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MAŁGORZATA BARBARA SIEMIONEK-RUSKAŃ

malgorzata.siemionek-ruskan@ug.edu.pl
University of Gdańsk. Faculty of Management
ul. Armii Krajowej 101, 81-824 Sopot, Poland
ORCID ID: https://orcid.org/0000-0002-0733-456X

ANNA SZELĄGOWSKA

aszelag@sgh.waw.pl
SGH Warsaw School of Economics. Collegium of Business Administration
Al. Niepodległości 162, 02-554 Warsaw, Poland
ORCID ID: https://orcid.org/0000-0003-2670-6100

Smartification as a New Paradigm of the Economy Development

Keywords: smartification; smart technology; artificial intelligence; information and communication technologies; Internet of Things

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Abstract

Theoretical background: This article systematizes the theoretical framework surrounding the concept of smartification, which refers to the process of integrating advanced digital technologies, such as artificial intelligence (AI), the Internet of Things (IoT), and data analytics, into various systems, objects, or processes to make them more intelligent, efficient, and responsive. The concept of smartification primarily aligns with theories related to innovation economics and the knowledge economy, both of which emphasize the role of technological innovation, information, and knowledge in driving societal transformations. Additionally, we propose embedding the concept of smartification within the theory of the economy of things.

Purpose of the article: The main aim of the article is to review existing definitions of smartification and propose an original definition in the context of this new paradigm. The article also seeks to determine the key factors influencing its development.
Research methods: The research methods used in this article include literature analysis, verification method, logical synthesis, and bibliometric analysis.
Main findings: To the authors' knowledge, this is the first approach aimed at reviewing the existing definitions of smartification found in the literature, proposing a holistic definition based on a theoretical framework, and highlighting the main determinants of its development. A comparative analysis of current smartification trends is also presented, along with the identification of its specific streams. The concept of smartification is emerging as a new development paradigm for society, business, cities, villages, and the economy. The result of the discussion is the structuring of the discourse on the contemporary role of smartification.

Introduction

The development of new technologies and smart solutions, such as automatization, blockchain, big data (datafication), cloud computing (cloudification), the Internet of Things (IoT), artificial intelligence (AI) is becoming a key force for change in society around the world and is a new paradigm (Damioli et al., 2024; Garcia, 2019; Javaid et al., 2024). These innovations are bringing fundamental changes to the way people live, work and communicate. On the one hand, these technologies are enabling greater efficiency (Gamarra, 2021) and automation in many areas of life – from industry sector to education and finance and business – while on the other hand, they are affecting social structures, labour markets and interpersonal relationships (Unuriode et al., 2024), creating new challenges such as digital exclusion (Bentley et al., 2024) or changes in employment (Acypreste & Parana, 2022; Sharif et al., 2023). In recent years, the rapid advancement of digital technologies has brought about significant transformations across various sectors, giving rise to the concept of "smartification".

Literature review

Specifics of smartification

Although the term "smartification" is increasingly invoked in discussions of technological and economic transformation, a thorough review of academic literature reveals that it remains an emerging and insufficiently theorized concept. Existing definitions are often narrowly framed and application-specific, focusing primarily on product-level technological enhancements rather than exploring smartification as a multidimensional, systemic process. Consequently, there is a lack of consensus on what constitutes smartification, how it functions across different economic and social layers, and what implications it has for theory and practice. By examining these definitions, we seek to contribute to a clearer understanding of smartification as a critical factor in the ongoing shift toward smarter systems, businesses, villages, cities, and societies.

According to Schuh et al. (2019), smartification refers to the digital refinement of an existing product by embedding digital technologies and smart services. While these new technologies introduce innovative capabilities, the core aspects of the product must still be considered, ensuring its main function remains unchanged. The authors described a method for identifying digital functions that can be integrated into smart products, using specific examples from manufacturing applications to illustrate the approach. Stich and Hicking (2019) analysed smartification of mechanical engineering products using a target-orientated method. From their perspective smartification is associated with a development process that begins with an existing product and involves modifications or adaptations to its structure or design. These authors define smartification in terms of the digital refinement of products, emphasizing integration of digital functions while preserving core functionalities.

Luis-Ferreira et al. (2019) described smartification process in home applications especially in furniture. The proposed process of smartification in this context refers to enhancing furniture by integrating technologies that allow it to monitor and respond to human behaviour, specifically focusing on detecting accidents or potential risks within indoor environments. Luis-Ferreira and others pinpointed that smartification process allows these objects or services to become more responsive and efficient, improving performance and functionality. Bello and Zeadally (2019) define smartification as the process of enhancing IoT services by making them more intelligent, interconnected, and efficient. This involves incorporating advanced technologies like AI and big data analytics to enable devices and systems to autonomously communicate, make decisions, and optimize performance in real-time. The goal is to improve the functionality and scalability of IoT ecosystems, fostering smarter and more responsive systems across industries. While these studies provide valuable micro-level insights, they fall short of articulating a cohesive conceptual framework.

The narrow definition of smartification is proposed by Oke et al. (2022) who investigated the smart city process in their study. According to their study smartification is connected with smart city processes. It brings improvements in making the city wireless and developing smart families simultaneously. Marzbali (2024) states that smartification brings to cities, achieving sustainable urban development indicators in communities will be more accessible and readily available to citizens in the urban space. According to Endlund and Harrison (2024), smart cities are built on visions for using technology to optimise various infrastructural functions; make city management more efficient and sustainable. Similarly, Couto and Patterson (2017) observed a new way of interpreting smart city as a smart performance on the example of Brazilian city. They indicated three major components of brand positioning, namely technological solutionism, sustainability and social inclusion.

More expansive views present Escolar et al. (2023) who observed that smartification refers not only to the digital enhancement of an existing product by incorporating digital technologies and smart services as it was defined in earlier years. They introduced in their article a comprehensive methodology for evaluating the smartification process for universities and campuses. Escolar et al. developed tools utilizing standardized indicators and common evaluation criteria to enable fair comparisons of the smartification processes at universities.

Anjomshoa (2024) investigated key factors in the application of building information modelling (BIM) systems in the smartification of green and sustainable buildings. Based on his research 5 factors were indicated: energy saving and consumption reduction, increased productivity and efficiency, life-cycle assessment, eco-friendly design, and integration with IoT and other technologies. This shows a significant increase in the role of smartification in building sector. Even though Escolar et al. (2023) and Anjomshoa (2024) explore smartification in higher-order systems, these contributions tend to focus on technical implementation and evaluation frameworks, rather than engaging in theoretical synthesis. As a result, the literature remains fragmented, and the full transformative potential of smartification remains underexplored. In response to this gap, this paper proposes a few new, integrated definitions.

Smartification can be understood as the process of transforming social structures (society) and economic structures (cities, regions) from the microstructure of smart products and services (smart products, smart services, and smart data), through the semi-structure of enterprises, villages, cities, and regions forming larger entities, to the macrostructure of the entire intelligent economy. This definition highlights the idea that smartification transforms systems into intelligent, self-regulating entities capable of interacting with their environments and users in more sophisticated ways, which aligns with the broader trends of digital transformation and the IoT. Nevertheless, it should be emphasized that smartification is a process closely associated with smart products, services, data, smart business, smart specializations, and smart villages, cities and regions. Consequently, these elements ultimately focus on a smart economy. This conceptualization recognizes smartification as a layered and scalable process – from the microstructures of smart products and services, through meso-level entities such as enterprises, villages and cities, to the macrostructure of national and global smart economies.

Smartification is the transformative process that integrates digital technologies, artificial intelligence, and connectivity into products, services, institutions, and socio-economic systems, enabling autonomous interaction, decision-making, and value creation within the Economy of Things (EoT). Smartification is a new paradigm of the digital transformation of society, business, villages, cities, regions and national as well as global economies. It can be viewed as the foundation or enabling process for the EoT which is the wider notion than IoT. In an EoT environment, connected devices can independently make decisions, exchange services, transfer assets, and even enter into contracts without direct human intervention. This system extends beyond mere connectivity to enable devices to participate actively in the economy by buying, selling, trading or managing resources, services, or data. Hence, through smartification, objects, systems, and environments are transformed into intelligent, interconnected entities. These smart entities can collect data, make decisions, and communicate with each other in real-time, enabling them to participate in EoT-based economic ecosystems. The EoT relies on smart systems that have been equipped with intelligence, autonomy, and digital capabilities (STI Partners, 2023). Smartification provides these essential qualities, making it a precursor to the full realization of EoT. Smartification belongs to the EoT theory because it serves as the underlying process that enables physical objects to become intelligent, autonomous, and interconnected participants in economic activities. Smartification transforms objects into active economic agents capable of engaging in the decentralized, machine-driven markets of the EoT, thus justifying its place within this economic theory. In the smartification paradigm, data becomes a critical resource. Smartified devices and systems continuously collect and analyse data, which drives informed decision-making, product customization, and innovation. This contrasts with traditional economies, where tangible goods like raw materials were the primary drivers of value. Today, economies that can harness, process, and monetize data gain a competitive advantage.

Not everything that is digitized is smart. Therefore, smartification is not synonymous with digitalization. Without digitalization, there would be no smartification, but not everything digitized can be considered smart and sustainable. While digitalization provides the technological foundation, smartification extends beyond it by incorporating cognitive and communicative dimensions – such as AI, interconnectivity, and real-time adaptability – that enable entities to operate autonomously within EoT environments. This perspective is supported by Liu et al. (2023), who emphasise that autonomous systems are central to the process of smartification. Consequently, smartification emerges as a distinct and more advanced paradigm compared to digitalization alone.

Risks associated with smartification

However, the emergence of the smartification paradigm is accompanied by several critical challenges that require closer examination. The lack of a standardized theoretical framework leads to conceptual incoherence, limiting cross-disciplinary integration and empirical validation. Moreover, unequal access to digital infrastructure may result in digital exclusion, exacerbating existing social and regional disparities. Environmental sustainability also becomes a concern, as the deployment of smart technologies often involves significant energy consumption and material use. Additionally, the increased reliance on data-driven systems raises serious questions about data privacy, security, and the potential for algorithmic bias. An overdependence on automation further risks sidelining human judgment and undermining context-sensitive decision-making. Addressing these issues is essential for developing a more nuanced and responsible understanding of smartification, thereby enhancing its theoretical robustness and practical relevance for future research, policy, and implementation. In a rapidly evolving environment influenced by risks and uncertainty, digitalization has introduced new business models that enable companies to broaden their customer reach and improve operational efficiency (Skrzypek, 2011). Building upon this digital foundation, smartification further accelerates technological integration across economic and social systems. However, this progression also coincides with growing regulatory scrutiny, particularly concerning AI – a key component of smartification. A pivotal step in this direction is the publication of the Artificial Intelligence Regulation (AI Act) by the European Commission on July 12, 2024 (2024/1689). This legislative framework establishes guidelines for the development, deployment, and governance of AI systems within the European Union, aiming to balance innovation with ethical oversight and risk management (Regulation (EU) 2024/1689). The AI Act categorizes AI-related risks into four levels: unacceptable, high, limited, and minimal. As smartification increasingly relies on AI technologies, its future development will be shaped by this regulatory environment. While the Act is expected to mitigate threats such as disinformation and deepfakes, it also imposes significant compliance demands on developers and users of high-risk systems, including requirements for data quality, transparency, human oversight, and cybersecurity.

These legal safeguards align with a broader recognition that smartification, despite its promise, is accompanied by critical risks. Digital exclusion remains a major concern, particularly among older populations. Gallistl et al. (2021) highlight how individuals aged 65 and above often perceive themselves as "non-users" of digital technologies – not only in relation to smartphones and computers but also in interactions with everyday smart devices such as ticket machines or digitalized vehicles. This exclusion risks marginalizing these groups further in increasingly digitized societies. Another pressing issue is the risk associated with AI. As noted by Staszkiewicz et al. (2024), the implementation of AI in smart systems may lead to unintended consequences such as algorithmic bias, lack of transparency, and ethical dilemmas related to autonomous decision-making. Cybersecurity also poses a significant threat, as emphasized by Parsons et al. (2023) and Almeida (2023), who document the growing vulnerabilities of interconnected systems to data breaches, hacking, and systemic failures. Environmental risks must also be considered: Salman and Hasar (2023) and Wang et al. (2021) warn that the production, deployment, and energy consumption of smart technologies may contribute to environmental degradation and increased carbon emissions, contradicting sustainability goals. Taken together, these findings emphasize the importance of approaching smartification with a balanced and critical perspective – one that maximizes its transformative potential while proactively managing its socio-technical and environmental risks.

Smartification as a new development paradigm

The assertion that smartification represents a new paradigm of economic development requires grounding in both theoretical and empirical literature. A paradigm, as originally conceptualized by Kuhn (1962, 1970), refers not only to a shared set of scientific assumptions and methods but also to a shift in worldview that redefines how knowledge is produced, interpreted, and applied. According to Kuhn (1970), a paradigm may refer to both a globally shared set of internalized beliefs within a scientific group and a particularly influential subset of those beliefs. In general, a paradigm is understood as a coherent system of cognitive assumptions shared by a scientific community. As Brzezin (1999) points out, paradigms should introduce new methods but also new areas of theoretical exploration. Following this understanding, smartification meets the criteria of a paradigm shift by introducing a comprehensive, interdisciplinary framework that reorients economic thinking, policy, and practice toward the integration of advanced digital technologies. Similarly, Faria et al. (2011) emphasize that paradigms consist of shared beliefs, theories, and empirical methodologies that serve as the foundation for further research within discipline. New paradigms are necessary for the advancement of scientific understanding. Ciesielski (2014) asserts that paradigms significantly influence research practices and can function as an integrative framework across diverse studies.

Several strands of literature substantiate this view. First, smartification aligns with the tradition of innovation economics, which emphasizes the central role of technological change in driving economic growth (Spulber, 2013). The integration of AI, IoT, and data analytics into production, services, and urban management systems signifies more than a technological upgrade – it transforms the structure and logic of economic value creation. Unlike previous models centred on physical capital and labour productivity, smartification enables decentralized, responsive, and automated systems that optimize efficiency, create new markets, and support sustainable development (Pluta-Zaremba & Szelągowska, 2021).

Second, smartification embodies core principles of the knowledge economy (Powell & Snellman, 2004), where intangible assets such as data, expertise, and innovation capacity become primary drivers of competitiveness and growth. In this model, smartification fosters the generation and application of knowledge through digital infrastructures, transforming passive systems into adaptive, data-rich platforms. The feedback loops created by real-time data flows and intelligent automation are emblematic of a paradigmatic shift toward cognitive, self-improving economic systems.

Third, the literature on smart villages (Mędrzycki, 2024; Nazarko & Bokun, 2024), smart cities (Blicharz, 2023), smart industry (Pluta-Zaremba & Szelągowska, 2021), and smart societies (Cifaldi, 2017; Deguchi, 2020) increasingly treats smartification not merely as a policy trend or technology application but as a comprehensive transformation of economic and societal systems (Bibri & Krogstie, 2017; Nam &

Pardo, 2011). These studies demonstrate how smartification redefines the relationships between citizens, businesses, and institutions, promoting more participatory governance models, resource-efficient infrastructures, and innovation ecosystems that are characteristic of post-industrial development paradigms.

From a paradigmatic perspective, smartification fulfils the criteria outlined by Brzezin (1999) and Sułkowski (2011), introducing new conceptual lenses, empirical approaches, and interdisciplinary research agendas. It connects digital transformation with sustainable development, contributing to the emergence of a hybrid paradigm at the intersection of technology, economics, and society. In support of this view, Sułkowski (2011) points out that in the social sciences, a paradigm can be comparable to scientific school, not necessarily accepted by a majority but united by shared fundamental assumption. Modern science increasingly embraces the idea of multiparadigmaticity, as Patel (2016) notes, advocating for paradigm crossing to enrich knowledge of complex phenomena by integrating insights from multiple perspectives. As Koźmiński and Latusek-Jurczak (2017) argue, such complex and dynamic systems demand a multiparadigmatic approach in economic theory – smartification fits this need by synthesizing elements of technological, institutional, and social innovation. In this spirit, Sułkowski (2013) promotes theoretical pluralism, encouraging the use of diverse conceptual tools drawn from different paradigms. In line with this approach, the triad of smart business, smart city/village, smart society, calls for a contemporary, interdisciplinary framework for understanding the development of the smart economy. Smartification is more than a technological trend – it constitutes a shift in the foundational logic of economic development.

The theoretical and empirical evidence supports the classification of smartification as a new development paradigm. It reshapes foundational assumptions about how economies function, how value is created, and how societies evolve – fulfilling Kuhn's (1970) criteria for paradigm change while advancing contemporary understandings of digital and sustainable transformation. As such, smartification is not a mere extension of existing models but a foundational shift in the economic logic of the 21st century.

In summary, the combined theoretical perspectives by Kuhn (1970), Brzezin (1999), Faria et al. (2011), Sułkowski (2013), Ciesielski (2014), Patel (2016), and others, along with empirical economic insights from Spulber (2013), Powell and Snellman (2004), Daum (2003), and Pluta-Zaremba and Szelągowska (2021), demonstrate that smartification fulfils the conditions of a new economic development paradigm. It not only reorganises the technological infrastructure of economies but also restructures the foundational assumptions of value creation, knowledge flow, and institutional design of the 21st-century economy.

Research methods

The authors used a multi-method approach comprising literature analysis, the verification method, logical synthesis, and bibliometric analysis. These methods were used in a complementary manner to explore, evaluate, and conceptualize the phenomenon of smartification. The bibliometric analysis, in particular, was conducted using the Web of Science (WoS) Core Collection, a widely recognized database for peer-reviewed academic literature. The authors selected "smartification" as the primary keyword to ensure focus on literature directly addressing the concept. The search was restricted to publications from 2017 to 2024, reflecting the term's relatively recent emergence in scholarly discourse. The results yielded 82 relevant records, which were exported in the Full Record and Cited References format for further processing.

Subsequent analysis was conducted using VOSviewer software, which facilitated the visualization and interpretation of bibliometric networks, including co-authorship, keyword co-occurrence, and citation patterns. In parallel, the logical synthesis method was used to integrate findings from the bibliometric analysis with insights gained from qualitative literature analysis. The verification method was employed to assess the internal consistency and conceptual soundness of the reviewed materials. Collectively, these methods not only provided a comprehensive overview of the current research landscape but also formed the empirical basis for the theoretical refinement and new definition of smartification proposed in this paper.

Results

The annual number of publications provides valuable insights into how research in a given field is progressing and developing over time. Authors of this paper use bibliometric analysis to discover topic smartification as a keyword. The bibliometric analysis was performed in September 2024 using the keyword "smartification". By choosing WoS database, researchers ensure that the evidence or insights drawn from the literature are based on well-regarded and trustworthy studies. A number of 82 articles were generated between 2017 and 2024, which were exported as full record and cited references. After collecting the data, it was then processed further using VOSviewer software. A VOSviewer viewer software was used to create visualizations for this study. We investigated first the most important subjects and topics in smartification through a keyword co-occurrence analysis. The criteria indicated in co-occurrence analysis was "minimum number of occurrences of a key word is 3". Out of 82 articles only 33 were deemed to fulfill these criteria (Figure 1).

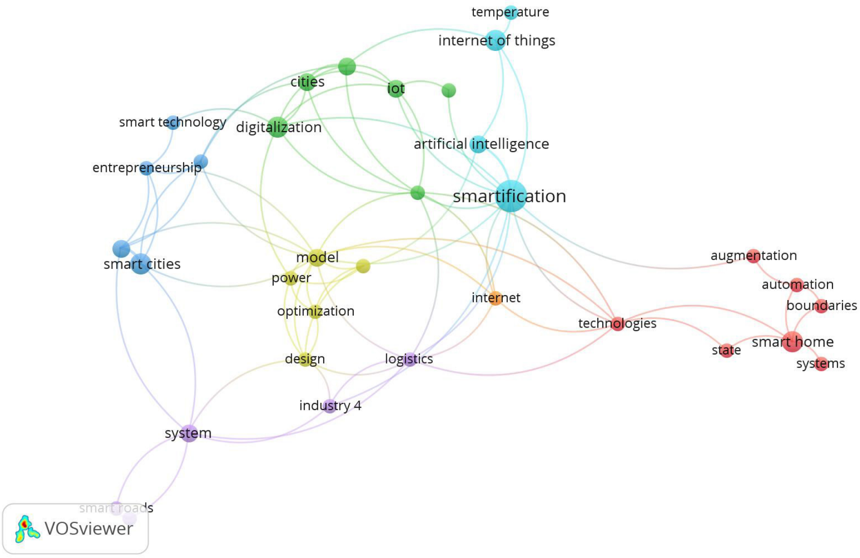

Figure 1. Keyword co-occurrence analysis for the smartification

Source: Authors' own study.

Colours in the figure represent different clusters of terms that frequently co-occur in the literature. Each colour indicates a group of related concepts or themes identified through the VOSviewer clustering algorithm. For example, light blue (central cluster): terms closely related to the core concept of smartification, such as AI and IoT. The thickness of the lines (edges) reflects the strength of co-occurrence between terms. The distance between the nodes symbolizes the relatedness: the closer the nodes, the more often the terms appear together in the literature. The literature review indicates that the research is mainly concentrated around: smartification, smart home, digitalization, IoT, industry 4.0 and smart cities (Figure 2).

To prepare a co-authorship analysis, we examined how researchers are connected through shared publications about smartification by countries. The criteria indicated in co-authorship analysis was: "minimum number of documents by a country is 3". And the results were presented in Figure 3.

There were seven countries which fulfilled the above-mentioned criteria, namely: Italy, the USA, China, Greece, Iran, Poland and Norway. Colours in the figure represent distinct clusters of countries that are more closely connected in terms of co-authorship based on the strength of their collaboration patterns. For example, red cluster includes countries with strong co-authorship ties to Italy, such as Iran and Greece. Green cluster includes Poland and Norway, which are also linked to Italy through shared publications but form a separate collaboration group.

The impact of research is usually assessed by the number of citations it receives, as citations serve as an indicator of the work's quality and relevance. When perform-

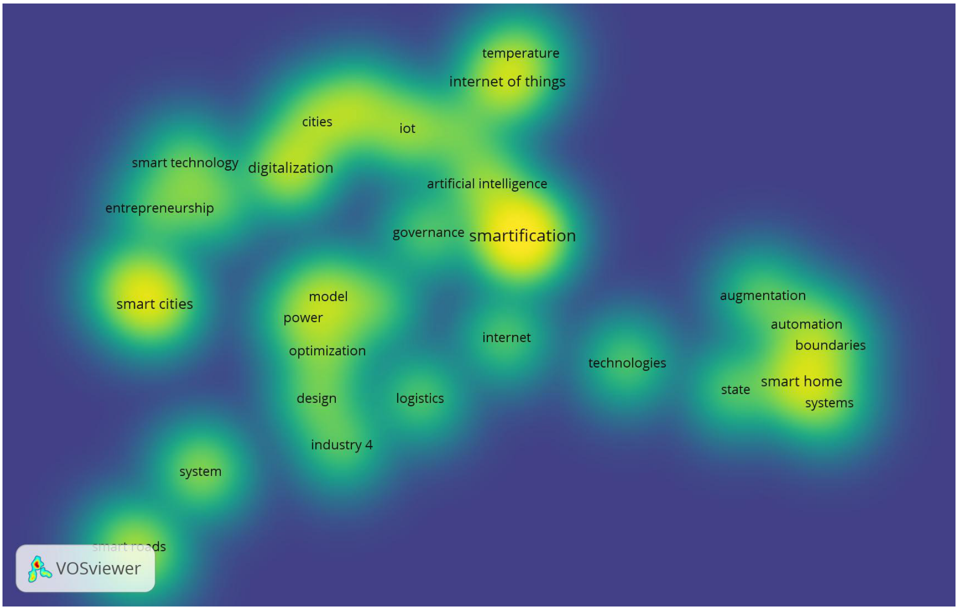

Figure 2. Keyword co-occurrence in density visualization

Source: Authors' own study.

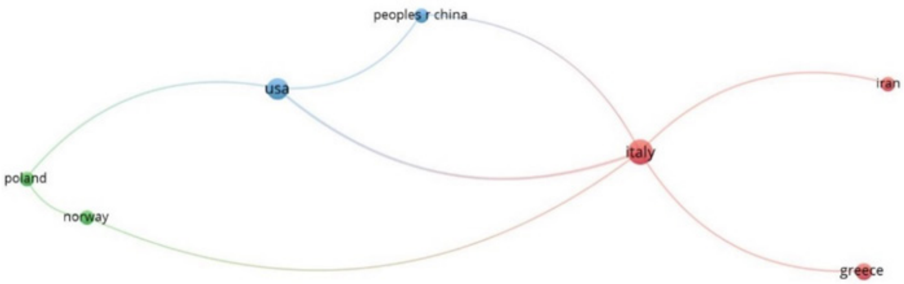

Figure 3. Co-authorship analysis

Source: Authors' own study.

ing an author-based citation analysis, VOSviewer generates visual outputs which was presented in Figure 4. This visualization presents the relationships between cited authors based on the number of citations and their temporal distribution. Size of the circles (nodes) indicates the number of citations received by a given author. Colour of the nodes represents the average publication year of the author's cited works, based on the colour scale at the bottom right.

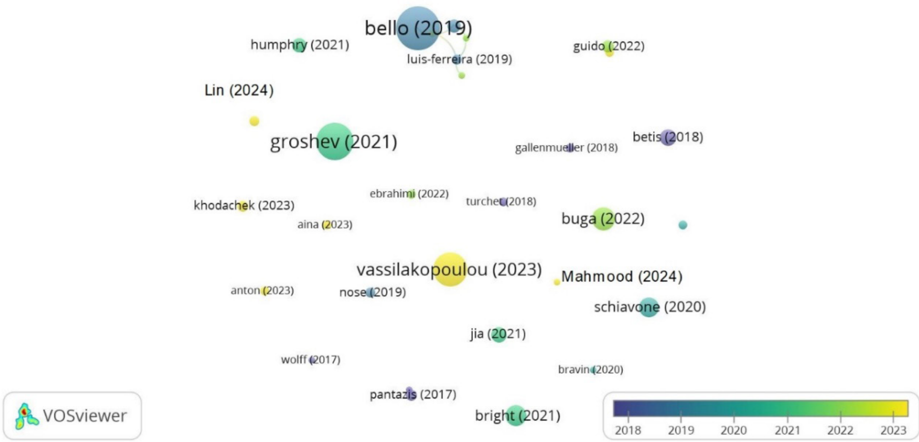

Figure 4. Citation author network analysis

Source: Authors' own study.

The criteria indicated in citation analysis was "minimum number of citations of a document is 2". The top six cited authors are: Bello (66), Vassilakopoulou (40), Bright (24), Groshev (22) and Buga (21) and Schiavone (18) which is shown in Figure 5.

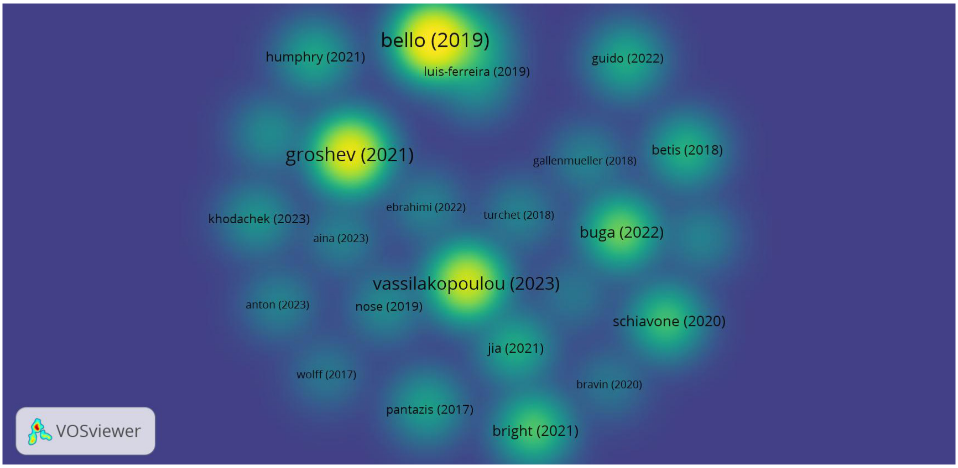

Figure 5. Citation organization network analysis in density visualization

Source: Authors' own study.

Colour intensity reflects the frequency and strength of citations for each author: yellow areas indicate authors with the highest citation impact and centrality within the citation network, green – moderate level and blue areas – relatively lower citation.

However, not all these authors define the notion of smartification. During the research studies of these papers, we recognized that the term "smartification" has gained traction in fields related to the IoT, AI, and digital transformation, with multiple researchers contributing less to its definition and more to its application. This lack of a unified definition creates a gap in understanding the full scope of smartification, as its implications extend beyond technological integration to broader societal and economic transformations. Addressing this gap is essential for comprehensively analyzing its role in shaping contemporary systems.

We face challenges that indicate the need for increasingly complex connections in the contemporary economy linking the triad: smart business – smart villages/cities – smart society. According to location theory, spatial concentrations of (intelligent) enterprises influence the emergence and development of smart cities and regions. This, in turn, translates into the behaviours of individuals and social groups making decisions based on available information, information flow, and digital technologies (ICT), evidenced by the so-called smartification of society, business, cities, regions, and the entire economy. The use of increasingly advanced technologies directly impacts the behaviour of individuals (units) and thus the whole society, ultimately leading to the smartification of the economy. Cities use smartification as one of the key elements of city management. Smartification of society means that society wants to use new, smart facilities, wants to develop and is open to new technologies that facilitate a large number of services such as payments.

The dynamic development of innovative information and communication technologies (ICT) used in various spheres of human activity significantly enhances the quality of life in the modern world. As a result, we are witnessing an intensively developing megatrend called the smartification of the economy. The process of smartification involves introducing smart products, services, and data with extended digital functions oriented towards business, cities, and society to the market (Figure 6).

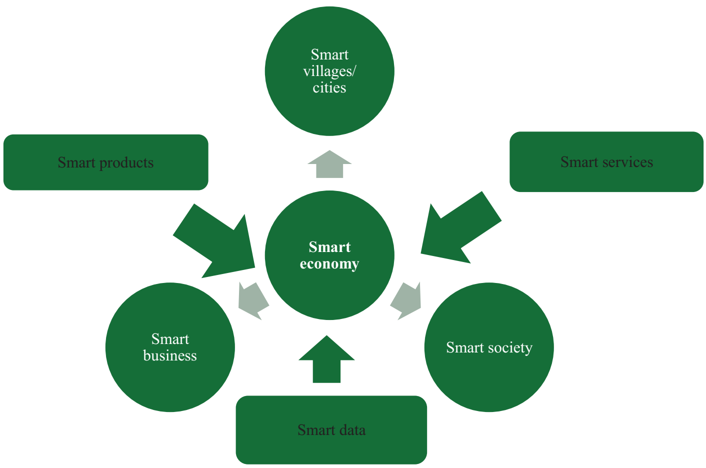

Figure 6. Main areas of the smartification of economy

Source: Authors' own study based on https://www.iwconsult.de/fuer-unternehmen/smartification

A smart economy is based on technological innovations, efficient resource management, sustainable development, and high social well-being as drivers of success (Frank & Aznar, 2020). By applying ICT technologies, blockchain, IoT/IIoT, and adopting new entrepreneurship initiatives, productivity, and competitiveness, the smart economy aims to improve the quality of life for all citizens (Table 1).

Table 1. Elements of smart cities and region development

<table>
<tr><th>Smart mobility</th><th>Smart environment</th><th>Smart governance</th><th>Smart economy</th><th>Smart living</th><th>Smart people</th></tr>
<tr><td>integrated transportation and logistics systems</td><td>climatic conditions</td><td>participation in public life</td><td>innovation</td><td>access to cultural centers</td><td>qualifications</td></tr>
<tr><td>balanced transportation system</td><td>air quality</td><td>social and public services</td><td>entrepreneurship</td><td>healthcare</td><td>lifelong learning</td></tr>
<tr><td>IT infrastructure availability</td><td>environmental awareness</td><td rowspan="5">transparency of operations</td><td>business image and trademarks</td><td>personal safety</td><td>ethnic diversity</td></tr>
<tr><td rowspan="4"></td><td rowspan="4">sustainable management of resources</td><td>productivity</td><td>living conditions</td><td rowspan="4">open-mindedness</td></tr>
<tr><td>flexible labour market</td><td>education</td></tr>
<tr><td rowspan="2">international importance</td><td>tourism attractiveness</td></tr>
<tr><td>welfare</td></tr>
</table>

Source: https://ideologia.pl/smart-city-jak-inteligentne-miasta-poprawiaja-zycie-mieszkancow/; http://www.smart-cities.eu/why-smart-cities.html

The components of the smart economy are innovation, entrepreneurship, economic image and trademarks, productivity, labour market flexibility, and transformation capacity.

A smart economy is closely related to Industry 4.0 technologies, which are inextricably linked and use ICT applications for economic development, spatial planning, and public health improvement. It combines higher productivity, efficiency, and competitiveness by increasing advanced innovation. It is characterized by many new flexible forms of work and startups. The smart economy is expected to generate more products and services with less energy consumption and significantly reduced pollution, maximizing social benefits. The components of a smart economy include: an innovative approach, entrepreneurship, productivity, labour market flexibility, international standing, and transformation capabilities (Smart cities, 2022).

Cardullo et al. (2018) observed in their research that a different approach to smart citizenship should be implemented. Emerllahu and Bogataj (2024) noted that smart villages are not only an important part of smartification of economy, but also are multifaceted, covering a wide range of areas such as infrastructure, governance, health, education, farming, and community development. Smart city should empower people by shifting control and should be based on the right to the city, entitlements, community involvement, shared resources, and values that extend beyond market-driven interests. The smart economy of businesses, villages, cities, and regions, including their financial economy, should skilfully leverage locational potential. Additionally, it should optimally utilize renewable energy sources, various technologies, and management strategies that reduce operating costs and the costs of achieving competitive advantages for residents characterized by high entrepreneurship.

Factors of smartification

Each of the three main areas of smartification of the economy (business, villages/cities, and society) relies on innovative information and communication technologies, which encompass solutions for transmitting, collecting, processing, and visualizing data in electronic form. The main component of ICT is information technology (IT), integrating telecommunications infrastructure (including wireless communication), computers, necessary enterprise software, user applications, data storage and collection means, and audiovisual systems that enable users to access, store, transmit, and manipulate data and information derived from them.

The spectrum of ICT possibilities is widely used in all modern Industry 4.0 technologies (Pluta-Zaremba & Szelągowska, 2021; Stasiuk-Piekarska, 2024) and the emerging Industry 5.0 (Pluta-Zaremba & Szelągowska, 2021). ICT-gathered information (data) provides vast opportunities to build competitive advantages and quickly adapt offered services and products to the needs of consumers, businesses (Kuźmicki, 2019), villages or cities. Data acquisition is carried out by IoT/IIoT devices, defined as a series of new, independent systems operating with their own infrastructure, partially based on existing internet infrastructure. In this area, there are three basic types of communication: thing-to-person (T2P), thing-to-thing (T2T), and machine-to-machine (M2M). An integral part of digital technology is the Internet of Things (IoT), a network connecting devices that independently collect, share, and process data. The industrial Internet of Things (IIoT) derives from IoT, encompassing industrial applications of networked devices. The IIoT is a technology of the fourth industrial revolution, fundamentally based on data usage. An example of IIoT application is sensors in manufacturing companies that reduce downtime by quickly responding to various types of equipment failures with machine data. When IIoT devices provide information to AI algorithms that analyze data in real-time, companies can conduct preventive maintenance by early anomaly detection. Additionally, IIoT, through high-quality data, aids in building digital twin models of manufacturing enterprises, production lines, and products.[1]

[1] Industrial Internet of Things – this is the technology of the fourth industrial revolution. It is based on the use of data. An example of the use of the IIoT are sensors in manufacturing companies that reduce downtime, as information from machines can be used to react quickly to various types of malfunctions.

Digital transformation is a priority in the European Union's Multiannual Financial Framework for 2021–2027. The growing level of smartphone adoption, resulting from increased mobility and the development of the mobile phone and tablet market, necessitates keeping up with users' needs for specialized software, including mobile applications, which shape contemporary smartification trends. Therefore, the question arises of how society can better use portable (mobile) devices like smartphones, tablets, and smartwatches to achieve sustainable development goals.

The implementation of modern, smart solutions of a groundbreaking nature entails economic, social, and cultural transformations. Smartification brings opportunities but also threats, especially in the context of sustainable development requirements. According to the Deloitte report *Digital with Purpose: Delivering a SMARTer 2030*, new digital technologies impact 103 out of 169 Sustainable Development Goals (SDGs). Deloitte's analysis of nearly 500 case studies shows that new digital technologies can accelerate the achievement of sustainable development goals by 22% and reduce declining trends by 23% (Deloitte, 2019). Society plays a significant role in creating an ecosystem based on a sustainable and digital development model. Deloitte forecasts indicate that in the coming years, leading technologies will be new ICTs, widely applicable in major industries such as agriculture, energy, medicine, and transport. In 2024, the global ICT market was valued at USD 5.11 trillion and expand at a compound annual growth rate (CAGR) of 5.20% from 2024 to 2031 (Cognitive Market Research, 2025). Deloitte also points out that apart from ICT, key technologies supporting the realization of the 2030 Agenda and sustainable development will be (Deloitte, 2019):

– cloud computing (cloudification);
– cognitive intelligence;
– blockchain;
– 5G networks;
– IoT/IIoT;
– virtual reality.

These seven leading technologies can advance the 2030 Agenda in several keyways:

– connecting and supporting communication, facilitating relationships, gathering information, ideas, and opportunities;

– monitoring what is happening around us to ensure transparency and purposefulness of our actions;

– analyzing vast areas of information, optimizing processes, procedures, and resources, and predicting where intervention is needed;

– enhancing human capabilities and automating systems, thus, creating an "active bridge" between the physical and digital worlds.

When IIoT devices provide information to AI algorithms analysing data in real time, the enterprise has the chance to carry out preventive maintenance involving early detection of anomalies.

The ideal solution would be the exclusive positive impact of smartification based on the above technologies on the sustainable development of enterprises, cities, and society. Smartification, relying on information technologies, is not related to meeting the needs of sustainable business, city, and society development. This contrasts with the evolution of smart cities (smart city 1.0, 2.0, 3.0, and 4.0), which also consider the quality of life and the capacity for socio-economic sustainable development.

The goal of smartification is to optimize processes and resources, leading to increased effectiveness in various areas such as manufacturing, urban management, transportation, health and education. The new paradigm of the smartification's current aim is to promote sustainable development through effective management of resources, reduction of emissions and minimization of environmental impact. The growth of urban populations requires effective management of urban resources and infrastructure, which drives the development of smart cities. Smartification supports the effective management of cities, regions and businesses – by automating production processes, improving the efficiency of management of water, energy, waste, transportation, traffic, greenhouse gas emissions, reducing costs and optimizing management and production processes, among others. Research conducted by Ghoushchi and others (2024) provided a robust hybrid framework to evaluate and rank potential smartification measures for Sicilian roads in Italy.

Smartification is affecting the job market by forcing the acquisition of new digital skills and competencies in cybersecurity as well as data analytics (including the ability to work with big data sets), programming, coding, knowledge of IoT technologies, knowledge and understanding of AI and machine learning algorithms and the application of AI in practice. Smartification is based on the continuous striving for innovation and technological development. Companies and institutions have to invest in research and development to implement new and better technologies and solutions that address future challenges and needs. Smartification requires the ability to adapt quickly to technological and market changes, a readiness to continuously learn and improve qualifications, as well as the ability to manage change processes in the organisation, the implementation of new technologies and the ability to create innovative solutions, including the ability to communicate and collaborate effectively in diverse teams, often working remotely.

AI is an integral part of the development of smartification. According to Bentley et al. (2024), AI is the latest wave of digitalisation. There are different types of AI. The most commonly described in literature are: artificial narrow intelligence (ANI), artificial general intelligence (AGI) and artificial superintelligence (ASI) (Staszkiewicz et al., 2024). Groppie and Jain (2024) associated ANI with limited capabilities to specific programmed tasks. AGI defines machines that can perform any intellectual task that a human can (Groppie & Jain, 2024), whereas ASI is connected with exceeding each person and each human organisation across most or all of the cognitive skills (Jebari & Lundborg, 2019). Korczak and Pawełoszek (2023) associated generative artificial intelligence with the simulation of broad human cognitive abilities within software, enabling the system to solve problems independently. The authors-research pinpointed the latest communication tools and AI models designed to handle management related questions expressed in natural language.

Almost every day people encounter solutions based on AI. Taking into consideration Central and Eastern European countries, AI companies were projected to create a total value of about USD 1.7 billion in 2023. The first country with the highest Al market value was Russia, on the second place was Poland and Czechia on the third place (Statista, 2023a). Research conducted by Thormundsson showed that expenditures on AI were different across industries in 2024. The most significant roles played industries such as banking with 15.7% of all investments and retail with 9.5%, software and information services with 8.3% (Statista, 2025b).

AI enables companies to find new ways to innovate and expand. At the beginning it was mainly used by tech companies, within the time frame it can be noticed a significant growth of using AI in various sectors in the world. In 2024, 22% of companies decided to continue the aggressive incorporation of AI in different technology products and business workflows (CompTIA IT Industry Outlook, 2024).

One of the examples of AI platforms which raised over USD 117 million is called Pecan. This AI platform facilitates business intelligence, operations, and revenue teams forecast mission-critical results. It is likely to expect that Pecan will be expanding its customers database from other countries (https://www.pecan.ai/company-about-us/). DataForSEO is a company which started in 2011 by creating in-house softwares. In 2023, company released DataForSEO API Wrapper for LangChain, Content Generation application programming interface (API), Artificial Intelligence Summary in SERP (Search Engine Results Page) API (application programming interface). One of the most popular products is DataForSEO Artificial Intelligence Assistant (https://dataforseo.com/).

The rapid adoption of AI technologies, such as ChatGPT, highlights the growing impact of smartification on both businesses and society. With over 367 million users globally (as of May 2025) and millions of monthly visits (https://explodingtopics.com/blog/chatgpt-users), ChatGPT exemplifies how AI-driven tools are becoming integral to daily workflows, streamlining processes, and reducing costs across industries. In countries like Poland, where ChatGPT has attracted over 2.85 million users, AI is becoming a key driver of digital transformation (Statista, 2023b).

Moreover, the financial benefits reported by companies in the US demonstrate the economic potential of AI. Surveys show that 24% of businesses have saved between USD 50,000 and USD 70,000 by incorporating ChatGPT, while 11% have reported savings exceeding USD 100,000 (Statista, 2023c). These examples illustrate how AI technologies contribute to the broader trend of smartification, as they optimize business operations, enhance decision-making, and facilitate more efficient resource management. The integration of AI, like ChatGPT, into everyday business practices not only accelerates the smartification of individual enterprises but also plays a crucial role in the larger shift toward a smart society and economy.

These financial gains from AI adoption, as seen with tools like ChatGPT, not only highlight the efficiency improvements within individual companies but also reflect the broader economic impact of digital transformation across regions. Revenues in the IT Services market reached a total amount of USD 1,420.00 billion in 2024. The most profitable sector indicated it the above-mentioned study was IT Outsourcing with a expected market volume of USD 541.10 billion in 2024 (Statista, 2023b).

According to studies conducted by Business Research Insights (2024), information technology (IT) market had a total value of USD 9481627.92 million in 2022 and by 2032 it is supposed to reach a level of USD 26925229.38 million. Companies pay more attention to issues related to digitalization, data security, and remote work capabilities. The aim of those actions is to increase productivity and competitiveness on a global market which is rapidly changing (Business Research Insights, 2024).

The COVID-19 pandemic had a profound impact on the information technology (IT) market, disrupting supply chains and increasing production costs while simultaneously accelerating the adoption of digital solutions and remote work technologies. As a result, IT services such as cloud computing and cybersecurity became crucial for supporting the rapid expansion of the tech sector. This accelerated shift towards digitalization laid the groundwork for even more advanced technological applications, including the IoT (Business Research Insights, 2024). The IoT is a network connecting devices that autonomously collect, share and process data. According to Statista, USD 805 billion were spent on the IoT technology worldwide. The largest share of IoT market had Asia Pacific region, the second place was North America, subsequently Europe (Statista, 2024a). Having into consideration the number of IoT connected devices worldwide 2024–2034, it can be noticed a significant growth in consumer sector starting with the amount of 7.7 million in 2024 to the predicted amount of more than 40.6 billon IoT devices for 2034 (Statista, 2025a).

By the year 2030, the number of business IoT connections should have reached about 24 billion (Statista, 2024b). In fact, it is estimated that about 90% of the world's data was created in the years 2023–2024. This shows a significant growing pace in data creation sector (https://explodingtopics.com/blog/data-generated-per-day).

Between the year 2024 and 2029, the number of internet users is projected to rise from 5.35 billion to 7.9 billion users in 2029. Research shows the average time spent on the internet on a daily basis amounts to six and a half hours. It is worth taking into consideration that people between the ages of 16 and 24 spend 2.5 hours daily more time online than those from the age group between 55 and 64. A growing part of the American population (94.6% in 2024) used various technological solutions on a regular basis (Pelchen, 2024).

In summary, the COVID-19 pandemic has acted as a catalyst for digital transformation, significantly advancing the adoption of IT services, cloud computing, and cybersecurity solutions. This shift has laid the foundation for more sophisticated technologies such as the IoT and EoT which is a key driver of the broader process of smartification. As IoT expands, connecting billions of devices globally, it plays a critical role in the smartification of businesses, cities, and entire societies by enabling data-driven decision-making and automation across various sectors. This interconnected, data-driven world is at the heart of smartification, where the integration of advanced technologies reshapes economic, social, and urban landscapes, driving efficiency and innovation.

Conclusions

According to the authors of this paper smartification is the process of integrating advanced technologies in the area of the EoT along with AI tools that support the development of society, cities, regions, business and the economy and change the way society, businesses, local and government entities communicate with each other. The main determinants of the development of smartification are new technologies such as AI, information and communication technologies (ICT), big data analytics, the IoT, including advanced sensors integrated with mobile applications, and the EoT.

This paper positions smartification as an emerging and transformative paradigm within contemporary economic development. Drawing on literature analysis, logical synthesis, and bibliometric methods, the study offers several original contributions to the conceptualization of smartification. Most notably, we proposed multiple, original definitions that articulate smartification as a layered, dynamic process – spanning from the integration of digital intelligence in products and services to its broader role in shaping smart cities, regions, and economic systems. These definitions are situated within the theoretical frameworks of innovation economics, the knowledge economy, and the emerging EoT, offering a foundational model for further academic exploration.

In addition to conceptual refinement, the paper identifies key determinants of smartification, including technological advancement (especially AI, IoT and EoT), regulatory influences, digital infrastructure, and socio-environmental drivers. It also outlines prevailing trends, such as the shift toward data-driven decision-making, the decentralization of economic activities via autonomous systems, and the growing emphasis on digital sustainability. Collectively, these elements underscore the multifaceted nature of smartification as both a technological and socio-economic phenomenon.

Despite its theoretical contributions, this study is not without limitations. The analysis is primarily conceptual and bibliometric in nature, with limited empirical data. While the bibliometric review provides insight into the fragmented state of current research, it also highlights the need for in-depth, interdisciplinary studies. Furthermore, the research is bounded geographically and temporally by its reliance on English-language sources indexed in the WoS between 2017 and 2024, which may not capture all relevant global developments.

Another important limitation is the dynamic and evolving legal landscape, particularly in relation to AI. The adoption of the EU AI Act (2024/1689) marks a significant regulatory milestone that will directly shape the development and application of smartification. Future studies should investigate how such legal frameworks – especially those categorizing AI risks – will impact smartification across sectors and regions, particularly in high-risk domains like healthcare, finance, or autonomous transportation.

In conclusion, smartification holds the potential to redefine the structures of modern economies and societies. However, realizing its benefits while mitigating its risks requires both theoretical clarity and empirical grounding. We encourage further research that explores sector-specific applications, evaluates socio-economic impacts, and monitors regulatory responses to ensure that smartification evolves in an inclusive, ethical, and sustainable direction.

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