovation centres, their

diffusion may be much slower and more diverse in suburban zones, which have been developing in Poland since as late as the system transition.

The purpose of this study is to examine whether the presence of innovative pro-environmental technologies (IPTs) in suburban zones is linked to the public management model. The primary data source was a nationwide survey conducted on a representative sample of 939 respondents living in different regions of the country. The study took the subjective opinions of residents as its starting point. Their observations were used to determine (1) what IPTs are present in a suburban space and what their saturation in this regard is; (2) how they perceive the governance of a given commune that is their place of residence, which made it possible to identify governance models; (3) whether there is a relationship between the highlighted models and the scale of IPTs implemented in the public space. In doing so, it was assumed that the public management model would determine the saturation of suburban space with IPTs. The more traditional commune with a managerial model of management (referring to New Public Management), the less susceptible it will be to the introduction of innovative solutions, and vice versa, the more participatory the model of commune management (close to Smart Governance), the greater the presence of IPTs and the greater the importance attributed to these solutions by residents.

Already at the outset, the very concept of innovative pro-environmental technologies (IPTs) requires some clarification. In the study, we will understand them as solutions available to the communes of a given area aimed at achieving the set environmental goals that are part of sustainable development (Cooper-Ordonez et al., 2019; Klaniecki et al., 2019; Manoli et al., 2019; Skene, 2021; Topal et al., 2021; Ziegler, 2021; Lim, 2022). The implementation of such solutions aims to reduce the anthropogenic burden on the environment and its resources. Pro-environmental innovations are most often equated with eco-innovations, which is quite an oversimplification (Sehnem et al., 2016; Almeida, Melo, 2017; Freire, 2018; Alshammari, Alshammari, 2023).

Indeed, eco-innovation is defined as a material element. However, the term eco-innovation itself has a broader connotation, primarily encompassing the thought process as well as decision-making processes. Therefore, improvements to existing technical solutions, as well as approaches to space management (De Jesus, Mendonca, 2018; Kasmi et al., 2022; Koval et al., 2022; Thakur, Wilson, 2023) that aim to reduce environmental impacts and induce changes in socio-cultural norms and institutional structures are also considered eco-innovations (Parashiv et al, 2012; Sheehy, Farneti, 2021). Therefore, depending on the approach, eco-innovation can be understood in two ways: as pro-environmental technologies and as innovative pro-environmental technologies. By adopting the first way of understanding eco-innovation, we redirect attention to pro-environmental technologies, i.e. modern technological solutions that minimise the nega-

tive impact of human activity on the environment. These technologies enable full recycling of materials, low-waste production, and the development of a circular economy. The goal of these technologies is not only to reduce human damage to the environment but also to bring economic benefits and, equally valuable, to shape the image of those implementing them (Andabaka et al., 2019; Ahmad et al., 2021; Domaracká et al., 2023). The second proposed approach focuses on innovative pro-environmental technologies, including both pro-environmental technologies and space management aspects. Therefore, it includes products, services, technologies, and practices that protect the environment and promote sustainable development. Examples of such solutions can include waste management systems that enable recycling and reuse, clean energy technologies, and business models that support sustainable consumption and production (Spangenberg et al., 2010; Staniškis, 2012; Vergragt et al., 2014). In line with the second, broader approach to eco-innovation, we will also use the term innovative pro-environmental technologies (hereafter referred to as IPTs) in this study.

LITERATURE BACKGROUND OF THE CONDUCTED RESEARCH

Nowadays, it is accepted that urbanisation is one of the main processes shaping the settlement network, but it also affects society, the economy, and the environment (Antrop, 2004; Seto et al., 2010). As recently as the 1950s, the percentage of the population living in cities was 30%; by the end of the first decade of the 21st century – it had equalled the percentage living in rural areas, and by 2050, according to UN estimates, it will be 66% (United Nations, Department of Economic and Social Affairs, Population Division, 2018). Such rapidly increasing numbers, percentages of urban populations and the rapidly increasing number of large cities worldwide are not without their multifaceted impact on urban functioning (Davis, 2011; Buhaug, Urdal, 2013). In general, however, their sustainable development requires the search for new solutions that respond to the challenges of urbanisation and provide an opportunity to improve the quality of urban life (Berke, Conroy, 2000; Ruggerio, 2021; Lim, 2022).

The innovative city concept, i.e. the smart city, is considered one such solution (Yin et al., 2015; Zubizaretta et al., 2016; Eremia et al., 2017). The first attempts to implement this concept were limited to modern information and communication technologies (ICT). Thus, it was assumed that the problems resulting from urbanisation could be solved if the vast city's space was saturated with devices that would allow data collection. These, in turn, will be the basis for efficient management of resources and services, which will improve the functioning of cities. This approach has received much criticism of the smart city concept (Kummitha, Crutzen, 2017; Zhao et al., 2021), and at the same time, its redefinition and expansion to include new aspects that would offer a real opportunity to improve the

quality of urban life. The first approach, Generation 1.0 or the technocratic era, was considered too focused on infrastructure improvements. This was because it was concentrated on smart solutions, such as smart lighting and traffic monitoring systems. These solutions were mainly introduced on the initiative of city governments or large ICT corporations and were aimed at increasing operational efficiency and reducing the cost of city management. A lack of recognition among users of urban space as to whether these solutions are needed and to what extent they solve real problems in cities was cited as their fundamental weakness.

Criticism of the rather narrow understanding of the smart city concept of Generation 1.0 gave rise to the development of Generation 2.0, also known as the era of cooperation. In this generation, main emphasis is put on the activities of public administration, i.e. local authorities, which first diagnose problems in the city and then, using ICT technologies, try to solve them. As it turned out, the weakness of this generation was the assumption that officials, identified with skilled managers, decide for themselves which projects should be implemented in the city. In practice, these are often implemented top-down with insufficient consultation with residents. Once again, therefore, critical voices have become the basis for developing the next generation of smart cities. Generation 3.0, also known as the era of resident-oriented smart cities, not only focuses on the needs of users of urban space but also actively involves them in shaping and managing the city. The role of local authorities is, therefore, to create spaces for joint meetings and dialogue, which are the basis of public participation. On the other hand, they have to encourage the use of modern technologies that improve life in cities, especially large ones, and to shape urban spaces that are livable, inclusive, and environmentally friendly (Macke et al., 2018; Martin et al., 2018; Aurigi, Odendaal, 2022).

It should also be noted that nowadays more and more dimensions of urban life are included in the smart city concept. According to Cohen's proposal (Cohen et al., 2016, see also Jucevičius et al., 2017; Ceballos, Larios, 2016), the main things to be considered here are (a) *smart people*, i.e. a learning and innovative society that improves the functioning of the city and optimises living conditions in it, (b) *smart economy*, i.e. a creative and innovative economy based on a flexible labour market, (c) *smart environment*, i.e. rational and sustainable use of environmental resources, (d) *smart mobility*, i.e. developing sustainable, low-emission transport systems and supporting active mobility, (e) *smart living*, i.e. ensuring high-quality public services, and (f) *smart governance*, i.e. effective and transparent management of space based on cooperation between a local government, residents, or business, with the use of modern communication technologies. Of the smart city dimensions mentioned above, a unique role is attributed to smart governance (Scholl, Scholl, 2014; Pereira et al., 2018; Tomor et al., 2019), i.e. an optimal governance model that is the basis for initiating and developing new solutions to improve the quality of life.

PUBLIC MANAGEMENT MODELS

The different generations of smart cities are characterised by variations in technological issues, especially in the implementation of public involvement. Along with technological advances, there has been an increase in awareness and participatory inclusion of residents. These elements are also a key differentiator for identifying contemporary public management models. However, it is worth looking at them against the background of solutions considered historical, especially since the variants used in practice are only sometimes clear and in line with the latest trends in the field of governance.

Among the models cited in the literature, many similar concepts appear (Zawicki, 2002; Kożuch, 2004; Zalewski, 2005; Noworól, 2020), but despite minor differences, there is a consensus among most researchers, according to which three models are most often distinguished. These are the Public Administration, New Public Management and Public Governance models. The first, based on assumptions similar to those proposed by Fayol, Wilson and Weber (Weber, 2002; Marks-Krzyszkowska, 2016; Raczyńska, Krukowski, 2020), is sometimes also referred to as the bureaucratic or Weberian model. The 1970s brought its criticism, pointing out that it is inefficient, leads to excessive bureaucratic overgrowth, and does not allow for the efficient use of resources. Significantly, from the perspective of the problem addressed, it is not conducive to the search for innovative solutions, as it prioritises routine paths rather than analytical tasks (Mazur, 2014).

Rapid response to market conditions and expectations of public service recipients (Pfiffner, 2004) was to be provided by a new model implemented in the early 1980s – New Public Management (NPM). It is still recognised in the way local government units operate. Zalewski (2005) points out that it is found in activities covered by strategic management, operational and other activities, including procurement law procedures (Zalewski, 2005). According to Kettl's (2005) characterisation of NPM, it consists of six assumptions: productivity, marketisation, service orientation, decentralisation, policy, and accountability. The introduction of managerial techniques into public sector management, reaching for clearly defined performance standards and indicators, and emphasising the evaluation of outcomes rather than processes (Hood, 1991) are some of the more characteristic features of the NPM model, referred to not without reason as the managerial model.

The use of tools unsuitable for the public sector, transferred from the economic sector, was considered a weakness of this solution, which resulted in a weakened ability to solve structural socio-economic problems where it would be necessary, for example, to consider cultural aspects (Mazur, 2014).

The response to the weaknesses of the NPM model was a shift away from the emphasis placed around government (in the sense of formal state institutions and monopoly in the exercise of power) towards governance (meaning public co-man-

agement, participatory public management) (Marks-Krzyszkowska, 2016). In practice, this means a fundamental change involving transferring some of their powers from public entities to other entities, which opens a framework for close cooperation between partners (Rhodes, 1997, 2007; Stoker, 1998). Rhodes (1997) pointed out its standard features: (1) interdependence between organisations, meaning that many non-state actors play an important role in co-management. The boundaries of state influence running between the private, public, and social sectors become fluid and unclear; (2) continuous interaction between network members: This is brought about by the need to exchange resources and define common goals constantly; (3) game interaction: Network members regulate and negotiate the game's rules; (4) a significant level of independence from the state: The state does not occupy a privileged position. The networks self-organise (Rhodes, 1997, p. 110, after Noworól, 2020).

The popularity of governance is also increasing due to the involvement of institutions such as the World Bank and the European Commission in disseminating the concept, which has even formulated the principles of so-called "good governance". Although the initial premise of the Good Governance concept was to improve the functioning of the public administration, over time, the emphasis began to be placed on improving political conditions in areas related to the democratisation of the state, respect for human rights, freedom of operation of non-governmental organisations, etc. (Raczyńska, Krukowski, 2020).

The concept of governance opens new perspectives on including governance participants in decision-making processes, albeit in different variants. As Noworól (2020) shows, the criterion of participation in decision-making processes and the roles assumed allows moving from Good Governance through Multilevel Governance and New Governance to Neo-Weberism and Rhodes (Noworól, 2020). One can also find a reference to innovative governance in the concept of open cooperation. This is because Smart Governance is understood as public management in which public participation processes in decision-making play an essential role (Noworól, 2012) (Table 1).

Table 1. Management participants in different concepts of public management

Concept	Who participates in governance?
NPM	citizens/residents treated as customers
Good governance	citizens/residents treated as human beings with rights and as stakeholders
Multilevel governance	all stakeholders
New governance	all stakeholders, end of hierarchy, polycentric management
Neo-weberism	citizen with their needs and aspirations
Rhodes	outside the public, networks, participants in the "game"

Source: own elaboration based on Noworól (2012).

INNOVATION OF LOCAL GOVERNMENT ENTITY

Although the level of involvement of various entities in the public management process is the basis for distinguishing its models, they undoubtedly also directly impact the level and forms of social participation. Different management models may enable residents to participate actively in the commune's life.

From the perspective of smart governance, we can also treat public management models as more or less innovative. Models with inclusive features based on co-management are a form of social innovation compared to Weberian or managerial models. The public management model directly influences how its resources, both natural and socio-economic, are used. Research shows a connection between the practice of commune management and the effectiveness of its functioning (Nam, Pardo, 2011; Meijer, Bolivar, 2016; Ruhlandt, 2018). Its innovativeness and susceptibility to implementing changes largely depend on the public management model. The decision-making power of the authorities also influences the directions adopted in the future development of the local government entity. Such attitudes include attitudes towards plans, strategies or the adopted approach to the widely known smart city concept, as indicated above, which is adequate for the city area within its administrative boundaries and its suburban zone. We are currently observing the migration of smart strategies from the city centre to suburban zones (suburbanisation zones).

In principle, the smart strategy includes various approaches to transforming spaces into smart, sustainable, resident-friendly living environments. Implementing such a strategy depends on innovation in six key areas: economy, environment and energy, management and education, life and health, mobility, and safety and security. Seven critical elements of an effective smart strategy should be considered when developing it. These include strategic documents, digital strategy, resilience strategy, cooperation plan with technologies/start-ups, selection of a management model, focus on people and problems, defining the role of technology and a collaborative approach. Without a doubt, the measure of success, apart from the implementation of technology itself, is the social involvement of residents – users of these spaces. Apart from the social reception of the infrastructure, creating a relationship between the resident and the space is crucial when the resident willingly uses the solutions in the space, feeling his presence and measurable agency, especially in pro-environmental issues.

The perspective imposed in this way naturally sanctions the subjective opinions of respondents. They constitute the basis for distinguishing different public management models, and these, in turn, based on the features assessed by respondents, were assigned to the above-described public management models indicated by researchers in the literature. As noted above, there has yet to be a complete agreement in the scientific community as to which models should be

distinguished. For this reason, the adopted categories are conventionally treated as an analogy, not necessarily faithfully reflecting the features of a given concept.

RESEARCH METHODOLOGY

The research problem determined the adopted methodology. The primary data source was a nationwide survey conducted on a probabilistically selected sample of 939 adult Poles, with an estimated statistical error in measurement of a maximum of 3%. The survey was carried out at the end of 2021 using the CAWI (Computer Assisted Web Interview) technique, which involves generating a link to the electronic version of the survey using a particular programme. The respondent can complete it in this form at any time and place, when one can access a device with an Internet connection. A survey conducted using the CAWI technique also offers additional possibilities, including the use of an extended range of functionalities, the inclusion of detailed instructions for respondents, greater clarity of questions and flexibility of the survey itself, and an increased degree of anonymity (Kagerbauer et al., 2013; D'Ancona, 2017). The benefits of using this method and the increasing access to the Internet in Poland mean that over the last decade, almost one-third of all research has been carried out using this technique.

An essential aspect of the study was the sample based on a probabilistic scheme, i.e. relating to probability theory. Such sample selection reflects the characteristics of the population, and the results obtained can be fully generalised to it (Chater et al., 2006; Matoušek, Vondrák, 2008). However, it should be added that the probabilistic sampling model may be based on various variables, most often gender, age and place of residence (Babbie, 2015). This was also done in this study. That is why, the sample included 62.3% of women and 37.7% of men aged from 18 to 83 years old. Most of the respondents declared the higher (47.1%) and secondary (43.6%) level of education. Moreover, the sample was requoted for three separate regions in Poland, which differ during the suburbanisation process. In this case, reference was made to the research of Biegańska (2019), who, based on multivariate analysis, distinguished (1) the suburban zone of Warsaw, which, due to its importance in the hierarchical settlement network, has created the most spatially extensive and most urbanised suburban zone; (2) suburban zones of capital cities in voivodeships (a voivodeship – NUTS 2, region of the 1st order in administrative division in Poland) in western Poland, i.e. in (in alphabetical order): Dolnośląskie, Kujawsko-Pomorskie, Lubuskie, Opolskie, Pomorskie, Śląskie, Warmińsko-Mazurskie, Wielkopolskie, Zachodniopomorskie; (3) suburban zones of capital cities in voivodeships in eastern Poland, i.e. in (in alphabetical order): Lubelskie, Łódzkie, Małopolskie, Podlaskie, Podkarpackie, Świętokrzyskie.

With regard to the division into western and eastern Poland, it should be noted that the voivodeship cities of western Poland, unlike eastern Poland, create a

spatially more extensive suburban zone. The degree of advancement of suburbanisation processes measured, among others, by the inflow of people from cities, the dynamics of changes in the population number, or the number of completed flats for the use per 1,000 people, is higher. The exclusive focus on suburban areas of capital cities in the voivodeships also requires clarification. This criterion is used in the research by Komornicki and Śleszyński (2009), who, while separating the impact zones of large cities among the surrounding rural areas, proposed that the so-called large cities comprise settlements with more than 150,000 inhabitants or performing administrative functions at the voivodeship level. The same authors, when making a functional classification of communes in Poland to monitor spatial planning (Śleszyński, Komornicki, 2016), assigned the most significant importance to the functional urban areas of voivodeship centres, also due to several socio-demographic and functional-spatial characteristics. Therefore, following these guidelines, the study was limited to suburban areas of large cities and capital cities in voivodships were considered such. The only exception was the urbanised area of the Upper Silesian conurbation (in Śląskie Voivodship), in which the suburban zone was extended to communes characterised by intensive suburbanisation processes. Based on the above criteria, it was finally assumed that 1/5 of the respondents would come from the suburban zone of Warsaw, 2/5 – from the suburban zone of voivodeship cities in western Poland, except the mentioned Śląskie Voivodeship and 2/5 – from suburban zones of voivodeship cities in eastern Poland. The collected survey data was coded in IBM SPSS software (version 29), which was used to conduct further statistical analyses.

EMPIRICAL ANALYSIS RESULTS

Demonstrating the relationship between the presence of innovative pro-environmental technologies and the public management model required, first of all, determining what IPTs exist in suburban space and what their saturation in this area is. As demonstrated by social research, the solution most frequently indicated by the respondents was the presence of bins for selective waste collection (52.8%) and the availability of public transport connecting the commune with the nearest large city (50.7%). Further, every third respondent mentioned monitoring of public space (30.5%), and every fourth – facility for disabled people (25.7%) and e-services (24.5%). On the other hand, every fifth respondent indicated ecological road lighting systems (22.1%), renewable energy sources in public buildings (19.3%) and public bicycle systems (18.9%). Respondents said traffic control systems were a relatively rare solution (13.6%). It should be noted, however, that only 13.3% of the respondents stated that there were no solutions of that type in the commune they live in (Fig. 1).

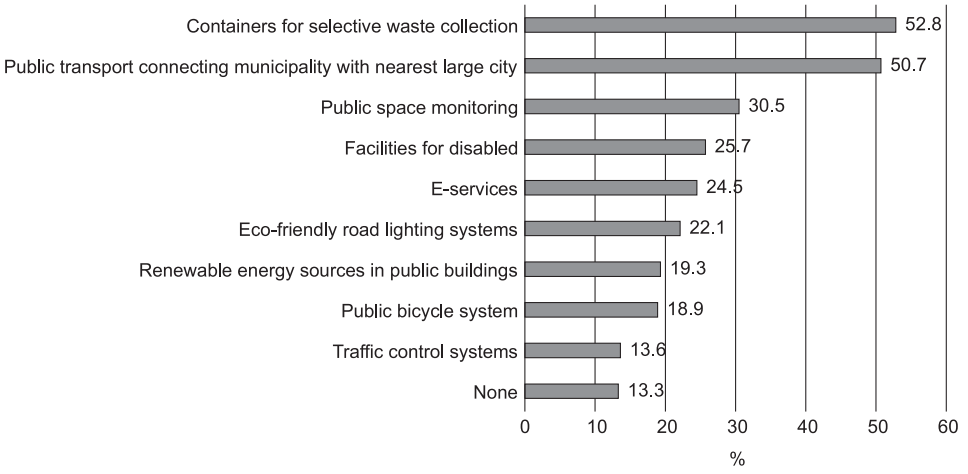

Fig. 1. Structure of responses to the question: "What solutions are available in your commune?" (multiple choice, %)
Source: own compilation based on the survey (N = 939).

Next, the focus was on diagnosing public management models in suburban spaces. As was mentioned in the introduction, these models were diagnosed mainly based on the respondents' indications. Therefore, respondents were first asked which of the proposed descriptions best reflects the situation in the commune where they live. These descriptions were prepared by referring to the models characterised in the theoretical part in the order corresponding to the increasing degree of their innovativeness and inclusiveness: New Public Management (local authorities themselves decide on essential matters in the commune, maintain a distance from residents, treat consultations only as a formality), Public Governance (local authorities respond to the needs of residents, do not introduce innovative solutions, but also do not make it difficult for residents to contact officials) and Smart Governance (local authorities introduce innovative solutions, encourage residents to engage in public consultations and support their initiatives). Among the possible models to choose from, as many as 45.2% of the respondents believed that in their commune, local authorities decided on essential matters themselves, kept their distance from residents, and treated consultations only as a formality, which was tantamount to assigning the management model in their commune to New Public Management. Then, 39.6% of the respondents stated that local authorities responded to the needs of residents but did not introduce innovative solutions and did not make it difficult for residents to contact officials. This allowed the management model in their places of residence to be classified as Public Governance. Against this background, only 15.2% of the respondents said that local authorities introduced innovative solutions, encouraged residents

to engage in public consultations and supported their initiatives. This choice allowed them to assign the management model in their places of residence to Smart Governance (Fig. 2).

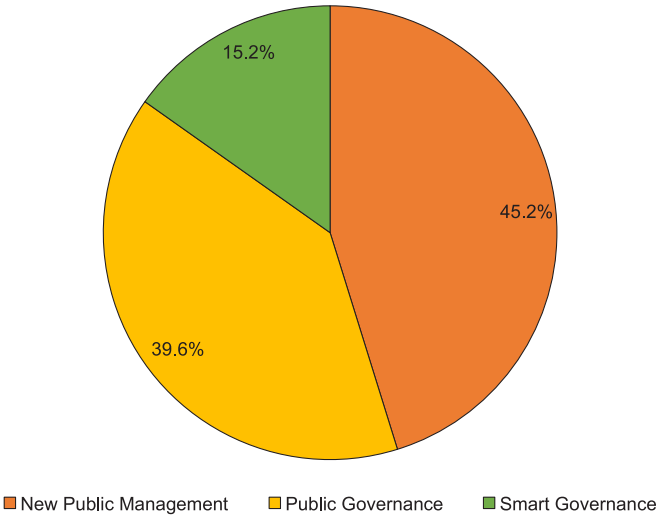

Fig. 2. Structure of responses to the question: "Which of the following best reflects the situation in your commune?" (%)
Source: own compilation based on the survey (N = 939).

The respondents' declarations regarding the indicated public management model in their commune were confronted with additional questions, which were also treated as diagnostic while verifying for a subjective determination of the situation in their place of residence. The first question was: "Do you think that officials expect residents to be involved in decision-making processes?" and were expressed on a three-point scale: 1 – no, 2 – hard to say, 3 – yes. Using the scale constructed in this way, it was possible to calculate the average values of the answers provided for individual public management models. The measure allowed us to formulate a statement that in each subsequent model, the level of support for such a question was higher and higher. For New Public Management, the average score was 1.58; for Public Governance – 1.89; and for Smart Governance – as much as 1.99 (Fig. 3). Analogous answer options were used for the second question, which was: "Do residents feel invited to co-decide on commune matters?" In this case, the average value for the response was also used. Their analysis allowed us to conclude once again that each subsequent model of public management was associated with increasing support for the issue posed in the question. In New Public Management, the average value was 1.41; in Public Hovernance – 1.82; and in Smart Governance – 2.02 (Fig. 3). The third question verifying the respondents'

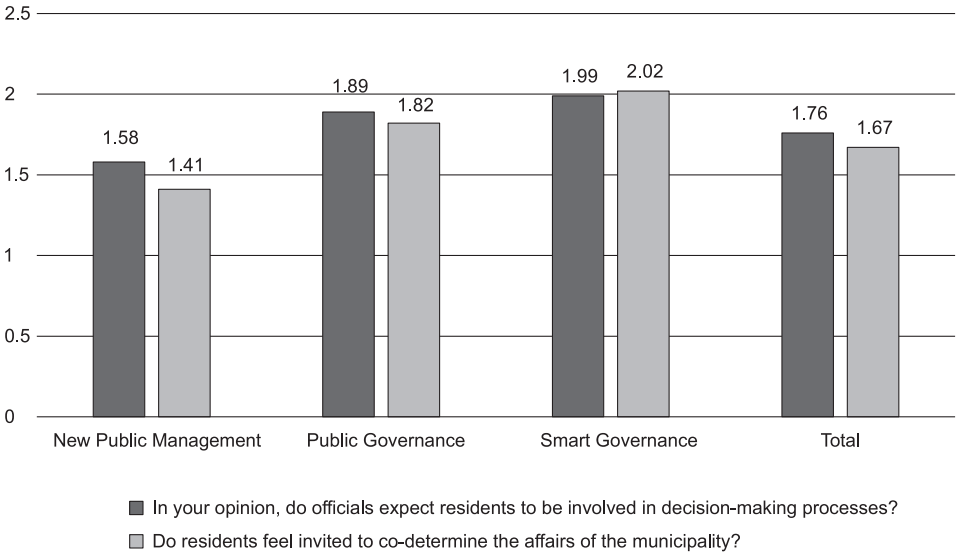

Fig. 3. Average values of responses to questions expressed on a scale: 1 – no, 2 – hard to say, 3 – yes
Source: own elaboration based on the survey (N = 939).

declaration regarding the public management model concerned civic participation in the commune. Of the proposed answer options, consultations were the most frequently chosen (51.3%). Only then did the respondents mark the following answers: participation in the implementation of public activities (22.6%), participation in decision-making (14.3%) and participation in the control over the implementation of public activities (11.6%). Forms of civic participation were also considered in connection with the previously distinguished management models. As shown, the more innovative and inclusive the management models were, the more often the respondents noticed that various forms of participation were observed in their area. The only minor exception here was the issue of participation in the control over the implementation of public activities (Fig. 4). The three questions used allowed for the verification of the subjective diagnosis made by the inhabitants of suburban areas regarding the public management model. At the same time, they also showed that this diagnosis, despite its high degree of subjectivity, was correct and consistent with the assumptions of individual models.

The crucial issue in the study, expressed in the last research question, concerned the relationship between the distinguished models and the scale of IPTs implemented in the public space. In communes that fit the New Public Management model, i.e. the most traditional ones, managed to a greater extent from the top down rather than through the involvement of residents, maintaining distance from residents and treating consultations only as a formality, the

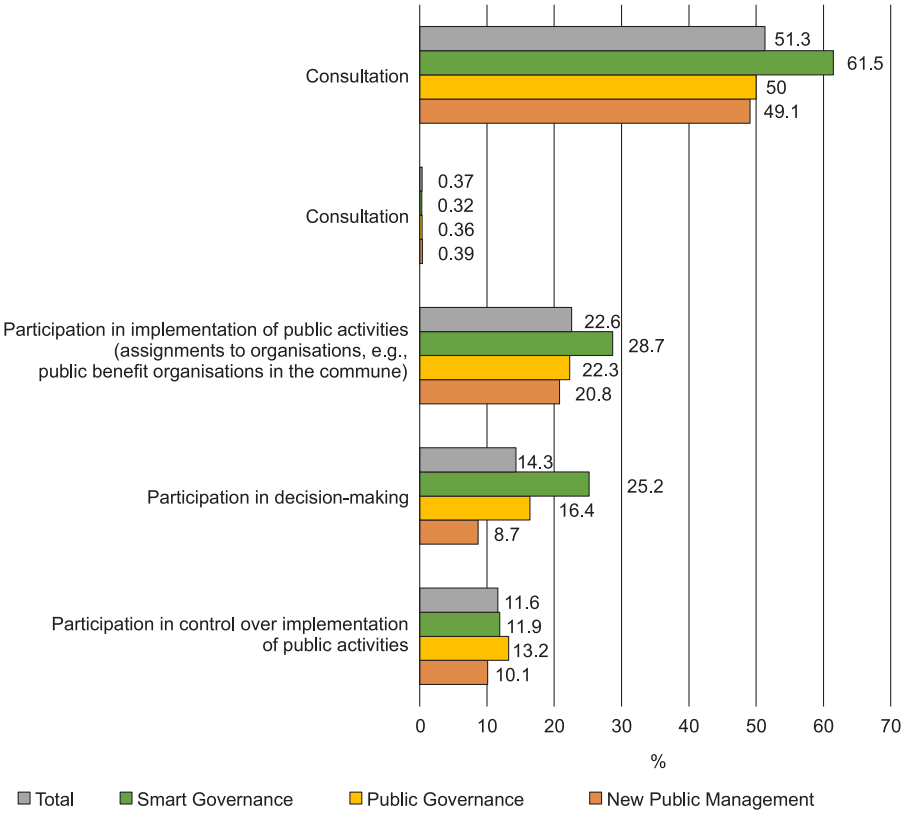

Fig. 4. Structure of responses to the question: "What forms of civic participation are present in your commune?" (multiple choice, %)
Source: own compilation based on the survey (N = 939).

lowest IPT was generally recorded compared to all management models. On the other hand, communes managed by the Smart Governance model, and therefore innovative, encouraging residents to engage in public consultations and supporting their initiatives, could boast the highest saturation of IPTs in the space. Communes classified as managed by the Public Governance model were most often located between communes managed in the New Public Management and Smart Governance models in terms of the presence and saturation of their IPT space. These observations were verified by chi-square tests, which showed statistically significant relationships between the saturation of IPTs in suburban space and the public management model (Table 2).

At the same time, a direct relationship was observed between the public management model in suburban communes and the lack of any IPT. In communes managed according to the Smart Governance model, the lack of any IPT was indicated by 5.6% of the respondents; in communes managed according to the

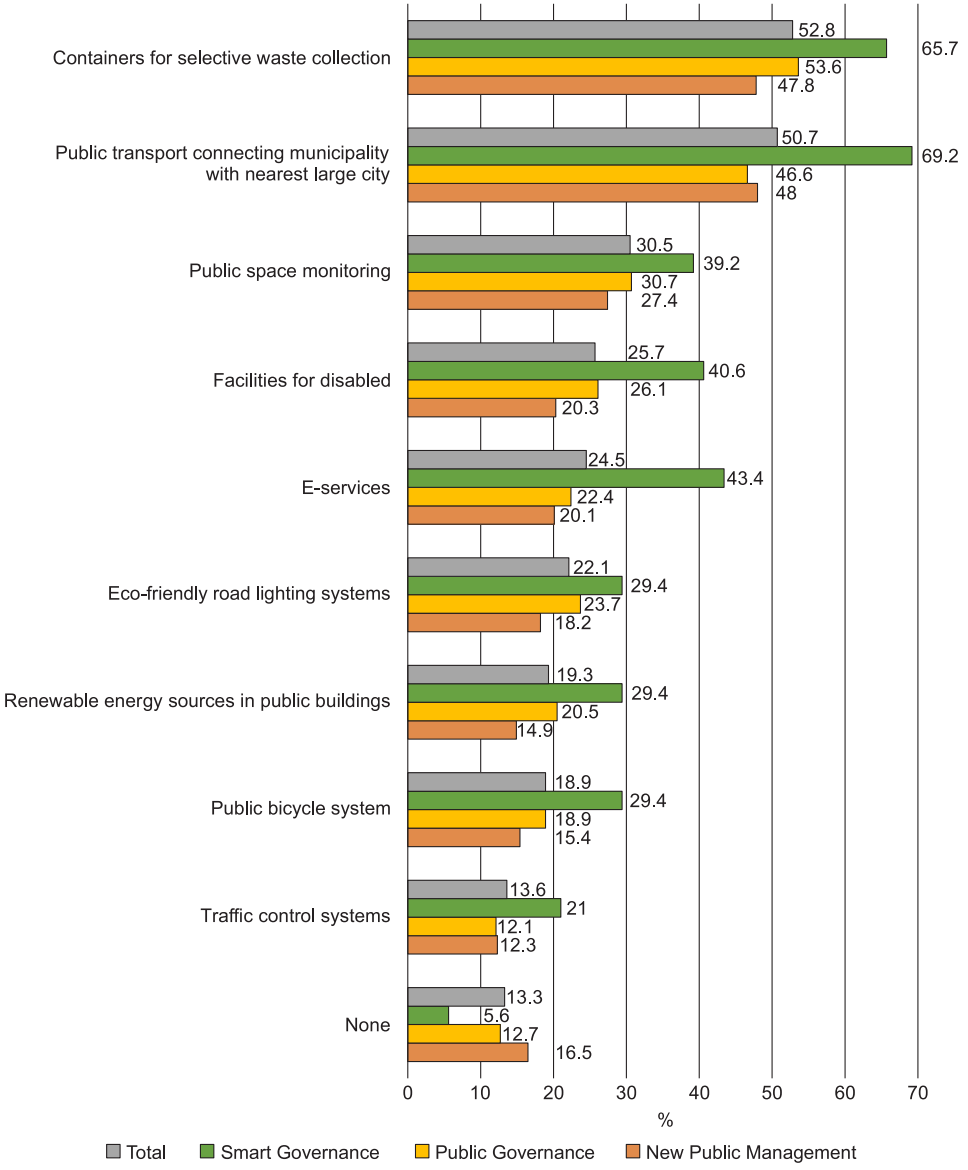

Fig. 5. Structure of responses to the question: "What solutions are available in your commune?" (multiple choice, %) in the context of public management models
Source: own compilation based on surveys (N = 939).

Public Governance model, this percentage was already 12.7%, while in communes managed according to the New Public Management model – as many as 16.5 % (Fig. 5). This conclusion was also confirmed by the chi-square test, which showed that this relationship exists and is statistically significant (Table 2).

Table 2. Tabular summary of statistical tests (chi-square), cross tables for public management models and IPTs implemented in communes

	New Public Management	Public Governance	Smart Governance	Total
Containers for selective waste collection	47.8%	53.6%	65.7%	52.8%
		Value	df	Asymptotic significance (bilateral)
	Pearson's chi-square	14.193a	2	<.001
	Reliability quotient	14.395	2	<.001
	Test of linear relationship	13.365	1	<.001
	N valid observations	939		
	a .0% of cells (0) have an expected size of less than 5. The minimum expected size is 67.62			
Public transport connecting commune with nearest large city	48.0%	46.6%	69.2%	50.7%
		Value	df	Asymptotic significance (bilateral)
	Pearson's chi-square	23.610a	2	<.001
	Reliability quotient	24.163	2	<.001
	Test of linear relationship	12.042	1	<.001
	N valid observations	939		
	a .0% of the cells (0) have an expected size of less than 5. The minimum expected size is 70.66			
Public space monitoring	27.4%	30.7%	39.2%	30.5%
		Value	df	Asymptotic significance (bilateral)
	Pearson's chi-square	7.043a	2	0.03
	Reliability quotient	6.854	2	0.032
	Test of linear relationship	6.394	1	0.011
	N valid observations	939		
	a .0% of cells (0) have an expected size of less than 5. The minimum expected size is 43.55			
Facilities for disabled	20.3%	26.1%	40.6%	25.7%
		Value	df	Asymptotic significance (bilateral)
	Pearson's chi-square	23.098a	2	<.001
	Reliability quotient	21.88	2	<.001
	Test of linear relationship	21.106	1	<.001
	N valid observations	939		
	a .0% of cells (0) have an expected size of less than 5. The minimum expected size is 36.70			

	New Public Management	Public Governance	Smart Governance	Total
e-services	20.1%	22.4%	43.4%	24.5%
		Value	df	Asymptotic significance (bilateral)
	Pearson's chi-square	33.002a	2	<.001
	Reliability quotient	29.962	2	<.001
	Test of linear relationship	23.491	1	<.001
	N valid observations	939		
	a .0% of cells (0) have an expected size of less than 5. The minimum expected size is 35.03			
Ecological road lighting systems	18.2%	23.7%	29.4%	22.1%
		Value	df	Asymptotic significance (bilateral)
	Pearson's chi-square	8.750a	2	0.013
	Reliability quotient	8.615	2	0.013
	Test of linear relationship	8.74	1	0.003
	N valid observations	939		
	a .0% of cells (0) have an expected size of less than 5. The minimum expected size is 31.52			
Renewable energy sources in public buildings	14.9%	20.5%	29.4%	19.3%
		Value	df	Asymptotic significance (bilateral)
	Pearson's chi-square	15.001a	2	<.001
	Reliability quotient	14.375	2	<.001
	Test of linear relationship	14.622	1	<.001
	N valid observations	939		
	a .0% of the cells (0) have an expected count of less than 5. The minimum expected count is 27.56			
Public bicycle system	15.4%	18.9%	29.4%	18.9%
		Value	df	Asymptotic significance (bilateral)
	Pearson's chi-square	13.782a	2	0.001
	Reliability quotient	12.821	2	0.002
	Test of linear relationship	12.145	1	<.001
	N valid observations	939		
	a .0% of cells (0) have an expected size of less than 5. The minimum expected size is 26.96			

	New Public Management	Public Governance	Smart Governance	Total
Traffic control systems	12.3%	12.1%	21.0%	13.6%
		Value	df	Asymptotic significance (bilateral)
	Pearson's chi-square	8.019a	2	0.018
	Reliability quotient	7.228	2	0.027
	Test of linear relationship	4.531	1	0.033
	N valid observations	939		
	a .0% of cells (0) have an expected size of less than 5. The minimum expected size is 19.34			
None	16.5%	12.7%	5.6%	13.3%
		Value	df	Asymptotic significance (bilateral)
	Pearson's chi-square	11.285a	2	0.004
	Reliability quotient	12.836	2	0.002
	Test of linear relationship	10.842	1	<.001
	N valid observations	939		
	and 0.0% of the cells (0) have an expected abundance of less than 5. The minimum expected abundance is 19.04			

Source: own elaboration.

DISCUSSION AND CONCLUSION

The presented analysis focuses on the issue of innovative pro-environmental technologies (IPTs), which are extremely important for the sustainable development of suburban zones in Poland, and examined the impact of the public management model on their implementation. During the analysis, the relationship between the diagnosed public management model and the scale of implementation of pro-environmental solutions was confirmed. Models that support greater civic participation respond better to local environmental needs and engage residents in pro-environmental activities, demonstrating greater openness to innovation and sustainable development. Conversely, communes following traditional management models are less active in implementing IPTs.

In the study, special attention was paid to the problem of developing suburban zones. In doing so, it was assumed that, like cities, they would implement IPTs in accordance with the smart city concept. Nevertheless, at the same time, it was assumed that this process would proceed more slowly than in cities, as cities are centres of innovation. This assumption is in line with the results of studies by, e.g.,

Carlino and Kerr (2015), Forsyth (2014), Garcia-Alvarez-Coque et al. (2021), who showed that suburban zones located peripherally to cities would adopt analogous solutions, but the process would be postponed in time (Yang et al., 2018; Liu et al., 2021; Liao et al., 2023; Smolinski et al., 2024). In addition to the city-suburban zone system, it is essential in the stage presented to pay attention to the geographic location of the suburban zones analysed. The development of suburban zones in Poland, as in Central and Eastern European countries, was initiated only with the systemic transformation. In Western Europe, the beginning of the development of suburban zones was in the post-war years, while in the US, it was already in the early 20th century (Kruse, Sugrue, 2006; Teford, 2006; McManus, Ethington, 2007; Ursić, 2015; Biegańska, 2019). Thus, as argued by Radosevic and Yoruk (2014), the space of Central and Eastern European countries will be less saturated with IPTs than, for example, the space of Western European countries. Thus, taking into account an unavoidable delay in the implementation of IPT-related investments in Central and Eastern European countries, but also the subsequent launch of suburbanisation processes, it should be expected that in the coming years, a tendency to balance differences in this regard will be observed in Polish suburban zones, among other places.

The study also allowed for the characterisation of the implemented pro-environmental solutions. IPTs are mainly identified in the form of infrastructure solutions such as waste segregation containers or energy-saving lighting, financed from EU environmental programmes. However, intelligent solutions focusing on monitoring, e-services, and traffic control systems were scarce. Such patterns of distribution and, at the same time, implementation of IPTs in the space of suburban zones require appealing, among other things, to the human and social capital of the residents of suburban zones, especially those who hold power in local government and decide on investments undertaken in communes (Dzialek et al., 2017; Wu, Liu, 2020). Indeed, given the very high support that Poland receives from the EU in successive programming periods, it should be assumed that it is not a matter of financial resources of local governments but of defining priorities in their development strategies reflected in project applications (Biegańska et al., 2018; Dymitrow et al., 2018). These, in turn, must be clearly defined and outlined. For this to happen, however, there needs to be an exchange of experience between the suburban communes that make up, for example, an urban or metropolitan region (Mularczyk, 2008; Forsyth, 2014) and often even support large cities that are central parts of urban or metropolitan regions. The latter, having a more significant number of qualified civil servants, can support their neighbouring communes, thus building the competitive advantage of the entire region and, as a result, position themselves higher in the global network of cities (Kaczmarek, Mikula, 2007; Furmankiewicz, 2018; Kwiatkowski et al., 2024).

At the same time, it should be noted that in the coming years, Poland is expected to see further population concentration in suburban zones at the expense of cities and peripheral rural areas (Ministerstwo Rozwoju Regionalnego, 2011; Heffner, Gibas, 2016; Biegańska, 2019). Thus, the influx of a population, usually relatively young and well-educated, with defined pro-environmental expectations (Fortmann, Kusel, 1990; Redclift, 1993; Sachs, 1993; Satterthwaite, 1997; Szczepańska, Pietrzyk, 2018; Shi et al., 2019; Lim, 2022; Smoliński et al., 2024), will determine not only the further saturation of the space of suburban zones with IPTs, but also such IPTs that do not include only relatively simple infrastructure solutions, but also more advanced smart solutions.

It is also pointed out that it is necessary to adapt management models to new ecological challenges and social expectations. The transition to more open, participatory management forms is necessary for the effective implementation of IPTs and the involvement of local communities in decision-making processes. It was noticed that management models directly impact communes' ability to adapt to new challenges and translate into their innovation.

The analyses conducted during the study indicate that the future of suburban zones in the context of sustainable development depends on the ability of communes to adapt and adopt modern management models. These models should promote pro-environmental innovations, support public participation and be open to change. Implementing such strategies not only responds to the growing expectations of residents regarding the quality of life and the environment but also puts communities on the path towards lasting and sustainable development, taking advantage of the potential of IPTs.

However, as research results have shown, the percentage of suburban communes in Poland that fit into the most innovative, open, and expected Smart Governance model still needs to be higher. This, in turn, prompts a look at municipal governance practice in Poland and Central and Eastern Europe in general (Kwiatkowski et al., 2024). With the system transformation, local government units, forced, as it were, to submit to the market rules of operation, focused on competition and rivalry, paying less attention to the development of a model of cooperation between communes but also neglecting the aspect of dialogue and cooperation between those in power and residents. Thus, crucial for the functioning of suburban communes and their efficient development is the need to redirect attention to public participation and the inclusion of residents in decision-making processes (Garnett, Cooper, 2014; Bouzguenda et al., 2019).

The results that were obtained lead to essential conclusions from the point of view of local policy practice. When identifying inequalities in space in the degree of IPT implementation, one should pay attention to whether the management model adopted in a given commune is a factor slowing down the pace of changes taking place? Its correction is not easy because it often results from unfavourable

conditions, e.g. limitations related to the quality of social capital, lack of a local leader, etc. However, it should be emphasised that the suburban zone is an area of dynamic changes, including social ones, which may bring solutions. In this case, the condition is local authorities' openness to new residents and their innovative potential. However, one of the priorities of local governments is to ensure the competitiveness of communes, and on the other hand, to ensure the quality of life of their residents. In that case, it seems crucial to change the approach to the governance model from traditional to more smart. This, in turn, will not only influence the more excellent saturation of the space of suburban zones with IPTs but will also increase the degree of inclusion of residents in decision-making processes, which seems crucial for further defining the needs of communes adequate to real expectations and needs. As a result, it will accelerate the transformation of suburban zones by the smart city concept, proceeding from the central cities to the areas immediately adjacent to them, all the way to the peripheral rural areas, which will also develop by this pattern over time. Given the importance of these issues, it should be noted that there is a need for further research that will not only focus on the specifics of individual settlement units, especially central ones such as a city or suburban zone but will take into account the situation of the entire urban-rural continuum in this regard.

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