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THE ROLE OF INTELLIGENT TRANSPORT SOLUTIONS IN THE SUSTAINABLE TRANSFORMATION OF CITIES

Monika CISZEWSKA

Faculty of Management, University of Technology; monika.ciszewska@pcz.pl, ORCID: 0000-0002-8066-2869

Purpose: The aim of this article is to identify the role of intelligent transport solutions in the transformation of cities towards sustainable development and their links to the implementation of the Sustainable Development Goals, with a particular focus on its pillars.
Design/methodology/approach: A literature review method was used to achieve the research objectives. The research approach adopted in this paper focuses on identifying the links between smart transport solutions and selected Sustainable Development Goals (SDGs). The theoretical scope includes the definition of sustainable development and the smart city concept. The subject-matter scope, on the other hand, refers to selected examples of mobility solutions that support the transformation of modern cities towards smart and sustainable structures.
Findings: The analysis found that smart mobility solutions significantly support the achievement of the Sustainable Development Goals, especially in relation to the environmental and social pillars. The greatest transformative potential is shown by measures aimed at improving the quality of life of the population, reducing the negative impact of transport on the environment supported by innovative solutions, modern technologies, data and digital tools. The literature review confirmed the compatibility of these findings with the existing body of research on smart city and sustainability concepts.
Practical implications: The article has practical implications for policy makers, urban planners and local government units. The smart mobility solutions presented in it can form the basis for developing urban development strategies towards smart and sustainable cities.
Social implications: The article has clear social implications. It raises issues related to smart mobility that directly affect the quality of life of city dwellers, environmental protection and the way urban policies are made.
Originality/value: The value of the article lies in demonstrating the link between intelligent transport solutions and the achievement of the Sustainable Development Goals. What is new is the presentation of a matrix of the relationship between individual smart mobility solutions and the Sustainable Development Goals, taking into account their impact on the social, environmental and economic pillars of sustainable development.
Keywords: transport in the city, sustainable development, Sustainable Development Goals (SDGs), smart mobility, pillars of sustainable development.
Category of the paper: General review.

1. Introduction

The dynamic growth of the urban population, combined with increasing environmental, social and economic challenges, has forced modern cities to seek innovative methods to ensure sustainability. Urban areas, which currently house more than half of the world's population, are major consumers of resources and contribute to global emissions. Their transformation is therefore essential to achieve the goals set out in the 2030 Agenda for Sustainable Development.

One of the most promising directions for the transformation of cities is the implementation of intelligent transport solutions that transform them into smart cities. This paper identifies and analyses smart mobility solutions and outlines their role in achieving sustainable development goals, with a focus on their potential impact on the Sustainable Development Goals (SDGs).

2. Literature review

2.1. Sustainable development and Sustainable Development Goals (SDGs)

The concept of sustainable development first appeared in a report by the World Commission on Environment and Development, published in 1987 and known as the Brundtland Report - Our Common Future. The report is named after the Commission's chairwoman, Gro Harlem Brundtland. In this document, an official definition of sustainable development was given for the first time: „sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987, p. 43). As Mensah (2019) rightly pointed out, the essence of this definition is intergenerational justice, understood as striving to balance the needs of current and future generations. The report also indicates that sustainable development should be based on three interrelated pillars: environmental, social and economic. Their integration was intended to enable the formulation of long-term development plans that respond both to the needs of societies and to environmental challenges.

The publication of the Brundtland Report drew the attention of the United Nations to the issues it raised. Just two years later, sustainable development issues were debated at the UN General Assembly. In the years that followed, the UN played a key role in popularising and developing the concept. One of the most important events in this process was the UN Conference on Environment and Development, held in Rio de Janeiro in 1992. The conference reiterated the need to protect the environment without impeding economic development. The importance of the three pillars of sustainable development outlined in the Brundtland Report was also reinforced. The main outcome of the conference was the adoption of Agenda 21 (United Nations, 1992), a comprehensive action plan for sustainable development

at local, national and global levels. Following the Rio de Janeiro conference, the concept of sustainable development was further developed at subsequent international summits and conferences. In 2002, the World Summit on Sustainable Development was held in Johannesburg, which emphasised the need to implement the principles of sustainable development at local and global levels. Another key moment was the adoption in 2015 by the UN General Assembly of Agenda 2030 and the 17 Sustainable Development Goals (SDGs), which replaced the earlier Millennium Development Goals. The new goals became comprehensive, universally applicable and aimed at achieving long-term development. Each of the 17 Sustainable Development Goals (SDGs) fits into at least one of the three main pillars of sustainable development: social, economic and/or environmental (Table 1).

Table 1.
Classification of the Sustainable Development Goals (SDGs) by sphere of influence

Goal number	Sustainable development goals	
	name of the goals	**main sphere of influence**
SDGs 1	No poverty	social
SDGs 2	Zero hunger	social/economic
SDGs 3	Good health and well-being	social
SDGs 4	Quality education	social
SDGs 5	Gender equality	social
SDGs 6	Clean water and sanitation	social/environmental
SDGs 7	Affordable and clean energy	environmental/economic
SDGs 8	Decent work and economic growth	economic
SDGs 9	Industry, innovation and infrastructure	economic
SDGs 10	Reduced inequalities	social
SDGs 11	Sustainable cities and communities	social/environmental
SDGs 12	Responsible consumption and production	environmental/economic
SDGs 13	Climate action	environmental
SDGs 14	Life below water	environmental
SDGs 15	Life on land	environmental
SDGs 16	Peace, justice and strong institutions	social
SDGs 17	Partnerships for the goals	social/economic

Source: compiled from Ministry of Funds and Regional Policy (2019, January 7). *Sustainable development goals*. https://www.gov.pl/web/rozwoj-technologia/cele-zrownowazonego-rozwoju

These goals, which as highlighted in "Transforming our world: the 2030 Agenda for Sustainable Development" (2015), are integrated and indivisible. They cover a diverse range of topics, responding to key challenges in today's world - from eradicating poverty and inequality, to developing education and infrastructure, to protecting the climate and natural resources. It should be noted that some goals are interdisciplinary in nature and support more than one pillar of sustainable development simultaneously (see Table 1). Goals 2, 6, 7, 11, 12 and 17 belong to this group. Of the total 17 goals, 10 goals relate mainly to the social area, 6 goals relate to the economic area, while 7 goals are related to the environmental area. 193 UN member states have committed themselves to the Sustainable Development Goals (SDGs). These countries have declared voluntary implementation of the goals and reporting on progress.

There is no shortage of criticism in the literature regarding the formulation and implementation of sustainable development goals. Particular attention is drawn to the fact that, despite their laudable objectives, these goals are often formulated too generally. In addition, their interpretation is sometimes divergent and their implementation inconsistent and fragmented. Critics also point to the lack of clear priorities and the inherent contradictions between the different goals. An example of this is the goal on economic growth, which can conflict with goals 13-15 to reduce the negative impact of human activities on the environment (Hickel, 2019; Eisenmenger et al., 2020). There is also a finding in the literature that the SDGs are sometimes used as part of a political narrative rather than as an actual tool to bring about change. Moreover, some authors argue that the Sustainable Development Goals often function as buzzwords rather than concrete tools to support the implementation of real action (Swain, 2018; Sachs et al., 2022).

Despite the weaknesses identified, the concept of the SDGs remains an important reference point in policy planning. However, it becomes crucial to support their implementation through concrete, well-designed solutions. One of the factors that could accelerate the achievement of these goals in the coming years are digital technologies in smart cities. Later in this article, this topic will be discussed in more detail.

2.2. The concept of a smart city

The origins of the term 'smart cities' are linked to the period of the global economic crisis. In 2008, IBM launched its 'Smarter Planet' strategy. Its aim was to create a better, more sustainable world through the use of smart technologies. IBM played an important role in shaping this vision by promoting technology solutions in support of the Sustainable Development Goals (Lenssen, Smith, 2019). It is worth noting that this framing was promotional and corporate rather than analytical and research, which may translate into its limited usefulness in the context of academic reflection on the smart city concept. Nonetheless, the message gained widespread support and its tenets were quickly translated into practical action. The introduction of innovative products and services has opened up new opportunities for development that had previously remained inaccessible (Martin et al., 2010), and the concept of smart systems itself has rapidly gained recognition among public and private sector decision-makers around the world (Palmisano, 2010).

One of the applications of innovative technologies was to be the transformation of cities into more efficient, greener and better managed urban areas. Accordingly, around 2010, a clarification of the concept of a smart city emerged, which had been developed since 2008. It was defined as follows “a smart city is one that uses technology to transform its core systems and optimise the use of limited resources” (Harrison et al., 2010). This definition, although it has gained a lot of popularity, focuses primarily on the technological aspect, neglecting the social and environmental context. The literature points out that this approach can lead to the

marginalisation of important social issues, which is one of the more frequently formulated criticisms of the concept (Kitchin, 2014; Hollands, 2015).

In the academic literature, the smart city concept was first defined in 2011 (taking into account a draft version of an article in 2009) and read as follows: "a city to be smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance" (Caragliu et al., 2011, p. 6). Although this definition has been accepted in the scientific community, as Hollands (2008) points out, many smart city concepts are too general and do not translate into concrete actions or measurable goals. In addition, the relationship between economic development and the social accessibility of these solutions is somewhat questionable.

The smart city concept gained prominence after 2010 and has been described by specialists in various fields. Contributions to the development of the definition were made by authors from the fields of urban planning, management, geography and technical and social sciences, both foreign (among others Deakin, Waer, 2011; Cohen, 2012; Townsend, 2013; Batty, 2013; Clark, 2013; Kitchin, 2014; Marvin el al., 2015; Ratti, Claudel, 2016; Shmelev, Shmeleva, 2019) as well as Polish ones (among others Klimczuk, 2015; Iwan et al., 2014; Iwan, 2016; Nosal, Macioszek, 2016; Bryx, 2018; Leszczyńska, 2018; Dziekoński, 2018; Komornicki, 2019). It is worth noting that, due to the diverse approaches of authors, there is no single, universally accepted definition. This makes both the comparison of research results and the practical implementation of smart cities difficult.

As the concept developed, its scope also changed. Today, the idea of the smart city - in addition to ensuring operational efficiency - focuses on improving the quality of life of residents, as well as supporting sustainable development and the smooth functioning of urban areas (IBM, 2023). These goals are to be achieved through appropriate infrastructure, support for innovation and the implementation of modern technologies (Bitkowska, Łabędzki, 2021). However, some researchers, such as Cardullo and Kitchin (2019), stress that technology deployment does not always go hand in hand with civic participation. This, in turn, can lead to a deepening of digital exclusion.

It should be noted at this point that there are several areas of smart city functioning. These include: smart governance, smart mobility, smart environment, smart economy, smart living, smart people. As stated by Vishnivetskaya & Alexandrova (2019), all areas within this concept interact with each other, increasing their scope of influence many times over through the use of synergies effect. It is worth noting at this point that this synergy is not always observed in practice. Often selected elements of the concept are introduced without a holistic approach. For this reason, it seems important to pay attention to analysing the degree of integration of the individual components of the smart city and assessing their interconnections and interactions. Only such an approach will allow a full understanding of the potential and limitations of the concept discussed in the context of sustainable urban development.

Taking into account the topic of the article, the empirical part will analyse smart mobility solutions.

3. Methods

The research presented in this article is an overview. Their aim was to identify solutions to support the functioning and development of smart cities in the area of transport. According to the author, this area currently plays a key role in the transformation of cities towards smart and sustainable cities. In addition, smart transport solutions significantly support the concept of sustainable development in urban areas.

The research carried out was divided into four stages. In the first step, smart mobility solutions were identified. In the next step, the potential benefits of implementing these solutions were identified. The third stage of the research consisted of linking smart mobility solutions to the 17 Sustainable Development Goals (SDGs). The final stage of the research identified which sustainability pillars are most supported by the introduction of smart mobility solutions.

4. Results

One of the solutions supporting the smart cities concept is smart mobility, which, as Wolniak (2023) rightly pointed out, is referred to as intelligent transport. Its implementation is based on the use of innovative solutions, modern technologies, data and digital tools. Table 2 presents a summary of smart mobility solutions compiled from an analysis of the scientific literature (among others Boichuk, 2020; Wróbel et al., 2023; Wolniak, 2023). This summary shows how smart mobility solutions can support sustainable development. An important element of the analysis was also to assign each group of solutions the respective Sustainable Development Goals (SDGs) to which they are linked.

As shown in Table 2, there are many solutions to support the functioning of smart cities in the area of mobility. To be effective, they must be integrated with each other. Their implementation makes it possible to solve a number of problems faced by modern cities. Smart mobility systems play an important role in sustainable urban development, contributing to an effective, efficient, accessible and safe transport system.

Table 2.
Smart mobility solutions and their role in ensuring sustainability

Smart mobility solutions	Role in development of smart city	Alignment with the Sustainable Development Goals
Sustainable modes of transport (electric cars, autonomous vehicles, city bikes, scooters, etc.) (**S01**)	– reducing emissions of pollutants into the environment and protecting the environment; – protection of the health of urban users; – reducing the occurrence of transport congestion.	SDG 3 SDG 7 SDG 9 SDG 10 SDG 11 SDG 12 SDG 13
Intelligent transport systems using data from different sources (**S02**)	– increasing the efficiency and effectiveness of the transport system; – integration of different forms of transport; – increasing the mobility of city dwellers; – reducing transport congestion; – improving transport safety; – reducing road collisions and accidents.	SDG 3 SDG 8 SDG 9 SDG 11 SDG 12 SDG 13
Mobile applications and digital solutions (**S03**)	– integration of different modes of transport; – optimisation of traffic and travel times; – increasing interest in the use of public transport through better travel planning; – increasing accessibility of transport for urban users; – collecting data for urban planning.	SDG 3 SDG 9 SDG 10 SDG 11 SDG 12 SDG 13
Shared mobility (e.g. car-sharing, bike-sharing, ride-sharing, mobility hubs, etc.) (**S04**)	– a reduction in the number of private vehicles on urban roads; – reducing pollutant emissions into the environment and protecting the environment; – optimisation of vehicle use; – improving access to transport infrastructure; – promoting active and local mobility; – promoting intermodal transport.	SDG 3 SDG 10 SDG 11 SDG 12 SDG 13

The labels in brackets next to each of the listed smart mobility solutions will be used in a table showing how they relate to the Sustainable Development Goals.

Source: Author's own work.

As shown in Table 2, smart mobility solutions can undoubtedly contribute to the Sustainable Development Goals (SDGs). In turn, Table 3 presents a matrix showing the extent to which individual intelligent transport solutions are linked to these Sustainable Development Goals and pillars.

Table 3.
Matrix for assessing smart mobility solutions in the context of the Sustainable Development Goals and the three pillars of sustainable development

SMS[2] / **SDGs**[1]	**S01**	**S02**	**S03**	**S04**	**TOTAL**	**Pillars of sustainabilitysupported by solutions S01-S04**
SDG 1						
SDG 2						
SDG 3	X	X	X	X	**4**	social (4)
SDG 4						
SDG 5						
SDG 6						

Cont. table 3.

SDG 7	X				**1**	environmental (1)/economic (1)
SDG 8		X			**1**	economic (1)
SDG 9	X	X	X		**3**	economic (3)
SDG 10	X		X	X	**3**	social (3)
SDG 11	X	X	X	X	**4**	social (4)/environmental (4)
SDG 12	X	X	X	X	**4**	environmental (4)/economic (4)
SDG 13	X	X	X	X	**4**	environmental (4)
SDG 14						
SDG 15						
SDG 16						
SDG 17						
TOTAL	**7**	**6**	**6**	**5**		**Summary:** • social **(11);** • environmental (**13**); • economic (**9**).

1) SDGs - Sustainable Development Goals.
2) SMS - Smart Mobility Solutions.

Source: Author's own work.

Among the solutions analysed, all of them aim to transform cities and communities towards more sustainable forms of functioning. In addition, it was deduced that all the solutions presented to ensure smart urban development contribute to the health and well-being of residents and users of urban space. Additionally, smart mobility solutions support the idea of responsible consumption and production and climate protection measures. Three of the four smart transport solutions presented support the sustainable development goals related to industrial development, innovation, infrastructure and the reduction of inequalities. Each of the objectives relating to access to affordable and clean energy and ensuring decent work and economic growth, was assigned to only one type of solution.

It is noteworthy that smart mobility solutions support, to a greater or lesser extent, efforts to achieve 47% of the total number of Sustainable Development Goals. This allows to conclude that smart mobility plays an important role in ensuring sustainable development, especially in the context of its environmental social and pillar.

5. Discussion

The findings suggest that smart mobility solutions can support almost half of the sustainable development goals to varying degrees. The strongest impact was observed in relation to the environmental and social pillars. Implementing smart mobility solutions can support Agenda 2030 by improving the quality of life in cities, increasing the well-being of residents and reducing the negative environmental impact of transport activities. Therefore, their systematic implementation should be an important part of urban development strategies.

The conclusions drawn from the study are confirmed by previous findings of researchers. Bitkowska and Łabędzki (2021) pointed out that the solutions characteristic of the smart city concept are primarily aimed at meeting the needs of residents. The authors emphasised their importance in strengthening the social dimension of sustainable development, pointing to the great potential of ICT in this regard. The approach of these authors, although directed at urban residents, assumes a rather technocentric perspective. This point of view presents technology as the main tool to achieve social goals. In fact, it may limit reflection on aspects of inclusivity and social equality.

In contrast, Goluchowski, Korzeb and Weichbroth (2015) noted that the effective implementation of smart solutions should be preceded by an in-depth identification of local residents' needs. The authors also emphasised the role of long-term planning of smart cities and the involvement of a wide range of stakeholders from public administration to the science and business sector in the process. In contrast to the approach presented by Bitkowska and Łabędzki, these authors place more emphasis on the process of planning and creating socially acceptable solutions. However, it should be stressed that these considerations are theoretical in nature, not supported by analysis of actual implementations.

Hajduk (2020) points out that each city operates in different social, economic and environmental conditions, so there is no single universal model of sustainable urban development. In his opinion, smart solutions should be implemented in a manner adapted to local conditions. The author also emphasises the importance of proven practices, which can provide a starting point in the process of finding solutions tailored to the specific needs of a given city. Hajduk's approach is pragmatic and flexible. For this reason, it is particularly valuable when considering the urban policy process. It is worth noting, however, that the nature of the publication is mainly a review and it does not include empirical research or specific cases of implementation of the smart city concept in Polish cities. Consequently, despite its undoubted theoretical merits, the publication does not provide analyses of the effectiveness of the presented models in urban management practice.

Despite the positive attitude to the smart mobility concept prevailing in the literature, there are also critical voices. Some researchers point to the risk of exacerbating social inequalities, for example through digital exclusion of the elderly, the less affluent or those with lower technological competence (Vanolo, 2016; Czupich et al., 2016). It is also highlighted that the uncontrolled deployment of technology can lead to the commercialisation of urban services and the dependence of local governments on private digital system providers (Hollands, 2015; Cardullo, Kitchin, 2019). In some cases, there is also a marginalisation of traditional forms of mobility which, despite being low-tech, are often more accessible and socially inclusive. Bringing these voices into the debate allows for a more balanced assessment of the potential benefits and risks of smart deployment. It also shows that further research should not only confirm the effectiveness of their deployment, but also identify possible side effects.

It is worth noting that much of the available studies on the presented topic are based on theoretical analyses or qualitative case studies, which limits the possibility to generalise conclusions. Apart from this, the analysis of the literature shows that there is a general consensus on the positive impact of smart mobility on sustainable development. Differences in views mainly relate to the level of involvement of citizens in the process of creating smart cities, the extent to which technology is used in the process and the approach to planning and implementing solutions. The shortcomings and discrepancies highlight the need for further empirical research on this topic. They will undoubtedly allow for an assessment of the effectiveness of the implementation of theoretical models in the realities of specific cities.

The above considerations indicate that the own research conducted also has its limitations. They are mainly due to the review character of the work, which, although it allows for the identification of general trends and relationships, does not allow for an in-depth analysis of specific cases. It therefore seems justified to conduct further research, including both quantitative and qualitative approaches, focused on selected cities. This will allow for a better understanding of the real impact of smart mobility on local sustainability goals. It is also worth including in future research an assessment of the effectiveness of the introduced solutions from the perspective of the inhabitants and the possible negative effects of their implementation, which will allow for more sustainable and responsible planning of activities in this area.

6. Summary

The analyses carried out allow the conclusion that smart mobility solutions play an important role in the transformation of modern cities towards sustainable development. It has been indicated that the implementation of smart mobility solutions can contribute to the achievement of almost half of the Sustainable Development Goals, with a particular focus on the environmental and social pillars. The study also showed that the greatest transformative potential lies in measures aimed at improving the quality of life of residents and reducing the negative environmental impact of transport. The significant role of innovative solutions, modern technologies, data and digital tools in this process was also highlighted.

The conclusions of the study are consistent with the current state of scientific knowledge and the recommendations of the literature. At the same time, attention was drawn to the need for further empirical research to verify the effectiveness of selected solutions in practice and their real impact on the implementation of sustainable development goals in specific conditions - i.e. in relation to individual cities.

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