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THE USAGE OF SMARTPHONE APPLICATIONS IN SMART CITY DEVELOPMENT – URBAN MOBILITY AND TRAFFIC MANAGEMENT

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Purpose: The purpose of this publication is to present the usage of smartphone application in Smart Cities in urban mobility and traffic management.
Design/methodology/approach: Critical literature analysis. Analysis of international literature from main databases and polish literature and legal acts connecting with researched topic.
Findings: Smartphone applications have undeniably transformed urban mobility and traffic management in smart cities. Their real-time data capabilities, optimization features, and user-friendly interfaces have created more efficient, sustainable, and enjoyable transportation systems. However, it is essential for smart cities to tackle the associated challenges effectively, ensuring that these applications contribute to equitable, safe, and efficient transportation systems within the urban landscape. The future of urban mobility is digital, and it's driven by the convenience and connectivity offered by our smartphones.
Originality/value: Detailed analysis of all subjects related to the problems connected with the usage of smartphone applications in urban mobility and traffic management in smart cities.

Keywords: Smart City, urban mobility, traffic management, smartphone applications, smart mobility.

Category of the paper: literature review.

1. Introduction

Smartphone applications are instrumental in the development of smart cities, revolutionizing urban living and improving city services in numerous ways. Smartphone applications are integral to the development of smart cities, enabling residents and authorities to optimize urban living, enhance services, and work toward a more sustainable and efficient future. Their real-time data capabilities and user-friendly interfaces are powerful tools for creating smarter, more connected urban environments (Prajeesh, Pillai, 2022; Kuntska et al., 2023).

Smart cities are on the rise, reshaping urban landscapes to make them more sustainable, efficient, and livable. A significant aspect of this transformation involves reimagining urban mobility and transportation. In the digital age, smartphone applications have emerged as a driving force behind the creation of smart, interconnected transportation networks. In this article, we explore how smartphone applications are revolutionizing urban mobility in smart cities.

The purpose of this publication is to present the usage of smartphone application in Smart Cities.

2. The usage of smartphone applications in urban mobility

One of the most visible impacts of smartphone applications on urban mobility is the proliferation of navigation apps like Google Maps, Apple Maps, and Waze. These apps have become essential tools for city dwellers, offering real-time traffic updates, optimized routes, and turn-by-turn directions. Commuters can now avoid traffic jams and arrive at their destinations faster, reducing both travel time and stress levels.

Smart cities recognize the importance of public transportation in reducing traffic congestion and carbon emissions. Smartphone applications play a pivotal role in making public transit more accessible and user-friendly (Wolniak, Sułkowski, 2015, 2016; Wolniak, Grebski, 2018; Wolniak et al., 2019, 2020; Wolniak, Habek, 2015, 2016; Wolniak, Skotnicka, 2011; Wolniak, Jonek-Kowalska, 2021, 2022). Many cities have developed their own transit apps that provide information on bus and train schedules, routes, and real-time arrival predictions. Passengers can plan their journeys with ease and even purchase tickets electronically, eliminating the need for paper tickets and long queues (Rahman, Dura, 2022).

Ridesharing and carpooling apps like Uber and Lyft have disrupted traditional transportation models. These platforms encourage carpooling, reducing the number of single-occupancy vehicles on the road. They also offer a more convenient alternative to traditional taxis, with the added benefit of cashless payments and driver ratings for safety and accountability (Rachmawati et al., 2021; Dutta et al., 2021; Ivanyi, Biro-Szigeti, 2019).

Smart cities are embracing micromobility solutions, such as electric scooters and bikes, as a means of reducing congestion and promoting eco-friendly transportation. Smartphone apps are the primary means by which users locate and unlock these vehicles. Users can easily check the availability of scooters or bikes in their vicinity, rent them with a few taps on their smartphones, and enjoy convenient and cost-effective short-distance transportation (Herdiansayah, 2023; Rose et al., 2021).

Traffic management is a significant challenge in urban areas, but smartphone applications are making strides in addressing this issue. Cities are increasingly implementing smart traffic management systems that utilize data from mobile apps to monitor traffic flow. This data helps traffic authorities adjust signal timings, reroute traffic, and minimize congestion. Additionally, apps that offer real-time parking information help drivers find parking spaces efficiently, reducing the time spent circling the block in search of a spot (Boichuk, 2020).

Smartphone applications are also contributing to sustainable commuting habits. They enable users to track their carbon footprint by monitoring their transportation choices. Some apps offer incentives for using eco-friendly modes of transportation, such as walking, cycling, or using public transit. These efforts encourage residents to make greener choices and contribute to a reduction in greenhouse gas emissions (Benevolo et al., 2016; Kalasova et al., 2021).

Smartphone applications are at the forefront of revolutionizing urban mobility in smart cities. These apps empower residents with real-time information, convenient options, and sustainable alternatives for their transportation needs (Wolniak, 2016; Czerwińska-Lubszczyk et al., 2022; Drozd, Wolniak, 2021; Gajdzik, Wolniak, 2021, 2022; Gębczyńska, Wolniak, 2018, 2023; Grabowska et al., 2019, 2020, 2021). As smart cities continue to evolve and prioritize efficient, eco-friendly transportation, smartphone applications will remain indispensable tools for making urban mobility more accessible and enjoyable for all. The future of urban transportation is digital, and it's driven by the convenience and connectivity offered by our smartphones (Simonofski et al., 2023; Chmielarz et al., 2021).

Table 1 gives examples of smartphone application usage in urban mobility within smart cities. These applications cover a wide range of urban mobility needs, from finding the quickest route to managing transportation services efficiently and promoting sustainable transportation options. Smart cities leverage these tools to create more efficient, convenient, and eco-friendly transportation systems.

Table 1.
Smartphone application usage in urban mobility within smart cities

Usage category	Examples
Navigation and Maps	Google Maps, Apple Maps, Waze
Public Transportation	City-specific transit apps, Moovit, Transit App
Ridesharing and Carpooling	Uber, Lyft, BlaBlaCar, DiDi
Micromobility Solutions	Lime, Bird, JUMP, Spin
Traffic Management	Waze, INRIX, TomTom Traffic
Parking Assistance	ParkMobile, SpotHero, ParkWhiz
Sustainable Commuting	Eco-friendly commute tracking apps, bike-sharing apps
Emergency Transit Alerts	Local government transit alert apps

Source: (Kalasova et al., 2021; Chmielarz et al., 2021; Rose et al., 2021; Dutta et al., 2019; Ivani, Biro-Szigeti, 2019; Leal et al., 2023; Chowdhury et al., 2023; Sanchez et al., 2018; Aguilera, Boutueil, 2018).

Table 2 contains descriptions of how smartphone applications are used in urban mobility within smart cities. These smartphone applications enhance urban mobility in smart cities by providing convenient, data-driven solutions that make transportation more efficient, sustainable, and user-friendly

Table 2.
How smartphone applications are used in urban mobility within smart cities

Usage category	Description
Navigation and Maps	Smartphone apps like Google Maps, Apple Maps, and Waze provide real-time navigation, traffic updates, and optimized routes, making daily commutes more efficient and less stressful.
Public Transportation	City-specific transit apps and platforms like Moovit and Transit App offer schedules, routes, and real-time updates for public transportation, making it easier for residents and visitors to navigate the city using buses, trains, and trams.
Ridesharing and Carpooling	Apps like Uber, Lyft, BlaBlaCar, and DiDi enable ridesharing and carpooling, reducing the number of single-occupancy vehicles on the road, lowering congestion, and providing convenient, cashless transportation options.
Micromobility Solutions	Micromobility apps such as Lime, Bird, JUMP, and Spin offer access to electric scooters and bikes, allowing users to conveniently cover short distances while promoting sustainable transportation and reducing traffic.
Traffic Management	Traffic management apps like Waze, INRIX, and TomTom Traffic use real-time data to monitor traffic conditions and provide users with alternative routes, contributing to reduced congestion and smoother traffic flow.
Parking Assistance	Apps like ParkMobile, SpotHero, and ParkWhiz help users find available parking spaces, reserve spots in advance, and streamline the parking process, reducing the time and stress associated with parking in urban areas.
Sustainable Commuting	Eco-friendly commute tracking apps and bike-sharing apps encourage users to make environmentally conscious transportation choices, such as walking, cycling, or using public transit, while offering incentives for green commuting.
Emergency Transit Alerts	Local government transit alert apps notify residents of critical information during emergencies, such as changes to public transportation schedules or disruptions in service, ensuring public safety and timely communication.

Source: (Kalasova et al., 2021; Chmielarz et al., 2021; Rose et al., 2021; Dutta et al., 2019; Ivani, Biro-Szigeti, 2019; Leal et al., 2023; Chowdhury et al., 2023; Sanchez et al., 2018; Aguilera, Boutueil, 2018).

Table 3 highlighting the advantages of using smartphone applications in urban mobility within smart cities. These advantages illustrate how smartphone applications play a pivotal role in shaping modern urban mobility in smart cities, ultimately leading to more efficient, sustainable, and livable urban environments.

Table 3.
Advantages of using smartphone applications in urban mobility within smart cities

Advantage	Description
Efficient Navigation	Smartphone apps offer real-time traffic data and optimized routes, reducing travel times and minimizing congestion for commuters.
Enhanced Public Transportation	Transit apps provide schedules, real-time updates, and mobile ticketing, making public transportation more accessible and user-friendly.
Reduced Traffic Congestion	Ridesharing and carpooling apps decrease the number of vehicles on the road, alleviating traffic congestion and improving air quality.

Cont. table 3.

Eco-Friendly Transportation	Micromobility apps promote sustainable commuting options, reducing carbon emissions and contributing to cleaner, greener cities.
Improved Traffic Management	Traffic apps help manage traffic flow, enabling authorities to adjust signals and routes for smoother traffic and fewer bottlenecks.
Convenient Parking Solutions	Parking apps simplify the process of finding and reserving parking spaces, reducing the time spent searching for parking in urban areas.
Promotion of Sustainable Commuting Habits	Eco-commute apps incentivize users to make environmentally conscious choices, leading to reduced environmental impact and healthier lifestyles.
Emergency Transit Alerts for Safety	Transit alert apps provide crucial information during emergencies, ensuring the safety and well-being of city residents and visitors.
Data-Driven Decision Making for Urban Planning	Mobility data collected by these apps aids city planners in making informed decisions to optimize transportation infrastructure.
Enhanced User Experience	Smartphone apps offer a user-friendly interface, making navigation and transportation services more accessible and enjoyable for residents and visitors alike.

Source: (Kalasova et al., 2021; Chmielarz et al., 2021; Rose et al., 2021; Dutta et al., 2019; Ivani, Biro-Szigeti, 2019; Leal et al., 2023; Chowdhury et al., 2023; Sanchez et al., 2018; Aguilera, Boutueil, 2018).

Table 4 highlighting some of the common problems and challenges associated with the usage of smartphone applications in urban mobility within smart cities. These problems and challenges underline the need for careful consideration and effective solutions when implementing smartphone applications in urban mobility to ensure equitable, safe, and efficient transportation systems within smart cities.

Table 4.

Problems of using smartphone applications in urban mobility within smart cities

Problem	Description
Data Privacy Concerns	Users often share personal and location data with these apps, raising concerns about data security and privacy breaches.
Digital Divide	Not all residents may have access to smartphones or the internet, creating disparities in access to transportation information.
Dependency on Technology	Overreliance on navigation apps can lead to reduced map-reading and navigation skills among users.
Traffic Data Accuracy	Traffic data used by apps may not always be accurate, leading to frustration and inefficient route planning for users.
Sustainability Challenges	While micromobility apps promote sustainability, they also face challenges related to vehicle maintenance and environmental impact.
Ridesharing Congestion	Increased use of ridesharing services can lead to additional traffic congestion and may not always reduce the number of vehicles on the road.
Digital Distractions and Safety	Smartphone use while driving or walking can lead to accidents and safety hazards, particularly in densely populated areas.
Service Reliability	Apps can suffer from downtime or technical issues, leaving users stranded or unable to access essential transportation services.
Inadequate Internet Connectivity	In some areas, poor internet connectivity can hinder the functionality of these apps, making them less reliable for users.
User Discrimination	Concerns exist about potential biases in algorithms used by ride-hailing services, resulting in discriminatory practices.
Environmental Impact of Data Centers	The data centers supporting these apps can consume significant energy, contributing to the environmental footprint of urban mobility solutions.
Accessibility Issues	Apps may not be fully accessible to individuals with disabilities, limiting their use and mobility options for some users.

Cont. table 4.

Congestion from App-Enabled Services	The convenience of on-demand services like food delivery can lead to increased road congestion and air pollution in urban areas.
Lack of Standardization	Different cities may use a variety of apps and platforms, making it challenging for travelers to adapt to different systems when moving between cities.
Security Risks	Apps are susceptible to hacking and cyberattacks, which can compromise user data and the functioning of transportation services.

Source: (Kalasova et al., 2021; Chmielarz et al., 2021; Rose et al., 2021; Dutta et al., 2019; Ivani, Biro-Szigeti, 2019; Leal et al., 2023; Chowdhury et al., 2023; Sanchez et al., 2018; Aguilera, Boutueil, 2018).

3. The usage of smartphone applications in traffic management

One of the most significant contributions of smartphone applications to traffic management is the collection and dissemination of real-time traffic data. Apps like Waze, Google Maps, and INRIX provide drivers with up-to-the-minute information on road conditions, accidents, and traffic jams. This data helps commuters make informed decisions about their routes, avoiding congested areas and reducing travel time (Kalasova et al., 2021).

Smartphone apps enable traffic management authorities to optimize traffic flow in real-time. By analyzing the data collected from these apps, city officials can adjust traffic signals, implement dynamic lane control, and reroute traffic as needed. This not only minimizes congestion but also reduces fuel consumption and greenhouse gas emissions. Crowdsourced traffic reporting is a game-changer in smart cities (Jonek-Kowalska, Wolniak, 2021, 2022, 2023; Rosak-Szyrocka et al., 2023; Gajdzik et al., 2023; Jonek-Kowalska et al., 2022; Kordel, Wolniak, 2021; Orzeł, Wolniak, 2021, 2022; Ponomarenko et al., 2016; Stawiarska et al., 2020; 2021; Stecuła, Wolniak, 2022; Olkiewicz et al., 2021). Smartphone apps allow users to report accidents, road closures, and other traffic incidents instantly. This crowdsourced data complements official traffic monitoring systems and helps authorities respond more swiftly to emergencies and incidents, improving overall safety (Rose et al., 2021).

Finding parking in a crowded city can be a daunting task, leading to traffic bottlenecks and frustration. Smartphone apps like ParkMobile and SpotHero help drivers locate available parking spaces and even reserve them in advance. This reduces circling for parking and eases traffic congestion near popular destinations. Smart cities aim to reduce the number of private vehicles on the road by promoting public transportation (Sułkowski, Wolniak, 2015, 2016, 2018; Wolniak, Skotnicka-Zasadzień, 2008, 2010, 2014, 2018, 2019, 2022; Wolniak, 2011, 2013, 2014, 2016, 2017, 2018, 2019, 2020, 2021, 2022; Gajdzik, Wolniak, 2023). Transit apps provide users with real-time information on bus and train schedules, routes, and delays. Users can plan their journeys efficiently, leading to increased use of public transit and reduced traffic congestion (Dutta et al., 2019).

Dynamic road pricing, or congestion pricing, is an effective tool for managing traffic in smart cities. Smartphone apps can calculate tolls or fees based on real-time traffic conditions, encouraging commuters to travel during off-peak hours or use alternative routes. This approach helps alleviate congestion during peak times and raises revenue for infrastructure improvements (Ivanyi, Biro-Szigeti, 2019).

Smart cities recognize the importance of offering multiple transportation options to reduce car dependency. Mobility apps integrate various modes of transportation, including public transit, ridesharing, bike-sharing, and walking, into a single platform. This encourages residents to choose the most suitable and sustainable mode for each journey (Chmielarz et al., 2021).

Smartphone apps can assist in traffic enforcement and safety efforts. Authorities can use traffic camera apps to monitor intersections and identify traffic violations. Additionally, some apps provide alerts about speed limits and dangerous road conditions, promoting safer driving practices.

Smartphone applications are invaluable tools in the quest to improve traffic management in smart cities. With real-time data, optimization capabilities, crowdsourced reporting, and integration of transportation modes, these apps contribute to more efficient, sustainable, and safe urban mobility. As smart cities continue to evolve, the role of smartphone applications in traffic management will only grow, creating smoother and more enjoyable commutes for residents and visitors alike.

Table 5 gives examples of smartphone application usage in traffic management within smart cities. These applications cover various aspects of traffic management, including real-time data collection, optimization, safety enforcement, and the promotion of sustainable transportation options, making them integral to the efficient functioning of smart cities.

Table 5.
Smartphone application usage in traffic management within smart cities

Usage category	Examples
Real-Time Traffic Data	Waze, Google Maps, INRIX, TomTom Traffic
Traffic Flow Optimization	City-specific traffic management apps, traffic signal control apps
Crowdsourced Traffic Reporting	Waze, Google Maps, HERE WeGo, community-based traffic apps
Parking Solutions	ParkMobile, SpotHero, ParkWhiz, PayByPhone
Promoting Public Transportation	Transit apps (e.g., Moovit, Transit App, City-specific transit apps)
Dynamic Road Pricing	Congestion pricing apps (e.g., Singapore's ERP system)
Integrating Multiple Modes	Mobility apps (e.g., Uber, Lyft, bike-sharing apps)
Traffic Enforcement and Safety	Traffic camera apps, speed limit alert apps

Source: (Kalasova et al., 2021; Chmielarz et al., 2021; Rose et al., 2021; Dutta et al., 2019; Ivani, Biro-Szigeti, 2019; Aljoufie, Tiwari, 2022; Sofat, Bansal, 2016; Campolo et al., 2012).

Table 6 covers descriptions of how smartphone applications are used in traffic management within smart cities. These smartphone applications play a crucial role in modern traffic management within smart cities, providing real-time data, optimizing traffic flow, enhancing safety, and encouraging sustainable transportation choices.

Table 6.
How smartphone applications are used in traffic management within smart cities

Usage category	Description
Real-Time Traffic Data	Smartphone apps like Waze, Google Maps, INRIX, and TomTom Traffic collect and provide real-time traffic data, including congestion, accidents, and alternative routes, aiding commuters in making informed travel decisions.
Traffic Flow Optimization	City-specific traffic management apps and traffic signal control apps leverage smartphone data and sensors to optimize traffic flow by adjusting signal timings, rerouting vehicles, and reducing congestion in real-time.
Crowdsourced Traffic Reporting	Apps like Waze and Google Maps allow users to report accidents, road closures, and traffic incidents, providing valuable crowdsourced data that complements official traffic monitoring systems, enhancing overall safety and incident response.
Parking Solutions	Smartphone apps such as ParkMobile, SpotHero, ParkWhiz, and PayByPhone help drivers locate available parking spaces, pay for parking, and even reserve spots in advance, reducing traffic congestion caused by parking searches.
Promoting Public Transportation	Transit apps like Moovit, Transit App, and city-specific transit apps provide real-time information on public transportation schedules, routes, and delays, encouraging the use of buses and trains to reduce traffic congestion.
Dynamic Road Pricing	Congestion pricing apps, as seen in cities like Singapore, calculate tolls or fees based on real-time traffic conditions, incentivizing commuters to travel during off-peak hours or use alternative routes, thereby reducing congestion.
Integrating Multiple Modes	Mobility apps like Uber, Lyft, and bike-sharing apps offer users a range of transportation options, integrating public transit, ridesharing, bike-sharing, and walking into a single platform, promoting multi-modal mobility.
Traffic Enforcement and Safety	Traffic camera apps assist authorities in monitoring intersections, identifying traffic violations, and enforcing traffic laws. Speed limit alert apps provide drivers with warnings about speed limits and hazardous road conditions, enhancing road safety.

Source: (Kalasova et al., 2021; Chmielarz et al., 2021; Rose et al., 2021; Dutta et al., 2019; Ivani, Biro-Szigeti, 2019; Aljoufie, Tiwari, 2022; Sofat, Bansal, 2016; Campolo et al., 2012).

Table 7 highlighting the advantages of using smartphone applications in traffic management within smart cities. These advantages illustrate how smartphone applications are pivotal in improving traffic management within smart cities, leading to more efficient, sustainable, and enjoyable urban transportation systems.

Table 7.
Advantages of using smartphone applications in traffic management within smart cities

Advantage	Description
Real-Time Traffic Data	Smartphone apps provide real-time traffic information, enabling users to make informed route decisions, reducing travel time and congestion.
Traffic Flow Optimization	Traffic management apps optimize traffic flow through signal control and dynamic routing, leading to smoother traffic and reduced delays.
Crowdsourced Traffic Reporting	Crowdsourced data from apps enhances incident response, allowing authorities to react quickly to accidents, road closures, and other issues.
Parking Solutions	Parking apps ease the search for parking spaces, reducing traffic congestion, fuel consumption, and environmental impact near popular areas.
Promoting Public Transportation	Transit apps encourage the use of public transportation, reducing the number of private vehicles on the road and mitigating congestion.
Dynamic Road Pricing	Congestion pricing apps reduce traffic during peak hours, generating revenue for infrastructure improvements and discouraging congestion.
Integrating Multiple Modes	Mobility apps offer convenience and flexibility by integrating various modes of transportation, encouraging sustainable travel choices.
Traffic Enforcement and Safety	Traffic camera apps enhance safety by monitoring intersections and deterring traffic violations, contributing to safer roadways.

Cont. table 7.

Efficient Resource Allocation	Data from apps allows authorities to allocate resources effectively, responding to incidents and traffic conditions in a timely manner.
Reduced Environmental Impact	By optimizing traffic flow and promoting sustainable transportation, these apps contribute to reduced air pollution and greenhouse gas emissions.
Enhanced User Experience	Smartphone apps offer user-friendly interfaces, improving the overall experience of navigating traffic and using transportation services.
Data-Driven Decision Making for Planning	Traffic data collected through apps aids city planners in making informed decisions for optimizing transportation infrastructure.

Source: (Kalasova et al., 2021; Chmielarz et al., 2021; Rose et al., 2021; Dutta et al., 2019; Ivani, Biro-Szigeti, 2019; Aljoufie, Tiwari, 2022; Sofat, Bansal, 2016; Campolo et al., 2012).

Table 8 put information about some of the common problems and challenges associated with the usage of smartphone applications in traffic management within smart cities. These problems and challenges underline the need for careful consideration and effective solutions when implementing smartphone applications in traffic management to ensure equitable, safe, and efficient transportation systems within smart cities.

Table 8.

Problems of using smartphone applications in traffic management within smart cities

Problem	Description
Data Privacy Concerns	Users often share personal and location data with these apps, raising concerns about data security and privacy breaches.
Digital Divide	Not all residents may have access to smartphones or the internet, creating disparities in access to real-time traffic information.
Over-Reliance on Technology	An over-dependence on navigation apps may lead to reduced map-reading and navigational skills among users, causing potential problems when technology fails.
Data Accuracy and Reliability	The accuracy of traffic data in apps can vary, leading to potential frustration and inefficiencies if users encounter inaccurate information.
Sustainability Challenges	While apps promote sustainable transportation, there can be sustainability challenges related to vehicle maintenance and environmental impact.
Traffic Congestion from Ridesharing Services	Increased use of ridesharing services can lead to additional traffic congestion, particularly in densely populated areas.
Digital Distractions and Safety Hazards	Smartphone use while driving or walking can lead to accidents and safety hazards, potentially contributing to road safety concerns.
Service Reliability and Downtime	Apps may suffer from downtime or technical issues, leaving users stranded or unable to access essential traffic and navigation information.
Inadequate Internet Connectivity	In areas with poor internet connectivity, the functionality of these apps may be compromised, impacting their reliability and usefulness.
User Discrimination and Bias in Algorithms	Concerns exist about potential biases in algorithms used by ridesharing and navigation services, resulting in discriminatory practices.
Environmental Impact of Data Centers and Servers	The data centers supporting these apps can consume significant energy, contributing to the environmental footprint of digital infrastructure.
Accessibility and Inclusivity	Not all apps are fully accessible to individuals with disabilities, limiting mobility options for some users and causing equity concerns.
Congestion from On-Demand Services and Deliveries	The convenience of on-demand services like food delivery can lead to increased road congestion and air pollution in urban areas.
Lack of Standardization Across Cities	Different cities may use a variety of apps and platforms, making it challenging for travelers to adapt to different systems when moving between cities.

Source: (Kalasova et al., 2021; Chmielarz et al., 2021; Rose et al., 2021; Dutta et al., 2019; Ivani, Biro-Szigeti, 2019; Aljoufie, Tiwari, 2022; Sofat, Bansal, 2016; Campolo et al., 2012).

4. Conclusion

This paper has highlighted the profound impact of smartphone applications on the development of smart cities, particularly in the domains of urban mobility and traffic management. Smart cities, characterized by their pursuit of sustainability, efficiency, and enhanced quality of life, have harnessed the capabilities of smartphone applications to create more connected and livable urban environments.

The usage of smartphone applications in urban mobility has ushered in a new era of convenience and efficiency for city dwellers. Navigation apps like Google Maps, Apple Maps, and Waze have become indispensable tools, providing real-time traffic data and optimized routes that reduce travel times and alleviate congestion. These applications have not only improved the daily commute but have also contributed to a reduction in stress levels for urban residents. Furthermore, smartphone apps have played a pivotal role in making public transportation more accessible and user-friendly. City-specific transit apps, along with platforms like Moovit and Transit App, offer schedules, real-time updates, and mobile ticketing options, making it easier for residents and visitors to navigate cities using public transportation.

Ridesharing and carpooling apps like Uber, Lyft, BlaBlaCar, and DiDi have disrupted traditional transportation models, encouraging carpooling and reducing single-occupancy vehicles on the road. These apps offer convenience, cashless payments, and safety measures, transforming the urban transportation landscape. Micromobility solutions, such as electric scooters and bikes, have gained popularity in smart cities. Smartphone apps are the primary means by which users locate and unlock these vehicles, providing convenient and eco-friendly options for short-distance transportation.

Traffic management in urban areas has always been a challenge, but smartphone applications have made significant strides in addressing this issue. These apps provide real-time traffic data that is crucial for smart traffic management systems. Cities can adjust signal timings, reroute traffic, and minimize congestion, all while reducing fuel consumption and greenhouse gas emissions. Moreover, parking apps have simplified the parking process, helping drivers find available spaces efficiently and reducing traffic caused by parking searches. These apps have made urban life more convenient and less frustrating.

In terms of sustainability, smartphone applications have promoted eco-friendly commuting habits. Some apps encourage users to track their carbon footprint and offer incentives for choosing environmentally conscious modes of transportation, such as walking, cycling, or public transit. Traffic enforcement and safety have also benefited from smartphone apps. Traffic camera apps monitor intersections and help identify violations, enhancing road safety. Speed limit alert apps provide drivers with warnings about speed limits and hazardous conditions, further contributing to safer roadways.

However, it's essential to acknowledge the challenges associated with the widespread usage of smartphone applications in smart cities. These include data privacy concerns, the digital divide, over-reliance on technology, data accuracy and reliability issues, sustainability challenges, and the potential for increased traffic congestion from ridesharing services. Furthermore, digital distractions, service reliability and downtime, inadequate internet connectivity in certain areas, user discrimination, and environmental impacts related to data centers and servers are challenges that must be addressed as smart cities continue to evolve.

Smartphone applications have undeniably transformed urban mobility and traffic management in smart cities. Their real-time data capabilities, optimization features, and user-friendly interfaces have created more efficient, sustainable, and enjoyable transportation systems. However, it is essential for smart cities to tackle the associated challenges effectively, ensuring that these applications contribute to equitable, safe, and efficient transportation systems within the urban landscape. The future of urban mobility is digital, and it's driven by the convenience and connectivity offered by our smartphones.

References

1. Aguilera, A., Boutueil, V. (2018). Urban mobility and the smartphone: Transportation, travel behavior and public policy. *Travel Behavior and Public Policy*, 1-222.
2. Aljoufie, M., Tiwari, A. (2022). Citizen sensors for smart city planning and traffic management: crowdsourcing geospatial data through smartphones in Jeddah, Saudi Arabia. *GeoJournal*, *87(4)*, 3149-3168.
3. Benevolo, C., Dameri, R.P., D'Auria, B. (2016). Smart mobility in smart city. *Empowering Organizations.* Cham, Switzerland: Springer International Publishing, 3-28.
4. Boichuk, N. (2020). Smart mobility jako podstawowy element koncepcji inteligentnego miasta—Studium przypadku wybranych polskich miast. In: A. Budziewicz-Guźlecka (Ed.), *Inteligentne Miasta. Rozprawy i* Studia, *Vol. 1153* (pp. 59-72). Szczecin: Uniwersytet Szczeciński, ISBN 978-83-7972-402-4.
5. Campolo, C., Iera, A., Molinaro, A., Paratore, S.Y., Ruggeri, G. (2012). SMaRTCaR: *An integrated smartphone-based platform to support traffic management applications*. 1st International Workshop on Vehicular Traffic Management for Smart Cities, VTM 2012, 6398700.
6. Chmielarz, W., Zborowski, M., Fandrejewska, A., Atasever, M. (2021). The contribution of socio-cultural aspects of smartphone applications to smart city creation. Poland–Turkey comparison. *Energies*, *14(10)*, 2821.

7. Chowdhury, P.K., Ghosh, N., Kuriakose, P.N. (2023). Towards Seamless Urban Mobility Through Smartphone-Based Mobility Apps: Insights from India. *Springer Geography*, 935-955.
8. Drozd, R, Wolniak, R. (2021). Metrisable assessment of the course of stream-systemic processes in vector form in industry 4.0. *Quality and Quantity*, 1-16, DOI: 10.1007/s11135-021-01106-w.
9. Drozd, R., Wolniak, R. (2021). Systematic assessment of product quality. *Journal of Open Innovation: Technology, Market, and Complexity, 7(4),* 1-12.
10. Dutta, J., Roy, S., Chowdhury, C. (2019). Unified framework for IoT and smartphone based different smart city related applications. *Microsystem Technologies*, *25(1),* 83-96.
11. Gajdzik, B., Grebski, M., Grebski, W., Wolniak, R. (2022). *Human factor activity in lean management and quality management.* Toruń: Towarzystwo Naukowe Organizacji i Kierownictwa. Dom Organizatora.
12. Gajdzik, B., Jaciow, M., Wolniak, R., Wolny R., Grebski, W.W. (2023). Energy Behaviors of Prosumers in Example of Polish Households. *Energies*, *16(7),* 3186, https://doi.org/10.3390/en16073186.
13. Gajdzik, B., Wolniak, R. (2021). Digitalisation and innovation in the steel industry in Poland - selected tools of ICT in an analysis of statistical data and a case study. *Energies, 14(11),* 1-25.
14. Gajdzik, B., Wolniak, R. (2021). Influence of the COVID-19 crisis on steel production in Poland compared to the financial crisis of 2009 and to boom periods in the market. *Resources*, *10(1),* 1-17.
15. Gajdzik, B., Wolniak, R. (2021). Transitioning of steel producers to the steelworks 4.0 - literature review with case studies. *Energies*, *14(14),* 1-22.
16. Gajdzik, B., Wolniak, R. (2022). Framework for R&D&I Activities in the Steel Industry in Popularizing the Idea of Industry 4.0. *Journal of Open Innovation: Technology, Market, and Complexity*, *8(3),* 133.
17. Gajdzik, B., Wolniak, R. (2022). Influence of Industry 4.0 Projects on Business Operations: literature and empirical pilot studies based on case studies in Poland. *Journal of Open Innovation: Technology, Market, and Complexity*, *8(1),* 1-20.
18. Gajdzik, B., Wolniak, R. (2022). Smart Production Workers in Terms of Creativity and Innovation: The Implication for Open Innovation. *Journal of Open Innovations: Technology, Market and Complexity, 8(1),* 68.
19. Gajdzik, B., Wolniak, R., Grebski, W. (2023). *Process of Transformation to Net Zero Steelmaking: Decarbonisation Scenarios Based on the Analysis of the Polish Steel Industry. Energies, 16(8),* 3384, https://doi.org/10.3390/en16083384.
20. Gajdzik, B., Wolniak, R., Grebski, W.W. (2023). Electricity and heat demand in steel industry technological processes in Industry 4.0 conditions. *Energies, 16(2),* 1-29.

21. Gajdzik, B., Wolniak, R., Grebski, W.W. (2022). An econometric model of the operation of the steel industry in Poland in the context of process heat and energy consumption. *Energies, 15(21),* 1-26, 7909.
22. Gębczyńska, A., Wolniak, R. (2018). *Process management level in local government.* Philadelphia: CreativeSpace.
23. Grabowska S., Saniuk S., Gajdzik, B. (2022). Industry 5.0: improving humanization and sustainability of Industry 4.0. *Scientometrics*, *127(6),* 3117-3144, https://doi.org/10.1007/s11192-022-04370-1.
24. Grabowska, S., Grebski, M., Grebski, W., Saniuk, S., Wolniak, R. (2021). *Inżynier w gospodarce 4.0.* Toruń: Towarzystwo Naukowe Organizacji i Kierownictwa – Stowarzyszenie Wyższej Użyteczności "Dom Organizatora".
25. Grabowska, S., Grebski, M., Grebski, W., Wolniak, R. (2019). *Introduction to engineering concepts from a creativity and innovativeness perspective.* New York: KDP Publishing.
26. Grabowska, S., Grebski, M., Grebski, W., Wolniak, R. (2020). *Inżynier – zawód przyszłości. Umiejętności i kompetencje inżynierskie w erze Przemysłu 4.0.* Warszawa: CeDeWu.
27. Hąbek, P., Wolniak, R. (2013). Analysis of approaches to CSR reporting in selected European Union countries. *International Journal of Economics and Research*, *4(6),* 79-95.
28. Hąbek, P., Wolniak, R. (2016). Assessing the quality of corporate social responsibility reports: the case of reporting practices in selected European Union member states. *Quality & Quantity*, *50(1),* 339-420.
29. Hąbek, P., Wolniak, R. (2016). Factors influencing the development of CSR reporting practices: experts' versus preparers' points of view. *Engineering Economy*, *26(5),* 560-570.
30. Hąbek, P., Wolniak, R. (2016). Relationship between management practices and quality of CSR reports. *Procedia – Social and Behavioral Sciences*, *220*, 115-123.
31. Herdiansyah, H. (2023). Smart city based on community empowerment, social capital, and public trust in urban areas. *Glob. J. Environ. Sci. Manag,. 9*, 113-128.
32. Hurwitz, J., Kaufman, M., Bowles, A. (2015). *Cognitive Computing and Big Data Analytics,* New York: Wiley.
33. Hys, K., Wolniak, R. (2018). Praktyki przedsiębiorstw przemysłu chemicznego w Polsce w zakresie CSR. *Przemysł Chemiczny*, *9*, 1000-1002.
34. Iványi, T., Bíró-Szigeti, S. (2019). Smart City: Studying smartphone application functions with city marketing goals based on consumer behavior of generation Z in Hungary, *Periodica Polytechnica Social and Management Sciences, 27(1),* 48-58.
35. Jonek-Kowalska, I., Wolniak, R. (2021). Economic opportunities for creating smart cities in Poland. Does wealth matter? *Cities*, *114*, 1-6.
36. Jonek-Kowalska, I., Wolniak, R. (2021). The influence of local economic conditions on start-ups and local open innovation system. *Journal of Open Innovations: Technology, Market and Complexity*, *7(2),* 1-19.

37. Jonek-Kowalska, I., Wolniak, R. (2022). Sharing economies' initiatives in municipal authorities' perspective: research evidence from Poland in the context of smart cities' development. *Sustainability, 14(4),* 1-23.
38. Jonek-Kowalska, I., Wolniak, R. (2023). *Smart Cities in Poland. Towards sustainability and a better quality of life?* London: Routledge.
39. Jonek-Kowalska, I., Wolniak, R., Marinina, O.A., Ponomarenko, T.V. (2022). *Stakeholders, Sustainable Development Policies and the Coal Mining Industry. Perspectives from Europe and the Commonwealth of Independent States*. London: Routledge.
40. Kalasova, A., Culik, K., Poliak, M. (2021). *Smartphone-based Taxi Applications as Essential Part of Smart City.* Smart City Symposium Prague, SCSP 2021, 9447376.
41. Kordel, P., Wolniak, R. (2021). Technology entrepreneurship and the performance of enterprises in the conditions of Covid-19 pandemic: the fuzzy set analysis of waste to energy enterprises in Poland. *Energies, 14(13),* 1-22.
42. Ku, D., Choi, M., Lee, D., Lee, S. (2022). The effect of a smart mobility hub based on concepts of metabolism and retrofitting. *J. Clean. Prod., 379*, 134709.
43. Kunytska, O., Persia, L., Gruenwald, N., Datsenko, D., Zakrzewska, M. (2023). The Sustainable and Smart Mobility Strategy: Country Comparative Overview. *Lecture Notes in Networks and Systems, Vol. 536.* Cham: Switzerland: Springer, 656-668.
44. Kwiotkowska, A., Gajdzik, B., Wolniak, R., Vveinhardt, J., Gębczyńska, M. (2021). Leadership competencies in making Industry 4.0 effective: the case of Polish heat and power industry. *Energies, 14(14),* 1-22.
45. Kwiotkowska, A., Wolniak, R., Gajdzik, B., Gębczyńska, M. (2022). Configurational paths of leadership competency shortages and 4.0 leadership effectiveness: an fs/QCA study. *Sustainability, 14(5),* 1-21.
46. Leal, D., Albuquerque, V., Dias, M.S., Ferreira, J.C. (2023). Analyzing Urban Mobility Based on Smartphone Data: The Lisbon Case Study. *Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering, LNICST, 486*, 40-54.
47. Michalak, A., Wolniak, R. (2023). The innovativeness of the country and the renewables and non-renewables in the energy mix on the example of European Union. *Journal of Open Innovation: Technology, Market, and Complexity, 9(2),* https://doi.org/10.1016/j.joitmc. 2023.100061.
48. Olkiewicz, M., Olkiewicz, A., Wolniak, R., Wyszomirski, A. (2021). Effects of pro-ecological investments on an example of the heating industry - case study. *Energies, 14(18),* 1-24, 5959.
49. Orłowski, A., Romanowska, P. (2019). Smart Cities Concept—Smart Mobility Indicator. *Cybern. Syst., 50*, 118-131. https://doi.org/10.1080/01969722.2019.1565120.

50. Orzeł, B., Wolniak, R. (2021). Clusters of elements for quality assurance of health worker protection measures in times of COVID-19 pandemic. *Administrative Science, 11(2),* 1-14, 46.
51. Orzeł, B., Wolniak, R. (2022). Digitization in the design and construction industry - remote work in the context of sustainability: a study from Poland. *Sustainability, 14(3),* 1-25.
52. Ponomarenko, T.V., Wolniak, R., Marinina, O.A. (2016). Corporate Social responsibility in coal industry (Practices of russian and european companies). *Journal of Mining Institute, 222*, 882-891.
53. Prajeesh, C.B., Pillai, A.S. (2022). Indian Smart Mobility Ecosystem—Key Visions and Missions. *AIP Conf. Proc., 2555,* 050005.
54. Rachmawati, I., Multisari, W., Triyono, T., Simon, I.M., da Costa, A. (2021). Prevalence of academic resilience of social science students in facing the industry 5.0 era. *International Journal of Evaluation and Research in Education, 10(2),* 676-683
55. Rahman, S.A.A., Dura, N.H. (2022). Malaysia smart tourism framework: Is smart mobility relevant? *Kasetsart J. Soc. Sci., 43,* 1009-1014.
56. Rosak-Szyrocka, J., Żywiołek J., Wolniak, R. (2023). Main reasons for religious tourism - from a quantitative analysis to a model. *International Journal for Quality Research, 1(17),* 109-120.
57. Rose, G., Raghuram, P., Watson, S., Wigley, E. (2021). Platform urbanism, smartphone applications and valuing data in a smart city. *Transactions of the Institute of British Geographers, 46(1),* 59-72.
58. Sanchez, J.A., Melendi, D., Paneda, X.G., Garcia, R. (2018). Towards Smart Mobility in Urban Areas Using Vehicular Communications and Smartphones. *IEEE Latin America Transactions, 16(5),* 1380-1387.
59. Simonofski, A., Handekyn, P., Vandennieuwenborg, C., Wautelet, Y., Snoeck, M. (2023). Smart mobility projects: Towards the formalization of a policy-making lifecycle. *Land Use Policy, 125,* 106474.
60. Sofat, C., Bansal, D. (2016). *SmartTrafMoniSys: Smartphone based traffic monitoring and management system.* MobiSys 2016 Companion - Companion Publication of the 14th Annual International Conference on Mobile Systems, Applications, and Services.
61. Stawiarska, E., Szwajca, D., Matusek, M., Wolniak, R. (2020). *Wdrażanie rozwiązań przemysłu 4.0 w wybranych funkcjonalnych obszarach zarządzania przedsiębiorstw branży motoryzacyjnej: próba diagnozy.* Warszawa: CeDeWu.
62. Stawiarska, E., Szwajca, D., Matusek, M., Wolniak, R. (2021). Diagnosis of the maturity level of implementing Industry 4.0 solutions in selected functional areas of management of automotive companies in Poland. *Sustainability, 13(9),* 1-38.
63. Stecuła, K., Wolniak, R. (2022). Advantages and Disadvantages of E-Learning Innovations during COVID-19 Pandemic in Higher Education in Poland. *Journal of Open Innovation: Technology, Market, and Complexity, 8(3),* 159.

64. Stecuła, K., Wolniak, R. (2022). Influence of COVID-19 Pandemic on Dissemination of Innovative E-Learning Tools in Higher Education in Poland. *Journal of Open Innovations: Technology, Market and Complexity, 8(1),* 89.
65. Sułkowski, M., Wolniak, R. (2016). Przegląd stosowanych metod oceny skuteczności i efektywności organizacji zorientowanych na ciągłe doskonalenie. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacja i Zarzadzanie*, *67*, 63-74.
66. Sułkowski, M., Wolniak, R. (2018). *Poziom wdrożenia instrumentów zarządzania jakością w przedsiębiorstwach branży obróbki metali.* Częstochowa: Oficyna Wydawnicza Stowarzyszenia Menedżerów Produkcji i Jakości.
67. Wolniak R., Grebski W. Functioning of predictive analytics in business, *Silesian University of Technology Scientific Papers. Organization and Management Series*, 175, 631-649.
68. Wolniak R., Grebski W. The concept of diagnostic analytics, *Silesian University of Technology Scientific Papers. Organization and Management Series*, 175, 650-669.
69. Wolniak R., Skotnicka-Zasadzień B. Development of Wind Energy in EU Countries as an Alternative Resource to Fossil Fuels in the Years 2016–2022, Resources, 2023, 12(8), 96.
70. Wolniak, R, Skotnicka-Zasadzień, B. (2014). The use of value stream mapping to introduction of organizational innovation in industry. *Metalurgija*, *53(4)*, 709-713.
71. Wolniak, R. (2011). *Parametryzacja kryteriów oceny poziomu dojrzałości systemu zarządzania jakością.* Gliwice: Wydawnictwo Politechniki Śląskiej.
72. Wolniak, R. (2013). A typology of organizational cultures in terms of improvement of the quality management. *Manager*, *17(1),* 7-21.
73. Wolniak, R. (2013). Projakościowa typologia kultur organizacyjnych. *Przegląd Organizacji*, *3,* 13-17.
74. Wolniak, R. (2014). Korzyści doskonalenia systemów zarządzania jakością opartych o wymagania normy ISO 9001:2009. *Problemy Jakości*, *3,* 20-25.
75. Wolniak, R. (2016). Kulturowe aspekty zarządzania jakością. *Etyka biznesu i zrównoważony rozwój. Interdyscyplinarne studia teoretyczno*-empiryczne, *1,* 109-122.
76. Wolniak, R. (2016). *Metoda QFD w zarządzaniu jakością. Teoria i praktyka*. Gliwice: Wydawnictwo Politechniki Śląskiej.
77. Wolniak, R. (2016). Relations between corporate social responsibility reporting and the concept of greenwashing. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacji i Zarządzanie, 87,* 443-453.
78. Wolniak, R. (2016). The role of QFD method in creating innovation. *Systemy Wspomagania Inżynierii Produkcji*, 3, 127-134.
79. Wolniak, R. (2017). Analiza relacji pomiędzy wskaźnikiem innowacyjności a nasyceniem kraju certyfikatami ISO 9001, ISO 14001 oraz ISO/TS 16949. *Kwartalnik Organizacja i Kierowanie, 2*, 139-150.

80. Wolniak, R. (2017). Analiza wskaźników nasycenia certyfikatami ISO 9001, ISO 14001 oraz ISO/TS 16949 oraz zależności pomiędzy nimi. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacji i Zarządzanie*, *108*, 421-430.
81. Wolniak, R. (2017). The Corporate Social Responsibility practices in mining sector in Spain and in Poland – similarities and differences. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacji i Zarządzanie*, *111*, 111-120.
82. Wolniak, R. (2017). The Design Thinking method and its stages. *Systemy Wspomagania Inżynierii Produkcji, 6*, 247-255.
83. Wolniak, R. (2017). The use of constraint theory to improve organization of work. 4th International Multidisciplinary Scientific Conference on Social Sciences and Arts. SGEM 2017, 24-30 August 2017, Albena, Bulgaria. Conference proceedings. Book 1, *Modern science. Vol. 5, Business and management*. Sofia: STEF92 Technology, 1093-1100.
84. Wolniak, R. (2018). Functioning of social welfare on the example of the city of Łazy. *Zeszyty Naukowe Wyższej Szkoły, Humanitas. Zarządzanie, 3,* 159-176.
85. Wolniak, R. (2018). Methods of recruitment and selection of employees on the example of the automotive industry. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacja i Zarządzanie*, *128*, 475-483.
86. Wolniak, R. (2019). Context of the organization in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *133*, 121-136.
87. Wolniak, R. (2019). Downtime in the automotive industry production process - cause analysis. *Quality, Innovation, Prosperity*, *2,* 101-118.
88. Wolniak, R. (2019). Leadership in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *133*, 137-150.
89. Wolniak, R. (2019). Support in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *137*, 247-261.
90. Wolniak, R. (2019). The level of maturity of quality management systems in Poland-results of empirical research. *Sustainability*, *15,* 1-17.
91. Wolniak, R. (2020). Design in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *148*, 769-781.
92. Wolniak, R. (2020). Operations in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *148*, 783-794.
93. Wolniak, R. (2020). Quantitative relations between the implementation of industry management systems in European Union countries. *Silesian University of Technology Scientific Papers. Organization and Management Series*, 142, 33-44.
94. Wolniak, R. (2021). Internal audit and management review in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *151*, 724-608.

95. Wolniak, R. (2021). Performance evaluation in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *151*, 725-734.
96. Wolniak, R. (2022). Engineering ethics – main principles. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *155*, 579-594.
97. Wolniak, R. (2022). Individual innovations. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *166*, 861-876.
98. Wolniak, R. (2022). Management of engineering teams. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *157*, 667-674.
99. Wolniak, R. (2022). Problems of Covid-19 influence on small and medium enterprises activities – organizing function. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *167*, 599-608.
100. Wolniak, R. (2022). Project management in engineering. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *157*, 685-698.
101. Wolniak, R. (2022). Project management standards, Silesian University of Technology *Scientific Papers. Organization and Management Series*, 160, 639-654.
102. Wolniak, R. (2022). Sustainable engineering, *Silesian University of Technology Scientific Papers. Organization and Management Series*, 160, 655-667.
103. Wolniak, R. (2022). The role of the engineering profession in developing and implementing sustainable development principles. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *155*, 595-608.
104. Wolniak, R. (2022). Traits of highly innovative people. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *166*, 877-892.
105. Wolniak, R. (2023). Analiza danych w czasie rzeczywistym, *Zarządzanie i Jakość*, 2(5), 291-312.
106. Wolniak, R. (2023). Analysis of the Bicycle Roads System as an Element of a Smart Mobility on the Example of Poland Provinces, *Smart Cities*, 2023, 6(1), 368-391; https://doi.org/10.3390/smartcities6010018.
107. Wolniak, R. (2023). Design thinking and its use to boast innovativeness. *Silesian University of Technology Scientific Papers. Organization and Management Series*, 170, 647-662.
108. Wolniak, R. (2023). Deskryptywna analiza danych, *Zarządzanie i Jakość*, 2(5), 272-290.
109. Wolniak, R. (2023). European Union Smart Mobility - aspects connected with bike road systems extension and dissemination. *Smart Cities*, 6, 1-32.
110. Wolniak, R. (2023). European Union Smart Mobility–Aspects Connected with Bike Road System's Extension and Dissemination, *Smart Cities* 2023, 6(2), 1009-1042; https://doi.org/10.3390/smartcities6020049.
111. Wolniak, R. (2023). Functioning of real-time analytics in business. *Silesian University of Technology Scientific Papers. Organization and Management Series*, 172, 659-677.

112. Wolniak, R. (2023). Industry 5.0 – characteristic, main principles, advantages and disadvantages. *Silesian University of Technology Scientific Papers. Organization and Management Series*, 170, 663-678.
113. Wolniak, R. (2023). Innovations in industry 4.0 conditions, *Silesian University of Technology Scientific Papers. Organization and Management Series*, *169*, 725-742.
114. Wolniak, R. (2023). Smart biking w smart city, *Zarządzanie i Jakość*, 2(5), 313-328.
115. Wolniak, R. (2023). Smart mobility in a smart city concept *Silesian University of Technology Scientific Papers. Organization and Management Series*, 170, 679-692.
116. Wolniak, R. (2023). Smart mobility in smart city – Copenhagen and Barcelona comparision. *Silesian University of Technology Scientific Papers. Organization and Management Series*, 172, 678-697.
117. Wolniak, R. (2023). Smart mobility jako element koncepcji smart city, Zarządzanie I Jakość, 1(5), 208-222.
118. Wolniak, R. (2023). Team innovations, *Silesian University of Technology Scientific Papers. Organization and Management Series*, *169*, 773-758.
119. Wolniak, R. (2023). The concept of descriptive analytics. *Silesian University of Technology Scientific Papers. Organization and Management Series*, 172, 698-715.
120. Wolniak, R. Sułkowski, M. (2015). Rozpowszechnienie stosowania Systemów Zarządzania Jakością w Europie na świecie – lata 2010-2012. *Problemy Jakości*, *5*, 29-34.
121. Wolniak, R., Gajdzik B., Grebski W. Environmental sustainability in business, *Silesian University of Technology Scientific Papers. Organization and Management Series*, 175, 611-630.
122. Wolniak, R., Grebski, M.E. (2018). Innovativeness and creativity as factors in workforce development – perspective of psychology. *Zeszyty Naukowe Politechniki Ślaskiej. Seria Organizacja i Zarządzanie*, *116*, 203-214.
123. Wolniak, R., Grebski, M.E. (2018). Innovativeness and creativity as nature and nurture. *Zeszyty Naukowe Politechniki Ślaskiej. Seria Organizacja i* Zarządzanie, *116*, 215-226.
124. Wolniak, R., Grebski, M.E. (2018). Innovativeness and Creativity of the Workforce as Factors Stimulating Economic Growth in Modern Economies. *Zeszyty Naukowe Politechniki Ślaskiej. Seria Organizacja i Zarządzanie*, *116*, 227-240.
125. Wolniak, R., Grebski, M.E., Skotnicka-Zasadzień, B. (2019). Comparative analysis of the level of satisfaction with the services received at the business incubators (Hazleton, PA, USA and Gliwice, Poland). *Sustainability*, *10*, 1-22.
126. Wolniak, R., Hąbek, P. (2015). Quality management and corporate social responsibility. *Systemy Wspomagania w Inżynierii Produkcji*, *1,* 139-149.
127. Wolniak, R., Hąbek, P. (2016). Quality assessment of CSR reports – factor analysis. *Procedia – Social and Behavioral Sciences*, *220*, 541-547.

128. Wolniak, R., Jonek-Kowalska, I. (2021). The level of the quality of life in the city and its monitoring. *Innovation (Abingdon*), *34(3),* 376-398.
129. Wolniak, R., Jonek-Kowalska, I. (2021). The quality of service to residents by public administration on the example of municipal offices in Poland. *Administration Management Public*, *37,* 132-150.
130. Wolniak, R., Jonek-Kowalska, I. (2022). The creative services sector in Polish cities. *Journal of Open Innovation: Technology, Market, and Complexity*, *8(1),* 1-23.
131. Wolniak, R., Saniuk, S., Grabowska, S., Gajdzik, B. (2020). Identification of energy efficiency trends in the context of the development of industry 4.0 using the Polish steel sector as an example. *Energies*, *13(11),* 1-16.
132. Wolniak, R., Skotnicka, B. (2011).: *Metody i narzędzia zarządzania jakością – Teoria i praktyka, cz. 1*. Gliwice: Wydawnictwo Naukowe Politechniki Śląskiej.
133. Wolniak, R., Skotnicka-Zasadzień, B. (2008). *Wybrane metody badania satysfakcji klienta i oceny dostawców w organizacjach.* Gliwice: Wydawnictwo Politechniki Śląskiej.
134. Wolniak, R., Skotnicka-Zasadzień, B. (2010). *Zarządzanie jakością dla inżynierów.* Gliwice: Wydawnictwo Politechniki Śląskiej.
135. Wolniak, R., Skotnicka-Zasadzień, B. (2018). Developing a model of factors influencing the quality of service for disabled customers in the condition s of sustainable development, illustrated by an example of the Silesian Voivodeship public administration. *Sustainability*, *7, 1*-17.
136. Wolniak, R., Skotnicka-Zasadzień, B. (2022). Development of photovoltaic energy in EU countries as an alternative to fossil fuels. *Energies*, *15(2),* 1-23.
137. Wolniak, R., Skotnicka-Zasadzień, B., Zasadzień, M. (2019). Problems of the functioning of e-administration in the Silesian region of Poland from the perspective of a person with disabilities. *Transylvanian Review of Public Administration*, *57E,* 137-155.
138. Wolniak, R., Sułkowski, M. (2015). Motywy wdrażanie certyfikowanych Systemów Zarządzania Jakością. *Problemy Jakości, 9,* 4-9.
139. Wolniak, R., Sułkowski, M. (2016). The reasons for the implementation of quality management systems in organizations. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacji i Zarządzanie*, *92*, 443-455.
140. Wolniak, R., Wyszomirski, A., Olkiewicz, M., Olkiewicz, A. (2021). Environmental corporate social responsibility activities in heating industry - case study. *Energies*, 14(7), 1-19, 1930.