SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 235

ROAD FREIGHT TRANSPORT IN SMART CITIES: RESULTS OF A BIBLIOMETRIC ANALYSIS

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Purpose: The aim of the paper is to identify the most significant research trends concerning the concept of road freight transport in smart cities within the field of social sciences, using selected bibliometric analysis techniques.
Design/methodology/approach: The paper presents a summary of selected theoretical approaches to the field of road freight transport in a smart city. A complement to the signaled theoretical frameworks of the issue are partially presented results of a bibliometric analysis, which illustrate international research activity concerning the title subject, as well as development directions and specific problems explored by researchers.
Findings: The conducted analysis of scientific journal publications, selected according to strictly defined assumptions, made it possible to identify the problems currently addressed in research on the area of road freight transport in a smart city.
Originality/value: The originality of the study lies in the combination of a review of theoretical approaches with the results of bibliometric analysis, which allows for the presentation not only of the current state of research, but also of the dominant development directions and the specificity of the problems being explored. This approach enables a better understanding of the dynamics of scientific exploration of the undertaken issue and may serve as a starting point for further interdisciplinary research.
Keywords: Road freight transport, smart city, logistics management, bibliometric analysis.
Category of the paper: Literature review.

1. Introduction

Road freight transport is one of the fastest growing branches of transportation worldwide. Similarly in Poland, as one of the key sectors of the national economy, it demonstrates a high level of development dynamics, serving as a significant example of the intensification of entrepreneurial initiatives. Over the past three decades, since the beginning of the political and economic transformation in Poland, road freight transport, which in the early 1990s played only a marginal role in the Polish economy, has undergone a fundamental evolution, becoming a dynamically developing sector that enables Polish enterprises to expand within the European

Union (EU) services market. Polish road freight transport companies have achieved a dominant position in the European market in terms of the number of active entities, the volume of transported goods, the number of kilometers traveled, and the total transport performance (Eurostat, 2024). According to Eurostat data from 2024, currently 75% of goods in the European Union are transported by trucks, with Poland holding a leading position in this category among EU member states. In light of the above statistical data, road freight transport can thus be viewed as a distinct hallmark of the Polish economy within the EU.

Similarly, data from the Central Statistical Office of Poland (GUS, 2023) for the year 2022 indicate that road freight transport is also the leading transport mode in Poland in terms of cargo volume. In 2022, Polish carriers transported over 1,976 million tonnes of cargo, accounting for 20.1% of the total volume of goods transported by road across EU countries, and carried out transport work amounting to 390 billion tonne-kilometers. Since Poland's accession to the European Union in 2004, a systematic increase in freight transport volumes has been recorded, with the weight of goods transported by Polish transport companies increasing more than sixfold. The revenues of the road freight transport sector amounted to PLN 190 billion in 2022, and when including warehousing and logistics services closely related to the sector, the total revenue reached PLN 210 billion. Between 2020 and 2022, the transport, forwarding, and logistics (TFL) sector maintained its status as one of the most dynamically developing sectors in Poland. Among the ten key sectors of the economy, only the information and communication technology (ICT) services sector showed a higher growth rate.

In reference to the significant achievements of freight transport activity, a consistent reflection of the essence of this domain is present in both theoretical and empirical scholarly discussions. The recognition of transport as a universal co-operator of all economic processes and forms of social life, by enabling the satisfaction of the natural need for mobility and thus integrating into the national economy system as an indispensable and irreplaceable komponent, is emphasized, among others, by Burnewicz (2013), Gajewski, Paprocki and Pieriegud (2018), Kuriata and Kordel (2022), Mindur and Mindur (2021), Mitraszewska (2019), Neider (2019), Rydzkowski (2017), and Wojewódzka-Król and Załoga (2022). Alongside this statement, transport services are considered an integral object of market exchange, with the overriding goal of their providers being to satisfy needs related to the movement of people and goods across time and space. Such an interpretation of transport activity is preferred, among others, by Gołembska and Gołembski (2023), Mężyk and Zamkowska (2019), Rucińska (2015), and Rydzkowski and Wojewódzka-Król (2007), who define transport as “an activity consisting of the paid provision of services, the effect of which is the movement of people and goods, as well as the creation of auxiliary services directly related to it”. In the scope of freight movement exclusively, the cited definition corresponds with the classification of transport as a consumer service in accordance with the Polish Classification of Activities (PKD, 2024), Section 49.41.Z: “Road freight transport” and Section 52: “Warehousing and support activities for transportation”, within Section H: “Transportation and storage”. These include, among

others, activities related to providing the transport of goods via road vehicles, including the rental of transport equipment with a driver, as well as support services such as storage, warehousing, handling, freight forwarding, and customs clearance intermediation. Therefore, road freight transport is a service activity concerning the movement of goods using wheeled vehicles on land roads (Łącka, Supron, 2020; Wojewódzka-Król, 2024). At the same time, both the above definitional perspective on road freight transport and its categorization in the PKD constitute the epistemological foundation most closely aligned with the subject matter of this paper and are thus recognized as the basis for further considerations.

Based on the adopted interpretation of the concept of road freight transport, considering both its functional dimension (Tarski, 1993) and its actor-related dimension (Madeyski et al., 1971), there are increasing proposals to situate it within the smart city concept. According to the results of the literature review, identifying a universally accepted and unambiguous definition of a smart city currently remains challenging. The term is often characterized by references to individual projects, implementations, and solutions developed within specific spatial and organizational contexts. In most contemporary formulations, smart city definitions emphasize especially technological applications and infrastructural components. The smart city concept is then specified as an advanced urban system that leverages the synergy between connected devices and sensors and high-performance digital telecommunications networks (Giffinger, 2007; Mitchell, 2007; Schaffers et al., 2011). In an alternative approach, a smart city is conceptualized as a complex urban system that simultaneously allocates resources into internet technologies, human capital, and communication infrastructure, thereby supporting the principles of sustainable development and the improvement of quality of life (Batagan, 2011; Caraligu et al., 2011; Vanolo, 2014). In both interpretations of the smart city, the role of transport— including road freight transport— is elevated to the level of a pillar of the concept. At the same time, the multifunctionality and complexity of the issue of road freight transport in a smart city manifest themselves from the definitional explorations of both concepts to the organizational and technological conditions and implications of the forms in which the activity of moving goods by road vehicles is carried out.

The aim of the paper is to identify the most significant research trends concerning the concept of road freight transport in smart cities within the field of social sciences, using selected bibliometric analysis techniques.

2. Research method

In order to identify the subject literature exploring the issue of road freight transport in a smart city, an attempt was made to conduct a bibliometric analysis (Pritchard, 1969; Wallin, 2005; Echchakoui, 2020), supporting objective and multi-source acquisition of information regarding publications in the selected area. For the purpose of preparing the bibliometric analysis, selected research techniques were applied, including: trend analysis, citation analysis, and word co-occurrence analysis (Ferrari et al., 2020). Assumptions were formulated allowing for the classification of purposeful and precise data collection methods in the context of the research subject. The resources were subjected to selection through the application of keyword-based and full-text reviewed publications in the field of social sciences. A classification criterion was applied for querying scientific publications containing the phrases in the title, abstract, or keywords: "road freight transport" or "road transport of goods" or "road transport of cargo" and "smart city". The postulate to limit the search to solely scientific, digital, full-text bibliographic databases recognized as leading among available electronic sources, i.e., the Web of Science Core Collection and Scopus, allowed for the preservation of objectivity and reliability in the research procedure. A time range for the analyzed literature was also determined, limited to the years 2010-2024. The quantitative and qualitative analysis of the selected set of publications (Czakon, 2016) led to the formulation of key conclusions regarding the subject issue. Due to volume limitations of this paper, only selected results of the conducted research are presented below in summary form.

3. Selected results of the bibliometric analysis of the concept of road freight transport in a smart city in global scientific literature

In the published scientific literature, only a small number of studies dedicated to the issues of road freight transport in a smart city can be found. The observed epistemological limitations concern, to a significant extent, research areas within engineering and technical science, in the disciplines of transport and computer science, but most notably the economic and social sciences, including management and quality studies, which constitute a relatively narrow research direction. Therefore, the main objective of the paper is to identify the scope and frequency of publication of research results devoted to the issue of road freight transport in a smart city. The specific objective is to recognize and analyze the dominant topics explored in the selected area of road freight transport in a smart city, as well as the directions of their development.

The adopted criteria and the results of the publication review for the Web of Science Core Collection and Scopus databases are presented in Table 1. The obtained research results indicate, among other things, that the selected area has not been a particularly popular subject of journal publications in the years 2010-2024, as evidenced by the relatively small number of identified publications. According to the assumed data selection framework, more publications were recorded in the Scopus database than in the Web of Science Core Collection, with the highest number of entries in both databases identified through abstract-based searches. In the years 2010-2024, the number of publications concerning the issue of road freight transport in a smart city shows fluctuations, however, since 2016 a clear upward trend can be observed. The highest year-on-year increase in the number of publications in the selected area was recorded in 2020 and 2021, both for the Scopus and Web of Science Core Collection databases (Figure 1). Publications by Polish authors qualified for the study represent a distinct minority, due to the low frequency of publishing in English in journals or publishing houses indexed in the aforementioned bibliographic databases.

Table 1.
Criteria and results of filtering publications indexed in the Web of Science Core Collection and Scopus databases in the years 2010-2024 (as of April 29, 2025)

Filtering criteria	Number of publications indexed in the databases:			
	Web of Science Core Collection		Scopus	
	foreign affiliation	Polish affiliation	foreign affiliation	Polish affiliation
Criterion 1. „road freight transport" and „smart city" in the title, abstract, or keywords	10	2	31	3
Criterion 2. „road transport of goods" and „smart city" in the title, abstract, or keywords	8	2	35	3
Criterion 3. „road transport of cargo" and „smart city" in the title, abstract, or keywords	3	n/a	15	n/a
Criterion 4. „road freight transport" and „smart city" in the field of social sciences	4	n/a	8	n/a
Criterion 5. „road transport of goods" and „smart city" in the field of social sciences	4	1	11	n/a
Criterion 6. „road transport of cargo" and „smart city" in the field of social sciences	1	n/a	5	n/a
Criterion 7. „road freight transport" and „smart city" in full-text peer-reviewed publications	4	n/a	7	n/a
Criterion 8. „road transport of goods" and „smart city" in full-text peer-reviewed publications	4	1	11	n/a
Criterion 9. „road transport of cargo" and „smart city" in full-text peer-reviewed publications	1	n/a	4	n/a

Source: own elaboration.

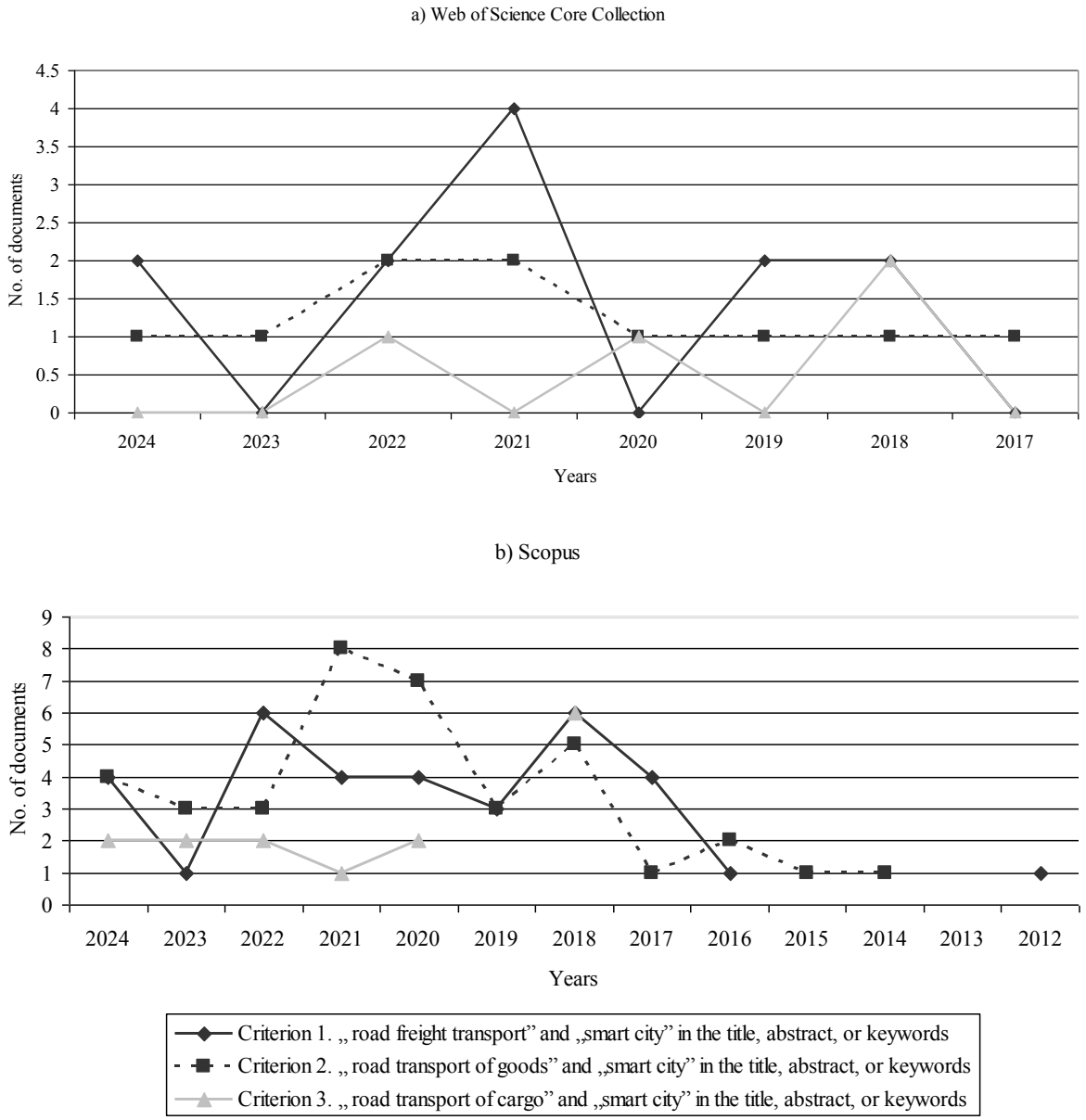

Figure 1. Number of documents published in 2010-2024 according to three filtering criteria in databases: a) Web of Science Core Collection, b) Scopus.

Source: Own elaboration.

Among the documents published between 2010 and 2024 that met the specified criteria 1 and 2, peer-reviewed journal articles emerged as the predominant publication type (Figure 2). Within the Web of Science Core Collection, articles represented 75% under criterion 1 and 70% under criterion 2. In the Scopus database, these proportions were slightly lower, amounting to 56% and 45%, respectively. Regarding criterion 3, the distribution of document types across both databases exhibited notable similarity; however, conference proceedings constituted the majority, accounting for 67% of the total output.

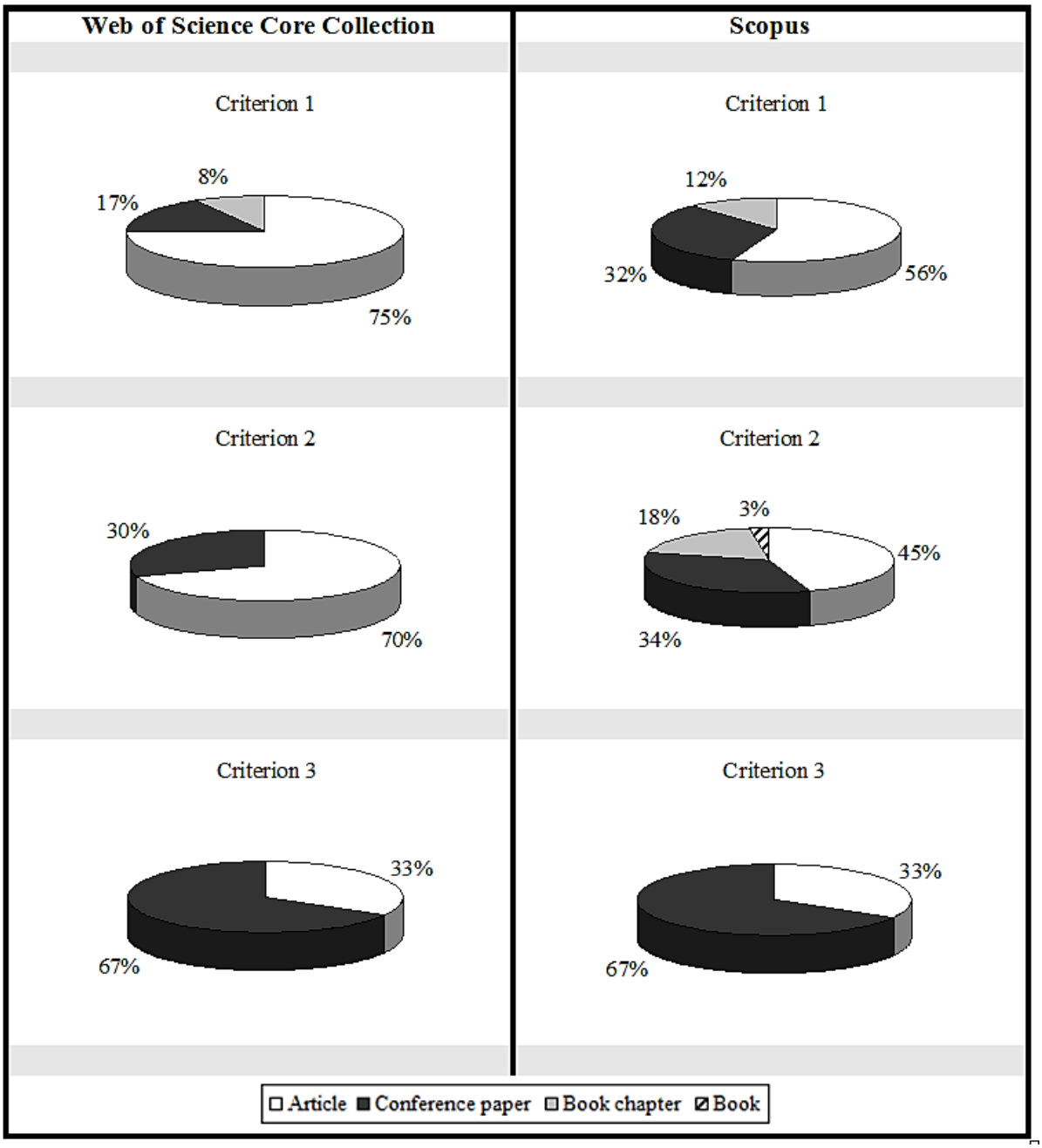

Figure 2. The types of documents published in 2010-2024 according to three filtering criteria in databases: Web of Science Core Collection and Scopus.

Source: Own elaboration.

Publications concerning the selected issue appeared in particular in such journals as: *Research in Transportation Business and Management, International Journal of Logistics Management, International Journal of Logistics – Research and Applications, Sustainability, Transportation Research Procedia, European Transport Research Review, Frontiers in Future Transportation, Sustainable Cities and Society,* and *Smart Cities*. Issues related to road freight transport, road transport of goods or cargo in a smart city were most frequently addressed by researchers from Italy, Belgium, and Germany.

The next stage of the bibliometric research involved conducting a citation analysis, the results of which are partially presented in Table 2. In the Web of Science Core Collection and Scopus databases, the five most frequently cited publications dedicated to the issues of road freight transport, road transport of goods or cargo in a smart city were identified. The dominant position, with 271 citations in the Scopus database and 215 in the Web of Science Core Collection, is held by the article by L. Ranieri, S. Digiesi, B. Silvestri, and M. Roccotelli entitled *A Review of Last Mile Logistics Innovations in an Externalities Cost Reduction Vision*, published in *Sustainability* in 2018.

Table 2.
Ranking of five publications dedicated to the issues of road freight transport, road transport of goods or cargo in smart cities with the highest number of citations in the Web of Science Core Collection and Scopus databases in the years 2010-2024 (as of April 29, 2025)

No.	Authors	Title of the publication	Year of publication	Number of citations of the publication in the databases:	
				Web of Science Core Collection	Scopus
1.	L. Ranieri, S. Digiesi, B. Silvestri, M. Roccotelli	A Review of Last Mile Logistics Innovations in an Externalities Cost Reduction Vision	2018	215	271
2.	R. Singh, R. Sharma, S. Vaseem Akram, A. Gehlot, D. Buddhi, K. Malik, R. Arya	Highway 4.0: Digitalization of highways for vulnerable road safety development with intelligent IoT sensors and machine learning	2021	37	70
3.	C. Macharis, L. Milan, S. Verlinde	A stakeholder-based multicriteria evaluation framework for city distribution	2014	52	63
4.	F. Borghetti, C. Caballini, A. Carboni, G. Grossato, R. Maja, B. Barabino	The Use of Drones for Last-Mile Delivery: A Numerical Case Study in Milan, Italy	2022	38	48
5.	C. Peprah, O. Amponsah, C. Oduro	A system view of smart mobility and it's implications for Ghanaian cities	2019	n/a	48

Source: own elaboration.

A co-occurrence analysis of words was also conducted, enabling the identification and grouping of research subareas, followed by their evaluation. The domains included in the analysis were selected based on the presence of the phrases: "road freight transport" and "smart city" in the title, abstract, or keywords. Terms with a frequency of occurrence in bibliographic descriptions exceeding the minimum threshold of 10 were eliminated. In accordance with the adopted criteria, 974 terms were identified, of which 86 were recorded at least 10 times. Subsequently, the most relevant terms were selected by reducing those unrelated to the chosen

subject matter. The result of the conducted co-occurrence analysis was the identification of three significant subareas related to the issues of road freight transport in a smart city (Table 3). The identified clusters concern: pro-environmental aspects, the technological dimension, and the optimization of logistics processes. The research subarea concerning pro-environmental aspects includes publications primarily addressing the reduction of greenhouse gas emissions and other air pollutants generated by transport, the development of electrification and the use of renewable energy sources, as well as improvements in energy efficiency in transport. The subarea of the technological dimension of road freight transport in a smart city relates to the application of intelligent transport management systems, digital platforms and mobile applications, as well as the use of the Internet of Things and big data for route optimization and fleet management. The final subarea, focusing on the optimization of logistics processes, refers in particular to innovative solutions for the distribution of goods in the so-called last mile stage and in the management of flows in supply chains, as well as the modernization of logistics infrastructure.

Table 3.
Main research subareas of the issue of road freight transport in a smart city

Research subareas	Issues
Pro-environmental	- reduction of greenhouse gas emissions and other air pollutants generated by transport, - development of electrification and the use of renewable energy sources, - improvement of energy efficiency.
Technological	- implementation of intelligent transport management systems, - application of digital platforms and mobile applications in transport management, - utilisation of the Internet of Things and big data in route optimisation and fleet management.
Processes	- optimisation of last-mile goods distribution, - innovative solutions in supply chain flow management, - modernisation of logistics infrastructure.

Source: own elaboration.

The results of the conducted study also demonstrated that the issue of smart cities is becoming an increasingly justified determinant in intensifying the transformation of the spectrum of topics related to road freight transport. It appears that issues related to the implementation and use of intelligent transport management systems and mobile applications, the application of flow optimization methods, the development of vehicle-to-vehicle communication, and the use of renewable energy sources constitute a promising perspective for both researchers and practitioners in the management of business entities, especially in the context of expected reorientations of future research. The ongoing trend in recent years of a steadily increasing number of publications indexed in recognized bibliographic databases in the area of road freight transport in the context of smart cities signals that the selected field remains relatively new and insufficiently explored. This indicates its potential as a current, original, and engaging subject of analysis in the field of social sciences. At the same time, considering the nature and limitations of the performed analysis and meta-analysis, defined by the selected bibliographic data, the obtained results should be interpreted as preliminary and as

a contribution to the discourse on the evolution of road freight transport, conditioned by the pursuit of improving the smart city concept. In conclusion to the presented reflections, it is also necessary to supplement the discussion with remarks on the limitations of the analysis resulting from the applied research method. First and foremost, restricting the analysis to two databases (Web of Science Core Collection and Scopus) led to the exclusion of other relevant publications that are not indexed within those resources. Furthermore, in line with the postulate to reduce the size of the analyzed publication set, a selection based on the highest citation counts was made. As a consequence, scientific works published relatively recently, which may constitute a significant contribution to the development of knowledge on road freight transport in smart cities, were excluded from consideration.

4. Conclusion

The bibliometric examination of scholarly contributions pertaining to road freight transport within the conceptual framework of smart cities, conducted through the application of established bibliometric techniques, and grounded in data sourced from the internationally acclaimed Web of Science Core Collection and Scopus databases, enabled the delineation of principal research orientations within this emergent domain. The results demonstrate a relatively modest representation of literature addressing this thematic scope within the discipline of social sciences.

Empirical findings reveal a discernible escalation in publication activity after 2016, which may be construed as indicative of a growing academic preoccupation with the multifaceted challenges of sustainable and intelligent road freight transport management in urbanized contexts. Particular prominence is accorded to works investigating environmental imperatives, the integration of digital technologies, and the refinement of logistics operations, insights corroborated through both citation analysis and term co-occurrence mapping. Within the analyzed corpus, three dominant research subdomains have been identified: (1) environmental determinants shaping the transformation of urban road freight systems, encompassing strategies aimed at decarbonization and energy efficiency enhancements, (2) the application of advanced technological solutions, including intelligent transport systems and digital platforms, in transport governance, and (3) the optimization of urban logistics, with special emphasis on last-mile distribution strategies and the modernization of logistics infrastructure.

In light of the above, it is reasonable to posit that the thematic area of road freight transport in the smart city milieu constitutes a fertile ground for further scientific inquiry, offering considerable potential both in epistemological and applied dimensions. The inherent complexity and multidimensionality of the subject suggest the necessity for continued, methodologically rigorous exploration, also conducted within an interdisciplinary framework.

Nonetheless, the employed research procedure is not without its epistemic constraints. The application of narrowly defined selection criteria, and the confinement of the dataset to two bibliographic repositories, may have inadvertently precluded the inclusion of significant contributions not indexed therein. Furthermore, the methodological emphasis on citation frequency as a proxy for scientific impact could have marginalized recent, yet substantively meaningful publications, thereby warranting a cautious interpretation of the derived conclusions.

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