Supply chain perspectives for achieving economic growth and environmental sustainability

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Abstract — A resilient supply chain is crucial for economic growth and the well-being of economies. However, it contributes to environmental challenges, such as resource extraction, material usage, climate change and biodiversity. This Special Volume of the Journal of Logistics, Supply Chain, Sustainability, and Global Challenges explores current research directions and challenges while offering solutions for sustainable supply chains. The volume examines existing European policy directives and strategies to comprehensively understand sustainable supply chain requirements. It conducts a content analysis of the current research in the field. The authors present valuable theoretical insights and empirical case studies addressing the interplay between sustainable supply chains, economic growth, and environmental impact mitigation. The papers in this Special Volume highlight the holistic and interconnected nature of the supply chain field and emphasise that there is still significant potential for improving supply chain processes to enhance their sustainability.

Index Terms — sustainable supply chains, economic growth, environmental impact, industry 4.0

I. INTRODUCTION

Supply chain management involves the strategic planning and systematic coordination of all activities related to sourcing and procurement, production and conversion processes, and logistics management operations (CSCMP, 2024). Consumers take for granted the stability and security of the supply chain (Francis et al., 2021) until local or global disruptions, such as conflicts, financial crashes or pandemics, emerge. Furthermore, a resilient supply chain is essential for the economic growth and well-being of the nations (Goel et al., 2021), but on the other hand, supply chain management causes environmental issues, e.g. materials extraction and usage, impacts on climate change, and biodiversity. Supply chain processes necessitate innovative environmental strategies to minimise the negative externalities generated during supply chain management. Concurrently, these adverse effects can be alleviated by adopting green technologies and implementing sustainable logistics operations on a global scale (Govindan et al., 2014; Zhu et al., 2008). Consequently, sustainable and green supply chains inspired worldwide practitioners and researchers to implement them (Mariadoss et al., 2016).

The European Commission and other policy-making organisations primarily supported efforts regarding integrating sustainability into supply chain activities. The European Parliament and the Council have reached a political consensus concerning the Corporate Sustainability Due Diligence Directive (European Commission, 2024), which establishes regulations to protect human rights and environmental sustainability in global supply chains. This legislative proposal promotes sustainable and responsible corporate conduct across international value chains. Under this directive, large enterprises will be mandated to identify and, when necessary, prevent, terminate, or mitigate the negative impacts of their operations on human rights—including child labour and worker exploitation—and on the environment, such as pollution and biodiversity degradation (European Commission, 2024). The EU has also recognised the importance of the critical raw materials essential to Europe's economy. Critical raw materials constitute a robust industrial foundation for producing various everyday products and advanced technological applications. The assurance of consistent and unobstructed access to these materials has become an escalating issue both within the European Union and globally. In response to this concern, the European Commission compiled an initial inventory of critical raw materials in 2011, with a fifth update in 2023 (European Commission, 2024a). In March 2024, the European Council enacted the European Critical Raw Materials Act in response to the projected exponential increase in demand for rare earth elements in the coming years. This legislation is designed to enhance and

diversify the EU's supply of critical raw materials, promote circular economy practices such as recycling, and support research and innovation to improve resource efficiency and develop alternative materials. The new regulations will bolster Europe's strategic autonomy (European Council, 2024).

Growing evidence indicates that economic expansion negatively impacts biodiversity. The connection between economic growth and biodiversity decline is mediated by several mechanisms, primarily driven by increased resource consumption (Otero et al., 2020). Biodiversity loss stands as one of the most pressing environmental challenges of our time, yet it has surprisingly garnered limited attention from scholars in management and supply chain research (Salmi et al., 2023). Regarding supplier practices, improving supply chain transparency and traceability is essential for identifying the points along supply chains and worldwide where companies exert significant environmental impacts, including on biodiversity (Salmi et al., 2023). In 2020, the European Commission introduced a comprehensive Biodiversity Strategy to address the primary factors contributing to biodiversity decline, including the unsustainable exploitation of terrestrial and marine environments, overuse of natural resources, pollution, and the spread of non-native species. This strategy plays a crucial role in bolstering the EU's resilience and ensuring the continuity of economic activities. Additionally, it seeks to integrate biodiversity considerations into the broader economic growth agenda of the EU. Key proposals within the strategy include setting legally binding targets for the restoration of degraded ecosystems and waterways, enhancing the condition of protected habitats and species within the EU, reintroducing pollinators to farmland, reducing pollution levels, promoting urban greening initiatives, and supporting organic and biodiversity-friendly agricultural practices (European Commission, 2020).

This SV section was developed mainly from papers presented at the 18th Sustainable Development of Energy, Water and Environment Systems (SDEWES) conference in Dubrovnik, Croatia, 24.–29. September 2023, where 646 scientists, researchers, and sustainable development experts discussed the latest research outcomes and frontrunning innovations. The International Centre organised the conference for Sustainable Development of Energy, Water and Environment Systems (SDEWES Centre) to provide a more comprehensive platform for communication and exchange of ideas between scientists and researchers that promotes multidisciplinary approaches to sustainability (SDEWES Center, 2024). The SV section brings examples of innovations and sustainability in supply chains, including biodiversity support with beekeeping and determinants for sustainable economic growth. It represents new knowledge and concepts and contributes to the sustainability of supply chain global discussion via papers that emphasise both theoretical approaches through literature review and practical perspectives of the topics emphasised at the conference.

II. SUPPLY CHAINS AND ENVIRONMENTAL SUSTAINABILITY UPDATE

An essential method for following and identifying current research trends is through a comprehensive literature review of recent studies published in scientific journals. Given the rapid evolution of supply chain research, driven by dynamic economic markets and a growing emphasis on sustainable development and the circular economy, there is a pressing need to deliver timely and relevant insights. To address this need, a thorough literature review incorporating paper content analysis was undertaken to identify prevailing research trends. The research used two of the most comprehensive academic databases, Web of Science (WoS) and Scopus, to ensure extensive coverage of relevant publications (Ewald et al., 2022). The review focused specifically on supply chains, employing the following search query in both databases: "All: (supply chain*) AND (environment OR sustainability)," with additional filters restricting results to English-language publications and types such as articles, review Articles, and book chapters. To ensure the review was focused on the most recent research, the time frame was limited to works published between the start of 2023 and 2025. This search yielded 647 results from WoS and 637 from Scopus.

Subsequently, a screening process was conducted to refine the initial results, focusing on relevance to the research objectives. This involved a detailed examination of titles, abstracts, and publication content, ultimately narrowing the selection to 237 relevant publications. After consolidating the results from both databases, the final count of publications deemed suitable for further analysis stood at 186.

Leximancer software was employed to analyse the selected publications and facilitate the identification of ongoing research trends. Leximancer differentiates itself from other visualisation tools by focusing on a

comprehensive analysis of the entire paper content (Leximancer, 2023). The software applies a statistical algorithm grounded in Bayesian inference to extract critical concepts and utilises thesauri to generate conceptual maps (Angus et al., 2013). This approach enables identifying and visualising dominant themes through the occurrence and co-occurrence of predefined seed concepts (Hyndman & Pill, 2018). By leveraging contextual analysis and visualisation, Leximancer facilitates the rapid assessment of the significance, strength, and interrelationships between identified themes and concepts (Wilk et al., 2018).

Following the compilation of the final database, Leximancer was utilised for an in-depth analysis. As detailed in the methodology section, the software allows for modelling concepts based on contextual data analysis. The analysis followed a systematic approach, as outlined by Engstrom et al. (2022), which included identifying key concepts, merging semantically similar concepts, and adjusting the thesaurus to refine the analysis (Leximancer, 2023). This approach improves the accuracy of the identified research trends. It ensures that the most relevant and meaningful insights are identified, providing a robust foundation for understanding the current state and future research direction in supply chain sustainability.
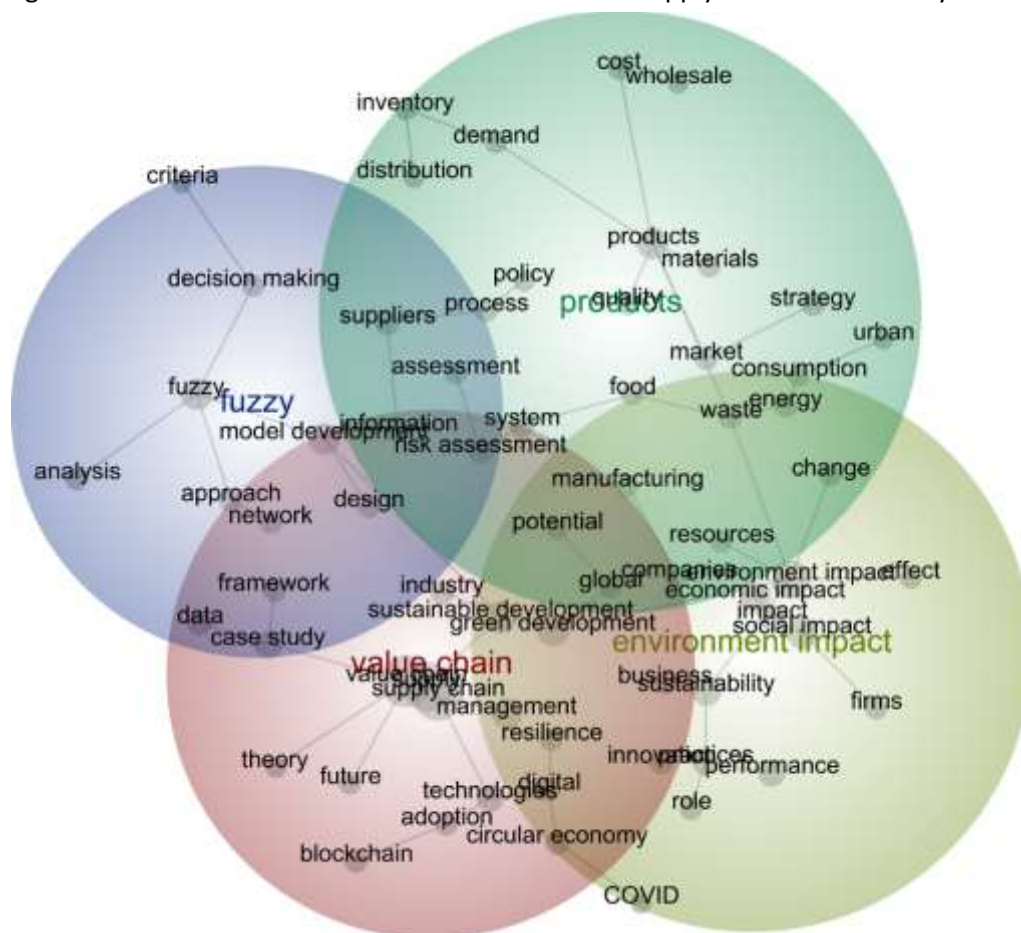

Figure 1: Indemnified main concepts within the supply chain research field.

As illustrated in Figure 1, the final conceptual map comprises four significant themes, within which 67 concepts were identified. Each theme is colour-coded according to its significance. Themes of higher importance are represented in warmer colours (e.g., red), while those of lesser importance are shown in colder colours (e.g., blue). Consequently, the themes, ranked from most to least important, are value chain, environmental impact, product, and fuzzy. Key concept clusters were identified in the most prominent theme, value chain. The primary cluster includes concepts such as 'value chain,' 'supply chain,' 'supply,' 'management,' and 'network,' all related to managing economic, informational, and value flows within existing supply chain networks. Another significant cluster encompasses 'sustainable development,' 'green development,' 'model development,' 'practices,' and 'design,' highlighting a focus on modelling supply chains

in line with green technology and implementing sustainable practices. The final cluster in this theme consists of 'technologies,' 'blockchain,' 'digital,' and 'adoption,' indicating a trend towards integrating digital technologies into supply chains.

The second most prominent theme, environmental impact, is marked by a lighter green colour. This theme contains two key concept clusters. The first includes 'environmental impact,' 'social impact,' 'economic impact,' 'resources,' 'companies,' and 'effect,' reflecting the incorporation of economic, environmental, and social perspectives in resource management within companies. The second cluster, comprising 'innovation,' 'role,' 'sustainability,' 'business,' and 'performance,' suggests that innovations geared toward sustainability play a crucial role in company performance. The third theme, products, reveals three significant concept clusters. The first cluster includes 'market,' 'strategy,' 'products,' 'materials,' and 'quality,' emphasising the importance of strategic planning regarding product material usage and quality in the competitive market. This is connected to the second cluster, which includes 'waste,' 'energy,' 'food,' 'system,' 'consumption,' and 'urban,' pointing to a comprehensive focus on the food system and related products from a life cycle perspective. The final cluster in this theme, consisting of 'inventory,' 'demand,' and 'distribution,' underscores the need for a systematic approach to enhancing current supply chain and logistics practices. The final theme, fuzzy, consists of two prominent clusters. The last cluster includes 'fuzzy,' 'analysis,' 'decision making,' 'criteria,' 'approach,' and 'network,' indicating the necessity of analysing current models and approaches through fuzzy logic and mathematical criteria. The second cluster, featuring 'model development,' 'information,' 'data,' 'framework,' and 'risk assessment,' suggests that data collection is crucial for developing new supply chain models, especially given the volatility of the markets in which these supply chains operate.

Based on the results obtained, it can be inferred that contemporary advancements in supply chains are converging in three key directions: the development of sustainable and green supply chains (Marty et al., 2024; Chaudhure et al., 2024), the evolution of value chains aligned with circular economy principles (Haseli et al., 2024; Das, 2024; Ravichandran et al., 2024), and the integration of digital technologies, including blockchain (Chen, 2024; Pandey et al., 2024). Most reviewed research papers reveal that advancements in supply chain paradigms, such as green and value chains, are primarily driven through case studies and the application of fuzzy logic. Fuzzy logic addresses the uncertainty and complexity inherent in supply chain decision-making, while case studies offer practical insights and validate theoretical models (Hezam et al., 2024; Najjar et al., 2024).

Although not explicitly indicated in the concepts, current supply chain research is pushed by two overarching trends: digitalisation, exemplified by Industry 4.0 and 5.0 (Kumar et al., 2023), and the circular economy paradigm. This latter focus emphasises sectors of significant importance as outlined in the Circular Economy Action Plan (European Commission, 2023), including the food industry (Alem Fonseca et al., 2024; Wilkinson et al., 2024), electronics (Chaudhuri et al., 2024; Ye et al., 2023), rare materials (Marty et al., 2024), and waste management (Haseli et al., 2024; Gage et al., 2024). The concurrent research thus focuses on a multitude of different paradigms. To transition from the traditional supply chains towards chains in line with modern progress.

III. SUMMARY OF THE PAPERS IN THIS SPECIAL VOLUME

This section provides a concise overview of the articles in this SV section. As illustrated in Figure 1, the field of supply chain research is highly intricate, encompassing a wide range of topics, theories, and methodologies. The complexity of this field continues to grow, driven by the emergence of new perspectives, interdisciplinary studies, global policy initiatives, and the practical implementation of theoretical models. The papers in this SV start with a case study on achieving environmental sustainability, adapting the Industry 4.0 tools and approaches to overcome the challenges of digital transformation (paper 1). It is followed by two theoretical studies related to software selection for logistics and supply chain processes (paper 2) and exploring the thermal insulation solutions, highlighting the different players in the supply chain with a focus on sustainable and recycled materials (paper 3). Paper 4 focuses on theoretical and practical approaches regarding the beekeeping value chain and introduces a case study from Columbia. The last paper in SV

focuses on economic growth and environmental sustainability in European countries, identifying significant contributors to economic growth in the long run (paper 5).

Paper 1 (Merroun et al., 2024): The authors conducted a case study to explore the environmental sustainability implications of Industry 4.0. The research aimed to examine how a particular company addressed the critical challenges associated with implementing Industry 4.0 and to evaluate the environmental impacts from both the company's perspective and that of three of its customers. The findings identified several recurrent challenges highlighted in the literature and confirmed by the case study: decision-making constraints, underutilised data potential, a shortage of skilled personnel, the integration of information technology with operational technology, the high investment demands of Industry 4.0, and the general lack of awareness regarding Industry 4.0. Additionally, the study demonstrated how the company successfully overcame these challenges, ultimately establishing itself as a market leader in Industry 4.0 implementation. The paper also discussed the environmental sustainability effects of Industry 4.0 from the company's and its customers' perspectives, focusing on three key areas directly impacted by Industry 4.0: waste management, CO_2 emission reduction, and energy efficiency. The results further revealed that artificial intelligence is the most frequently utilised technology to enhance environmental sustainability.

Paper 2 (Doğaner Duman et al., 2024): The authors investigated the factors involved in software selection within the logistics supply chain. In this context, they conducted a bibliometric analysis of existing literature to create a comprehensive overview of the research landscape. The VOSviewer software was utilised for mapping and analytical purposes. Keywords such as "Logistics or supply chain and software selection" were queried in the database, with the search covering publications from 1994 to the present (as the earliest relevant article dates back to 1994). The search was restricted to English-language articles, resulting in a total of 258 relevant publications being identified as of September 2023. A critical aspect of software package evaluation involves defining the selection criteria, assigning appropriate weights to each, establishing a rating scale, calculating scores, ranking the options, and ultimately choosing the most suitable software. However, the interpretation of each criterion can vary among evaluators, leading to inconsistencies in terminology and confusion during the selection process. To address this issue, the authors have proposed standardised lists of evaluation criteria that can be universally applied to software assessment. These criteria include technological capability, cost and pricing, functionality, service, and the software provider's reputation. The study also offers detailed insights into software selection, highlighting the countries with the most significant contributions to the field, the most cited publications, and leading researchers. Overall, this work provides a valuable resource for researchers by offering an overview of critical contributors, prominent institutions, and emerging concepts, thereby helping to streamline future research efforts in this domain.

Paper 3 (Benedetti et al., 2024): The authors focus on optimising the Italian Off-Site Construction (OSC) supply chain, emphasising renovation projects instead of new construction. Their work includes an evaluation of the current market dynamics, supply chain status, and potential for enhancing energy efficiency. Additionally, they explore tools that could facilitate a shared understanding among key stakeholders. A significant aspect of their investigation is focused on External Thermal Insulation Composite Systems (ETICS) for buildings, as the ETICS market serves as a critical entry point for evaluating the existing state of building renovation technologies. This market comprises various participants, including manufacturers of components (such as insulation materials, structural elements, and accessories), system builders (who purchase and certify these insulation systems), distributors, and installers. The components used in ETICS are predominantly energy-intensive materials (like expanded polystyrene insulation, rock wool, glass wool, fibreglass, metal structures, and concrete).

Consequently, reducing energy and material consumption within this context enhances the overall competitiveness of the supply chain. The authors also discovered that in Italy, the level of integration of proposed solutions and the supply chain organisation are significantly influenced by the type of primary insulation material used, which is further linked to the NACE classification of the insulation manufacturer. Currently, certified kits are the predominant method of commercialising ETICS, while fully OSC solutions remain relatively uncommon. However, these applications are growing interest among designers, end-users, and producers.

Paper 4 (Leones-Cerpa et al., 2024): The authors conducted research to assess the current state of beekeeping in Colombia, with a particular focus on the Colombian Caribbean region, aiming to identify opportunities for innovation in the development of products, practices, and technical equipment to support beekeeping activities. The study utilised a range of data sources, including databases such as Science Direct, Springer, Taylor & Francis, Scopus, and PatentPulse, over ten years from 2013 to 2023. Additionally, information was gathered from Colombian government databases and reports, including those from the Ministry of Agriculture and Rural Development (MADR), the Information and Communication Network for the Agricultural Sector (Agronet), the Colombian Agricultural Institute (ICA), as well as regional and national institutes and associations. A survey was also conducted using the CAWI (Computer Assisted Web Interviewing) method, targeting a random sample of 31 beekeepers from the Colombian Caribbean region. The survey included questions designed to gauge beekeepers' perspectives on their practices and the state of beekeeping in the region. The findings revealed that beekeeping in Colombia has seen significant growth in recent years. Beekeepers in the Colombian Caribbean region possess substantial empirical knowledge of production processes; however, there needs to be more standardised protocols, and information on regulations and hive products is limited. The results also indicated that beekeepers show a strong interest in developing new products, establishing specific regulations for beekeeping and its products, and the genetic improvement of bees.

Paper 5 (Bytyqi et al., 2024): The authors thoroughly explored and analysed the key determinants influencing economic growth and environmental sustainability. They examined the relationship between these factors and evaluated their impacts on economic growth and environmental sustainability. The study was based on data from EU member states over ten years (2011–2020) and employed the panel autoregressive distributed lag (ARDL) technique to estimate these effects. The ARDL model was applied to assess the influence of various explanatory variables, including CO_2 emissions, renewable energy consumption, recycling, and total environmental taxes, on the two primary outcomes: economic growth and environmental sustainability. This robust methodological approach enabled a comprehensive and reliable analysis of the determinants driving the EU's transition towards a green economy. The findings indicate that recycling and total environmental taxes significantly contribute to economic growth and environmental sustainability, particularly over the long term. While renewable energy consumption also plays an important role, it was found to have a negative impact on economic growth, suggesting that its current implementation may not yet be fully aligned with economic benefits despite its importance for sustainability. However, these variables do not significantly impact economic growth in the short term. Overall, the group of determinants collectively positively influences economic growth. Specifically, recycling emerged as a critical factor in promoting environmental sustainability.

Additionally, total environmental taxes were identified as a crucial determinant of economic growth. Conversely, CO_2 emissions were found to have a detrimental effect on environmental sustainability in the long term. In contrast, none of the three variables—recycling, total environmental taxes, or CO_2 emissions— significantly impacted environmental sustainability in the short term.

IV. CONCLUSIONS

The articles included in this SV section explore research, practical experiences, and prospective advancements related to sustainable supply chains. They analyse recent progress from multiple angles, from theoretical frameworks to case studies and practical applications. The models, approaches, and methods presented here have the potential for broader application across various contexts or scenarios. These could be adapted to suit the specific needs of different industries, sectors, or scales. Furthermore, they propose potential solutions, at least partially, to many of the challenges outlined by the European Commission, particularly concerning the secure and uninterrupted access to essential materials within the European Union and globally. Additionally, they address objectives related to restoring degraded ecosystems and waterways, improving protected habitats and species, and promoting economic growth through increased digitalisation. This SV section emphasises the following key points:

- The environmental sustainability implication of Industry 4.0 is challenged by decision-making constraints, underutilised data potential, a shortage of skilled personnel, integrating information technology with operational technology, the high investment demands of Industry 4.0, and a general lack of awareness regarding Industry 4.0.
- The factors in selecting software within the logistics supply chain that can be universally applied comprehend technological capability, cost and pricing, functionality, service, and the software provider's reputation.
- Reducing energy and material consumption within this context enhances the overall competitiveness of the supply chain, and certified kits are the predominant method of commercialising ETICS. At the same time, fully OSC solutions remain relatively uncommon.
- Beekeeping in Colombia has seen significant growth in recent years and has influenced biodiversity. Beekeepers in the Colombian Caribbean region possess empirical knowledge of production processes, but there needs to be standardised protocols and information on regulations and hive products.
- Recycling and total environmental taxes significantly contribute to economic growth and environmental sustainability, particularly over the long term.

While researching the current development of sustainability supply chain research, the field emerged as complex, comprehending 67 concepts gathered under four themes: value chain, environmental impact, product, and fuzzy. All the papers in this SV contribute to various themes. For example, the most dominant theme covers technologies,' 'blockchain,' 'digital,' and 'adoption,' indicating a trend towards integrating digital technologies into supply chains, where Papers 1 and 2 contribute. Both papers also contribute to the theme "fuzzy", as they include 'decision making', and 'criteria'. Papers 3, 4 and 5 contribute to the themes "products", "value chain", and "environmental impacts".

The papers in SV indicate the complexity and interconnectedness of the sustainable supply chain and are coherent with the current research directions. Furthermore, they contribute to and support the global and EU policy directives on sustainable supply chains, economic growth and environmental impacts.

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Prespektive oskrbovalnih verig za doseganje gospodarske rasti in okoljske trajnosti

Povzetek – Odporna oskrbovalna veriga je ključnega pomena za gospodarsko rast in blaginjo. Po drugi strani pa prispeva tudi k okoljskim izzivom, kot so pridobivanje virov, uporaba materialov, podnebne spremembe in biotska raznovrstnost. Ta posebna izdaja revije Journal of Logistics, Supply Chain, Sustainability, and Global Challenges raziskuje trenutne smeri raziskav in izzive ter hkrati ponuja rešitve za trajnostne oskrbovalne verige. V tej izdaji avtorji raziskujejo obstoječe evropske politične direktive in strategije za celovito razumevanje zahtev trajnostnih oskrbovalnih verig. Opravljena je vsebinska analiza trenutnih raziskav na tem področju. Avtorji nadalje predstavijo zanimiva teoretična spoznanja in empirične študije primerov, ki obravnavajo medsebojni vpliv trajnostnih oskrbovalnih verig, gospodarske rasti in zmanjševanja vplivov na okolje. Prispevki v tej posebni izdaji poudarjajo celostno in medsebojno povezano naravo področja oskrbovalnih verig ter navajajo, da je še vedno veliko možnosti za izboljšanje procesov in povečanje trajnostnosti oskrbovalnih verig.

Ključne besede – trajnostne dobavne verige, gospodarska rast, vpliv na okolje, industrija 4.0