SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2023
ORGANIZATION AND MANAGEMENT SERIES NO. 184

ENERGY EFFICIENCY MANAGEMENT IN SMART CITY – SMARTPHONE APPLICATIONS ASPECTS

Radosław WOLNIAK[1*], Wies GREBSKI[2]

[1] Silesian University of Technology, Organization and Management Department, Economics and Informatics Institute; rwolniak@polsl.pl, ORCID: 0000-0003-0317-9811
[2] Penn State Hazletonne, Pennsylvania State University; wxg3@psu.edu, ORCID: 0000-0002-4684-7608
* Correspondence author

Purpose: The purpose of this publication is to present the usage of smartphone application in Smart Cities in energy efficiency 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: The rise of the Internet of Things has made smart devices commonplace in homes and businesses. Smartphone apps play a key role in enabling users to control and monitor these devices, thereby enhancing energy efficiency. Real-time data on energy consumption informs users' decisions, leading to reduced energy waste and costs. These apps not only offer convenience but also support customization and automation for energy-efficient operations. Participation in demand response programs and integration with renewable energy sources further enhance energy efficiency. Smartphone applications also contribute to eco-friendly commuting and optimized waste management, while educating users about their environmental impact and ways to reduce energy consumption sustainably. Despite their advantages, smartphone applications face challenges related to data privacy, adoption, compatibility, user education, reliability, affordability, and access inequalities. Overcoming these challenges is crucial for smart city planners and developers to fully harness the potential of smartphone applications in creating energy-efficient and sustainable smart cities.

Keywords: Smart City, energy efficiency, energy efficiency management, smartphone applications, smart mobility.

Category of the paper: literature review.

1. Introduction

Energy efficiency management in smart cities, particularly in the context of smartphone applications, plays a pivotal role in creating sustainable, environmentally friendly urban environments. This article will delve into the various aspects of how smartphone applications are contributing to energy efficiency in smart cities.

Smartphone applications are integral to the success of energy efficiency management in smart cities. By providing users with real-time data, control over their surroundings, and information about sustainable practices, these apps empower individuals and organizations to contribute to the broader goal of creating greener and more energy-efficient urban spaces.

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

2. The usage of smartphone applications in energy efficiency management

Smartphone applications enable users to remotely control and monitor various aspects of their homes and workplaces. This includes adjusting the thermostat, turning off lights, and managing appliances. This level of control helps in reducing energy consumption by ensuring that devices are not unnecessarily left running. These applications collect and analyze real-time data from sensors embedded in the infrastructure of smart cities. This data includes information on traffic flow, weather conditions, and energy usage patterns. By processing this data, the applications can suggest optimal routes for commuters, encourage carpooling, and even predict and manage energy demand more efficiently (Rachmawati et al., 2021; Dutta et al, 2021; Ivanyi, Biro-Szigeti, 2019).

With the advent of the Internet of Things (IoT), smart devices and appliances have become ubiquitous in modern homes and commercial buildings. Smartphone applications play a central role in enabling users to remotely control and monitor these devices. From adjusting the thermostat and controlling lighting to managing heating, ventilation, and air conditioning (HVAC) systems, these apps put the power of energy efficiency in the palm of your hand. Whether you're at home or halfway around the world, you can ensure that your spaces are using energy optimally (Wolniak, Sułkowski, 2015, 2016; Wolniak, Grebski, 2018; Wolniak et al., 2019, 2020; Wolniak, Habek, 2015, 2016; Wolniak, Skotnicka, 2011; Wolniak, Jonek-Kowalska, 2021; 2022). One of the key advantages of remote control and monitoring is the access to real-time energy data. Smart meters and sensors collect detailed information about electricity, water, and gas usage. This data is then presented to users through intuitive smartphone apps, allowing them to track and visualize their energy consumption patterns. By having this data at their fingertips, individuals and organizations can make informed decisions about how to reduce energy wastage and cut down on costs. Many modern appliances are now "smart" and can be integrated with smartphone apps. Users can schedule the operation of appliances like washing machines, dishwashers, and ovens, so they run during off-peak energy hours or when electricity rates are lower. Moreover, users can remotely turn off or put appliances into an energy-saving mode when they are not in use (Herdiansayah, 2023; Rose et al., 2021).

Heating and cooling systems can be significant energy consumers. Smartphone apps enable users to remotely adjust the temperature, set schedules for HVAC operation, and even receive alerts when filters need replacement. These capabilities not only enhance comfort but also contribute to energy savings. Smart city applications also extend to security and surveillance systems. Users can monitor their homes or businesses through connected cameras and sensors, receiving real-time alerts and taking action remotely. This not only enhances safety but also reduces the energy footprint associated with maintaining a physical presence on-site. For users with renewable energy sources like solar panels, smartphone apps can display real-time data on energy generation and consumption. This allows homeowners to maximize their use of clean energy and minimize reliance on the grid (Rahman, Dura, 2022).

Smartphone applications allow users to remotely control lighting systems, including turning lights on and off or adjusting their brightness. This level of control is not only convenient but also promotes energy efficiency by ensuring that lights are only used when needed. For example, users can turn off lights in unoccupied rooms with a simple tap on their smartphones.

Many smartphone apps provide users with insights into their energy consumption. They can track and visualize how much energy is being used in different areas of their homes or workplaces. This awareness helps individuals and businesses make informed decisions about energy usage and, in turn, reduce their energy bills. Smartphone applications can connect with smart appliances and systems within buildings, allowing users to schedule tasks and create automation rules. For instance, lights can be programmed to turn off when a room is empty, and thermostats can adjust temperature settings based on the occupants' schedules (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).

Some smart city smartphone applications participate in demand response programs. These programs allow utilities to remotely manage energy consumption during peak periods. Users can opt into such programs and receive incentives for reducing their energy usage during high-demand times. Many smart cities are incorporating renewable energy sources like solar panels and wind turbines. Smartphone applications can provide users with information on the availability of renewable energy sources and even allow them to sell excess energy back to the grid, promoting a more sustainable energy ecosystem (Chmielarz et al., 2021).

Smartphone apps can help manage traffic flow, reducing congestion and thereby cutting down on fuel consumption. Real-time traffic updates and navigation services can guide drivers along the most efficient routes, helping to lower carbon emissions. Efficient waste collection and disposal contribute to energy efficiency. Smartphone apps can optimize waste management by scheduling collection services based on real-time data and encouraging recycling and composting practices (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).

Many smart cities promote the use of public transportation and ride-sharing as eco-friendly alternatives to private car ownership. Smartphone apps for booking buses, trains, and rideshare services help users make more sustainable transportation choices. Smartphone applications also play a role in fostering behavioral change among citizens. They can educate users about the environmental impact of their actions and suggest ways to reduce energy consumption and live more sustainably (Simonofski et al., 2023; Chmielarz et al., 2021).

Table 1 contains descriptions of how smartphone applications are used in in energy efficiency management. It provides a concise overview of how smartphone applications are utilized in various aspects of energy efficiency management within smart cities.

Table 1.
How smartphone applications are used in energy efficiency management

Aspect of Energy Efficiency Management	Use of Smartphone Applications
Remote Control and Monitoring	Users can control home appliances, lighting, and HVAC systems remotely through smartphone apps, ensuring devices are not left running unnecessarily.
Real-time Data Analytics	Smartphone apps collect and analyze real-time data, such as traffic flow, weather conditions, and energy usage patterns, to optimize routes, encourage carpooling, and manage energy demand efficiently.
Energy Consumption Insights	Apps provide users with insights into their energy consumption, helping them track and visualize energy usage in different areas and make informed decisions to reduce energy consumption.
Smart Appliances Integration	Smartphone apps connect with smart appliances and systems, enabling users to schedule tasks and create automation rules for energy-efficient operation.
Demand Response Programs	Users can participate in demand response programs through apps, allowing utilities to manage energy consumption during peak periods, offering incentives for reducing usage.
Renewable Energy Integration	Apps provide information on the availability of renewable energy sources and enable users to sell excess energy back to the grid, promoting sustainability.
Traffic Management for Reduced Congestion	Apps offer real-time traffic updates and navigation services to guide drivers along efficient routes, reducing fuel consumption and carbon emissions.
Waste Management Optimization	Apps optimize waste collection by scheduling services based on real-time data, encouraging recycling and composting practices to reduce energy consumption.
Public Transportation and Ride-Sharing Services	Smartphone apps for booking public transportation and rideshare services promote eco-friendly alternatives to private car ownership.
Behavioral Change	Apps educate users about their environmental impact and suggest ways to reduce energy consumption and live more sustainably.

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 highlighting the advantages of using smartphone applications in energy efficiency management within smart cities. These advantages illustrate how smartphone applications are pivotal in energy efficiency management within smart cities, offering both convenience and sustainability benefits to individuals and communities alike.

Table 2.
Advantages of using smartphone applications in energy efficiency management

Advantage	Description
Convenience and Accessibility	Users can control and monitor energy-related devices and systems from anywhere, enhancing convenience and accessibility.
Real-time Data Insights	Apps provide real-time data on energy consumption, helping users make informed decisions to reduce usage and costs.
Remote Control	Remote management of appliances, lighting, and HVAC systems promotes energy efficiency by preventing unnecessary usage.
Customization and Automation	Users can schedule tasks and create automation rules to optimize energy usage based on their preferences and needs.
Integration with Renewable Energy	Smartphone apps can integrate with renewable energy sources, allowing users to monitor and maximize clean energy usage.
Demand Response Participation	Users can participate in demand response programs, earning incentives for reducing energy consumption during peak periods.
Environmental Impact Awareness	Apps educate users about their environmental impact, encouraging sustainable practices and reducing energy consumption.
Traffic Management and Eco-friendly Commuting	Smartphone apps assist in reducing congestion and promoting eco-friendly transportation choices, reducing fuel consumption.
Waste Management Optimization	Efficient waste collection and recycling are facilitated, contributing to energy efficiency and environmental sustainability.
Security and Surveillance	Users can enhance security and reduce energy usage by remotely monitoring and controlling surveillance systems through apps.
Increased Comfort and Well-being	Smartphone apps optimize heating and cooling, enhancing comfort and well-being while conserving energy.
Grid Stability and Reliability	By participating in demand response and monitoring energy usage, smartphone apps support grid stability and reliability.

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).

Smartphone applications make it incredibly convenient to control and monitor energy-related devices and systems. Users can adjust settings, receive real-time updates, and make informed decisions from anywhere, ensuring that energy management is at their fingertips. These apps provide users with valuable real-time data on their energy consumption. This information empowers individuals and organizations to track usage patterns, identify areas of improvement, and ultimately reduce energy consumption and costs.

Smartphone apps allow users to remotely manage appliances, lighting, and HVAC systems. This not only enhances convenience but also helps prevent unnecessary energy consumption. Lights, for example, can be turned off in unoccupied rooms with a simple tap on the app. Users can create customized schedules and automation rules for their devices and systems. For instance, they can program thermostats to adjust temperatures based on daily routines, promoting energy-efficient operation (Kalasova et al., 2021).

Smartphone applications can integrate with renewable energy sources such as solar panels and wind turbines. This enables users to monitor energy generation and consumption, maximizing their use of clean energy and minimizing reliance on the grid. Users can participate in demand response programs through these apps, allowing them to earn incentives for reducing their energy consumption during peak periods. This not only benefits users but also contributes to grid stability and reliability.

Many applications educate users about their environmental impact. By raising awareness of energy usage, these apps encourage sustainable practices and motivate users to reduce their energy consumption, thereby lowering their carbon footprint. Smartphone applications play a role in reducing traffic congestion and promoting eco-friendly transportation choices. Real-time traffic updates and navigation services guide users along the most efficient routes, reducing fuel consumption and emissions (Dutta et al., 2019).

Efficient waste collection and recycling are facilitated by these apps. They enable the scheduling of waste collection based on real-time data and encourage recycling and composting practices, contributing to energy efficiency and environmental sustainability. Users can enhance security and reduce energy usage by remotely monitoring and controlling surveillance systems through smartphone apps. This feature not only provides peace of mind but also contributes to efficient energy management.

Smartphone apps optimize heating and cooling systems, improving comfort and well-being in homes and buildings. This ensures that energy is used efficiently without sacrificing occupant comfort. By participating in demand response programs and monitoring energy usage, smartphone apps contribute to grid stability and reliability. This is essential for ensuring that cities have a consistent and dependable power supply (Boichuk, 2020).

Table 3 highlighting some of the common problems and challenges associated with the usage of smartphone applications in energy efficiency management within smart cities.

Table 3.
Problems of using smartphone applications in energy efficiency management within smart cities

Problem	Description
Data Privacy and Security	Concerns about the protection of personal or sensitive data when using these applications can be a significant issue. Users may worry about their data being vulnerable to cyberattacks or misuse.
Limited Adoption and Accessibility	Not everyone has access to smartphones or may not be comfortable using these apps, potentially leaving certain demographics or groups without the benefits of energy efficiency management.
Interoperability and Compatibility	The compatibility of various devices, systems, and applications can be a challenge. Ensuring that different components can work together seamlessly is a common hurdle.
Reliability and Downtime	Smart city applications may experience downtime or technical issues that could disrupt energy management. Dependence on technology can sometimes lead to inconvenience.
Cost and Affordability	The initial setup and ongoing costs of smart devices and their associated apps can be a barrier for some individuals or organizations, limiting their ability to invest in energy-efficient solutions.
Digital Divide	Not all residents of a smart city may have equal access to smartphones or high-speed internet, creating a digital divide that hinders the widespread adoption of energy efficiency applications.
User Education and Awareness	Some users may not be fully aware of the benefits and capabilities of these applications, which can lead to underutilization and missed opportunities for energy savings.
Complexity and Learning Curve	Smartphone apps for energy management can be complex, requiring users to learn how to operate them effectively. Some may find this learning curve challenging.

Cont. table 3.

Dependence on the Grid	In cases where smartphone applications rely on the grid for real-time data and control, power outages or grid failures can limit their effectiveness, especially during emergencies.
Maintenance and Updates	Ongoing maintenance and software updates are essential for keeping these applications secure and functional. Neglecting these aspects can lead to vulnerabilities and performance issues.
Lack of Internet Connectivity	Smart city applications depend on internet connectivity, and areas with poor or no internet access may face limitations in utilizing these tools for energy management.
Sustainability Concerns	The production and disposal of smartphones and related hardware may have environmental implications. Ensuring the sustainability of these technologies is an ongoing challenge.
Privacy Invasion	Some users may feel that using these applications invades their privacy by collecting data on their habits, routines, and preferences, raising concerns about surveillance and data use.

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).

The integration of smartphone applications into energy efficiency management within smart cities offers numerous benefits, as previously discussed. However, it's important to recognize that there are challenges and problems associated with the use of these applications in the context of energy efficiency. Smartphone applications used for energy efficiency management often collect and process sensitive data related to a user's behavior and energy consumption patterns. This data can be vulnerable to security breaches or misuse, raising concerns about privacy and the potential for cyberattacks.

Not all residents of smart cities have access to smartphones, and some may not be comfortable using these applications. This limitation could result in certain demographics or groups being excluded from the benefits of energy efficiency management. The compatibility of various devices, systems, and applications used for energy efficiency can be a significant challenge. Ensuring that different components can work together seamlessly is essential to achieving an integrated and efficient energy management system (Benevolo et al., 2016; Kalasova et al., 2021).

Smart city applications may experience downtime or technical issues, which could disrupt energy management. Dependence on technology can sometimes lead to inconvenience and operational disruptions. The initial setup and ongoing costs of smart devices and their associated apps can be a barrier for some individuals or organizations. This financial constraint may limit their ability to invest in energy-efficient solutions. The digital divide can manifest in smart cities, with not all residents having equal access to smartphones or high-speed internet. This disparity can hinder the widespread adoption of energy efficiency applications.

Some users may not be fully aware of the benefits and capabilities of these applications, leading to underutilization and missed opportunities for energy savings. Promoting user education and awareness is crucial. Smartphone apps for energy management can be complex and may require users to learn how to operate them effectively. Some individuals may find this learning curve challenging, leading to suboptimal usage. In cases where smartphone

applications rely on the grid for real-time data and control, power outages or grid failures can limit their effectiveness, especially during emergencies. This dependence on a centralized infrastructure may introduce vulnerabilities (Wolniak, 2016; Czerwińska-Lubszczyk et al., 2022; Drozd, Wolniak, 2021; Gajdzik, Wolniak, 2021, 2022; Gębczyńska, Wolniak, 2018, 2023; Grabowska et al., 2019, 2020, 2021).

Ongoing maintenance and software updates are crucial for keeping these applications secure and functional. Neglecting these aspects can lead to vulnerabilities and performance issues. Smart city applications depend on reliable internet connectivity. Areas with poor or no internet access may face limitations in utilizing these tools for energy management. The production and disposal of smartphones and related hardware may have environmental implications. Ensuring the sustainability of these technologies and their responsible end-of-life management is an ongoing challenge. Some users may feel that using these applications invades their privacy by collecting data on their habits, routines, and preferences. Concerns about surveillance and data use can lead to user resistance and hesitance.

3. Conclusion

Energy efficiency management in smart cities, facilitated by smartphone applications, is a vital component of creating sustainable, environmentally friendly urban environments. These applications empower users and organizations to take control of their energy consumption, contributing to the broader goal of making cities more energy-efficient. Smartphone apps offer real-time data insights, remote control capabilities, and a wealth of information about sustainable practices, making them integral to the success of energy efficiency in smart cities.

Smartphone applications enable users to remotely control and monitor various aspects of their homes and workplaces, from appliances and lighting to HVAC systems. The real-time data collected from sensors embedded in smart city infrastructure allows for optimal energy management, route optimization, and efficient energy demand prediction.

The advent of the Internet of Things has made smart devices and appliances ubiquitous in modern homes and commercial buildings. Smartphone apps are at the forefront of enabling users to control and monitor these devices, contributing to energy efficiency. Real-time data on energy consumption patterns helps users make informed decisions to reduce energy wastage and costs.

Smartphone apps not only provide convenience but also promote customization and automation, allowing users to schedule and automate tasks for energy-efficient operation. Participation in demand response programs and integration with renewable energy sources further enhance energy efficiency in smart cities.

These applications play a pivotal role in promoting eco-friendly commuting and waste management optimization. Moreover, they educate users about their environmental impact and suggest ways to reduce energy consumption and live more sustainably.

While smartphone applications offer numerous advantages, they are not without their challenges. Concerns about data privacy and security, limited adoption, compatibility issues, and user education must be addressed. Reliability and affordability can be stumbling blocks, and the digital divide can create inequalities in access. Dependence on the grid, maintenance, and sustainability concerns also require attention, and some users may raise privacy-related objections.

In light of these challenges, it is essential for smart city planners and developers to work towards solutions that mitigate these problems and create a more inclusive and secure energy management ecosystem. By doing so, we can harness the full potential of smartphone applications to create energy-efficient, sustainable, and livable smart cities.

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. (2021a). 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. (2021b). 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., Jaciow, M., Wolniak, R., Wolny, R., Grebski, W. (2023). Assessment of Energy and Heat Consumption Trends and Forecasting in the Small Consumer Sector in Poland Based on Historical Data. *Resources, 12(9),* 111.
14. Gajdzik, B., Wolniak, R. (2021a). 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.
15. Gajdzik, B., Wolniak, R. (2021b). 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.
16. Gajdzik, B., Wolniak, R. (2021c). Transitioning of steel producers to the steelworks 4.0 - literature review with case studies. *Energies, 14(14),* 1-22.
17. Gajdzik, B., Wolniak, R. (2022a). 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.
18. Gajdzik, B., Wolniak, R. (2022b). 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.
19. Gajdzik, B., Wolniak, R. (2022c). 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.
20. Gajdzik, B., Wolniak, R., Grebski, W. (2023a). 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.
21. Gajdzik, B., Wolniak, R., Grebski, W. (2023b). Electricity and heat demand in steel industry technological processes in Industry 4.0 conditions. *Energies, 16(2),* 1-29.

22. Gajdzik, B., Wolniak, R., Grebski, 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.
23. Gajdzik, B., Wolniak, R., Nagaj, R., Grebski, W., Romanyshyn, T. (2023). Barriers to Renewable Energy Source (RES) Installations as Determinants of Energy Consumption in EU Countries. *Energies, 16(21),* 7364.
24. Gębczyńska, A., Wolniak, R. (2018). *Process management level in local government.* Philadelphia: CreativeSpace.
25. 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.
26. 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".
27. Grabowska, S., Grebski, M., Grebski, W., Wolniak, R. (2019). *Introduction to engineering concepts from a creativity and innovativeness perspective.* New York: KDP Publishing.
28. Grabowska, S., Grebski, M., Grebski, W., Wolniak, R. (2020). *Inżynier – zawód przyszłości. Umiejętności i kompetencje inżynierskie w erze Przemysłu 4.0.* Warszawa: CeDeWu.
29. 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.
30. 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.
31. 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.
32. Hąbek, P., Wolniak, R. (2016). Relationship between management practices and quality of CSR reports. *Procedia – Social and Behavioral Sciences, 220,* 115-123.
33. 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.
34. Hurwitz, J., Kaufman, M., Bowles, A. (2015). *Cognitive Computing and Big Data Analytics,* New York: Wiley.
35. Hys, K., Wolniak, R. (2018). Praktyki przedsiębiorstw przemysłu chemicznego w Polsce w zakresie CSR. *Przemysł Chemiczny, 9,* 1000-1002.
36. 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.
37. Jonek-Kowalska, I., Wolniak, R. (2021a). Economic opportunities for creating smart cities in Poland. Does wealth matter? *Cities, 114,* 1-6.

38. Jonek-Kowalska, I., Wolniak, R. (2021b). 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.
39. 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.
40. 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.
41. Kalasova, A., Culik, K., Poliak, M. (2021). *Smartphone-based Taxi Applications as Essential Part of Smart City.* Smart City Symposium Prague, SCSP 2021, 9447376.
42. 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.
43. 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.
44. 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.* Springer: Cham, Switzerland, 656-668.
45. 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.
46. 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.
47. 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.* LNICST, 40-54.
48. 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.
49. 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.
50. Orłowski, A.; Romanowska, P. (2019). Smart Cities Concept—Smart Mobility Indicator. *Cybern. Syst., 50,* 118-131. https://doi.org/10.1080/01969722.2019.1565120.

51. 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.
52. 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.
53. 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.
54. Prajeesh, C.B., Pillai, A.S. (2022). Indian Smart Mobility Ecosystem—Key Visions and Missions. *AIP Conf. Proc., 2555,* 050005.
55. 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
56. Rahman, S.A.A., Dura, N.H. (2022). Malaysia smart tourism framework: Is smart mobility relevant? *Kasetsart. J. Soc. Sci., 43*, 1009-1014.
57. 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.
58. 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.
59. Samarakkody, A., Amaratunga, D., Haigh, R. (2022). Characterising Smartness to Make Smart Cities Resilient. *Sustainability*, *14*, 12716.
60. 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.
61. 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.
62. 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.
63. 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.
64. 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.

65. 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.
66. 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.
67. 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.
68. Sułkowski, M., Wolniak, R. (2018). *Poziom wdrożenia instrumentów zarządzania jakością w przedsiębiorstwach branży obróbki metali.* Częstochowa: Oficyna Wydawnicza Stowarzyszenia Menedżerów Produkcji i Jakości.
69. Wolniak, R, Skotnicka-Zasadzień, B. (2014). The use of value stream mapping to introduction of organizational innovation in industry. *Metalurgija, 53(4),* 709-713.
70. Wolniak, R. (2011). *Parametryzacja kryteriów oceny poziomu dojrzałości systemu zarządzania jakością.* Gliwice: Wydawnictwo Politechniki Śląskiej.
71. Wolniak, R. (2013). Projakościowa typologia kultur organizacyjnych. *Przegląd Organizacji, 3,* 13-17.
72. Wolniak, R. (2014). Korzyści doskonalenia systemów zarządzania jakością opartych o wymagania normy ISO 9001:2009. *Problemy Jakości*, *3*, 20-25.
73. Wolniak, R. (2016a). Kulturowe aspekty zarządzania jakością. *Etyka biznesu i zrównoważony rozwój. Interdyscyplinarne studia teoretyczno-empiryczne*, *1,* 109-122.
74. Wolniak, R. (2016b). *Metoda QFD w zarządzaniu jakością. Teoria i praktyka*. Gliwice: Wydawnictwo Politechniki Śląskiej.
75. Wolniak, R. (2016c). Relations between corporate social responsibility reporting and the concept of greenwashing. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacji i Zarządzanie, 87,* 443-453.
76. Wolniak, R. (2016d). The role of QFD method in creating innovation. *Systemy Wspomagania Inżynierii Produkcji, 3*, 127-134.
77. Wolniak, R. (2017a). Analiza relacji pomiędzy wskaźnikiem innowacyjności a nasyceniem kraju certyfikatami ISO 9001, ISO 14001 oraz ISO/TS 16949. *Kwartalnik Organizacja i Kierowanie, 2*, 139-150.
78. Wolniak, R. (2017b). 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.
79. Wolniak, R. (2017c). 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.

80. Wolniak, R. (2017d). The Design Thinking method and its stages. *Systemy Wspomagania Inżynierii Produkcji, 6,* 247-255.
81. Wolniak, R. (2017e). 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.
82. Wolniak, R. (2018a). Functioning of social welfare on the example of the city of Łazy. *Zeszyty Naukowe Wyższej Szkoły, Humanitas. Zarządzanie, 3,* 159-176.
83. Wolniak, R. (2018b). 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.
84. Wolniak, R. (2019a). Context of the organization in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *133*, 121-136.
85. Wolniak, R. (2019b). Downtime in the automotive industry production process - cause analysis. *Quality, Innovation, Prosperity*, *2,* 101-118.
86. Wolniak, R. (2021). Performance evaluation in ISO 9001:2015. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *151*, 725-734.
87. Wolniak, R. (2022). Engineering ethics – main principles. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *155*, 579-594.
88. Wolniak, R. (2023a). Analiza danych w czasie rzeczywistym. *Zarządzanie i Jakość, 2(5),* 291-312.
89. Wolniak, R. (2023b). Analysis of the Bicycle Roads System as an Element of a Smart Mobility on the Example of Poland Provinces. *Smart Cities, 6(1),* 368-391; https://doi.org/10.3390/smartcities6010018.
90. Wolniak, R. (2023c). Design thinking and its use to boast innovativeness. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *170*, 647-662.
91. Wolniak, R. Sułkowski, M. (2015). Rozpowszechnienie stosowania Systemów Zarządzania Jakością w Europie na świecie – lata 2010-2012. *Problemy Jakości*, *5*, 29-34.
92. Wolniak, R., Grebski W. (2023a). Comparison of traditional and sustainable business practices. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *177*, 671-688.
93. Wolniak, R., Grebski W. (2023b). Smart biking and traditional biking. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *178*, 717-734.
94. Wolniak, R., Grebski W. (2023c). Smart mobility in smart city – Singapore and Tokyo comparison. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *176*, 751-770.

95. Wolniak, R., Grebski W. (2023d). The basis of prospective analytics in business. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *176*, 771-789.
96. Wolniak, R., Grebski W. (2023e). The five stages of business analytics. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *178*, 735-752.
97. Wolniak, R., Grebski W. (2023f). The implementation of Industry 4.0 concept in Smart City. *Silesian University of Technology Scientific Papers. Organization and Management Series*, *178*, 753-770.
98. Wolniak, R., Grebski, M.E. (2018a). Innovativeness and creativity as factors in workforce development – perspective of psychology. *Zeszyty Naukowe Politechniki Ślaskiej. Seria Organizacja i Zarządzanie*, *116*, 203-214.
99. Wolniak, R., Grebski, M.E. (2018b). Innovativeness and creativity as nature and nurture. *Zeszyty Naukowe Politechniki Ślaskiej. Seria Organizacja i* Zarządzanie, *116*, 215-226.
100. Wolniak, R., Grebski, M.E. (2018c). 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.
101. 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.
102. Wolniak, R., Hąbek, P. (2015). Quality management and corporate social responsibility. *Systemy Wspomagania w Inżynierii Produkcji*, *1*, 139-149.
103. Wolniak, R., Hąbek, P. (2016). Quality assessment of CSR reports – factor analysis. *Procedia – Social and Behavioral Sciences*, *220*, 541-547.
104. Wolniak, R., Jonek-Kowalska, I. (2021a). The level of the quality of life in the city and its monitoring. *Innovation (Abingdon*), *34(3)*, 376-398.
105. Wolniak, R., Jonek-Kowalska, I. (2021c). The quality of service to residents by public administration on the example of municipal offices in Poland. *Administration Management Public*, *37*, 132-150.
106. 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.
107. 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.
108. Wolniak, R., Skotnicka, B. (2011).: *Metody i narzędzia zarządzania jakością – Teoria i praktyka, cz. 1.* Gliwice: Wydawnictwo Naukowe Politechniki Śląskiej.
109. Wolniak, R., Skotnicka-Zasadzień, B. (2008). *Wybrane metody badania satysfakcji klienta i oceny dostawców w organizacjach.* Gliwice: Wydawnictwo Politechniki Śląskiej.
110. Wolniak, R., Skotnicka-Zasadzień, B. (2010). *Zarządzanie jakością dla inżynierów.* Gliwice: Wydawnictwo Politechniki Śląskiej.

111. 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.
112. Wolniak, R., Skotnicka-Zasadzień, B. (2022). Development of photovoltaic energy in EU countries as an alternative to fossil fuels. *Energies, 15(2),* 1-23.
113. Wolniak, R., Skotnicka-Zasadzień, B. (2023). Development of Wind Energy in EU Countries as an Alternative Resource to Fossil Fuels in the Years 2016-2022. *Resources, 12(8),* 96.
114. 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.
115. Wolniak, R., Sułkowski, M. (2015). Motywy wdrażanie certyfikowanych Systemów Zarządzania Jakością. *Problemy Jakości, 9,* 4-9.
116. 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.
117. 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.