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Sustainable Development: Combination with SCM for Engineering Education

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ABSTRACT

BACKGROUND & CONTEXT

Engineering education traditionally emphasizes core technical subjects, but engineers increasingly need broader managerial competencies, particularly supply chain management (SCM). SCM covers the planning and optimization of goods, services, and information flow from raw materials to final delivery, aimed at efficiency and responsiveness. Industry 4.0, IoT, AI, and blockchain have further drawn engineering and SCM closer, requiring interdisciplinary skills. However, quantitative research examining this integration remains limited.

PURPOSE OR GOAL

This study reviews how SCM is applied within engineering education through systematic contextual analysis, identifying key areas of convergence and proposing future research directions toward sustainable, green development in engineering education.

APPROACH OR METHODOLOGY

A systematic literature review was conducted using Web of Science and SCI-hub databases, searching titles for terms such as "engineering education" and "SCM." From an initial 77 articles, 12 were excluded after abstract screening, yielding 65 articles for full-text thematic analysis.

OUTCOMES

Publications on both fields grew substantially from 2020 to 2024, with engineering education rising 100% and SCM rising 125%. Four convergence areas emerged: curriculum integration, skill development, research and innovation, and industry collaboration. Green Supply Chain Management (GSCM) was identified as a critical emerging direction for sustainability.

CONCLUSIONS

The findings provide a theoretical foundation for reforming engineering curricula and strengthening university-industry partnerships. The study underscores the importance of embedding GSCM into engineering education to prepare graduates for operational and environmental challenges.

KEYWORDS

Engineering education, supply chain management, green supply chain management.

Introduction

Engineering education is a systematic academic and practical training framework in the manufacturing business that is aimed at creating qualified professionals with the expertise to solve intricate technical problems (Tominaga & Martins, 2021). It combines basic scientific fundamentals with practical applications and trains the students for a career in highly diversified fields of mechanical, electrical, civil, and computer engineering. Traditionally, engineering programs set an emphasis on core subjects such as math, physics, and principles of design with laboratory courses and industrial internships to provide real-life preparedness. But as industries develop over time, there is an increased demand for engineers with a deeper comprehension of not just technical aspects but of more overall operation and managerial issues—one of the most significant of these is supply chain management (SCM) (Van et al., 2023; Nisrina et al., 2025).

Supply chain management (SCM) first appeared in the mid-1980s (Gariya et al., 2024; Khan et al., 2023). SCM is the entire process of planning, coordination, and optimizing the movement of goods, services, information, and financials from raw materials to final delivery of the product for consumer (Pai et al., 2025). It involves everything that is from procurement and production up to logistics, warehousing, delivery, and even handling returns. The aim of SCM is efficiency, lower costs, better quality, and better customer satisfaction with flexibility in response to market demand as well as disruptions (Barman, 2025). Therefore, SCM has emerged as a discipline aimed at minimizing the overall expenses across the supply chain, from raw material to final products (Gariya et al., 2024).

Integrating SCM into engineering education is becoming increasingly important due to the interconnected nature of modern industries. Today's engineers are not merely a product-designing individual but equally accountable for considering sourcing materials. A deep understanding of SCM enables them to streamline the production process, decrease costs, and make the process more sustainable (Al Amin & Baldacci, 2025). For example, a mechanical engineer involved in automobile production needs to have an idea of the world supply chain in order to choose the appropriate material, manage the relationship with suppliers, and avoid delays. Lack of this information might render the best-designed product with bottlenecks in logistics that result in increased costs and inefficiency (Razavian et al., 2025). Further, Industry 4.0 and smart manufacturing have brought engineering and supply chain management much closer. The Internet of Things (IoT), artificial intelligence (AI), and blockchain technologies have brought a significant change into the way supply chains run and engineers need to possess interdisciplinary skills (Ning et al., 2025).

Although the significance of combining engineering education with SCM is increasingly recognized in qualitative level, quantitative research is much important to explore today's engineering education whether better considers SCM. Based on this perspective, this paper will seek to review SCM application in manufacturing engineering education by contexts analysis. Besides, the study will also propose a new view on future research to support the green development in engineering education system.

Material Collection

This study focuses on the literature that combines engineering education in manufacturing companies with SCM, with a systematic literature review (SLR) methodology to analysis the contexts of the academic literatures. This way can give the research the primary perspective to analyse questions (Alsehaimi et al., 2025).

Systematic literature review (SLR) applies a systematic methodology towards the extensive analysis of pertinent existing evidence on a predefined topic. Defining specific objectives and articulating key questions of inquiry is the first step that guides the research process. Then the second step involves creating an appropriate search approach by determining the pertinent academic databases, choosing the right keywords, and setting the inclusion/exclusion criteria in such a manner that the selected articles fall within the scope of the proposed research.

Methodological rigor and reproducibility need to be maintained throughout the process in order to make the review academically valid. SLRs contribute significant value by aggregating scattered evidence, identifying trends, and creating evidence-based foundations for advanced works.

For the process of SLR, we conducted a systematic keyword structure by using Wos and SCI-hub databases, targeting terms in article titles such as “engineering education”, “supply chain management”, “manufacture”, “SCM” and so on. By preliminary screening in English literatures, the study has found 77 relative articles.

The abstracts of these papers were then reviewed to determine their relevance to the research scope, which 12 articles were excluded at this stage because they didn’t talk about engineering education or SCM really. By this way, the study narrowed the selection sample to 65. By full-text analysis, the other literature all meets the theme standards. So ultimately, a sum of 65 literatures was selected to support the study theme.

Data Analysis

First, an initial coding phase was carried out, during which each article was thoroughly examined to identify explicit and implicit themes related to the implementation of circular economy strategies. This involved extracting information on practices, strategies, and contextual emphases specific to both university and manufacturing settings. Subsequently, the identified codes were grouped into broader thematic categories based on conceptual coherence and functional relevance. Through an iterative process of comparison and refinement, three core aspects consistently emerged across the literature, reflecting distinct dimensions of CE implementation: management approaches, design-related strategies, and economic mechanisms. These were respectively classified as Management System, Eco-Design, and Investment Recovery. A comparative analysis was then performed to delineate how each aspect manifests differently in university and manufacturing contexts.

Results and Discussion

Year Wise Publication Details

Based on the literature analysis, both engineering education and SCM have attracted growing scholarly interest, as evidenced by the increasing number of publications from 2020 to 2024.

During this period, a total of 37 articles addressed engineering education, while 28 articles focused on SCM. Besides, the articles for combination of them have become much wider. For instance, in 2020, only 5 articles were published on engineering education compared to 4 on SCM, while none were for combination. By 2024, engineering education had risen to 10, with a growth rate of 100%. While SCM had reached 9, with 125 percent increase speed. Additionally, the articles about the combination between engineering education and SCM had increased to 4, suggesting increasing momentum and interest in the application of SCM in engineering education.

Overall, this trend highlights the emerging potential of engineering education in contributing to sustainable development.

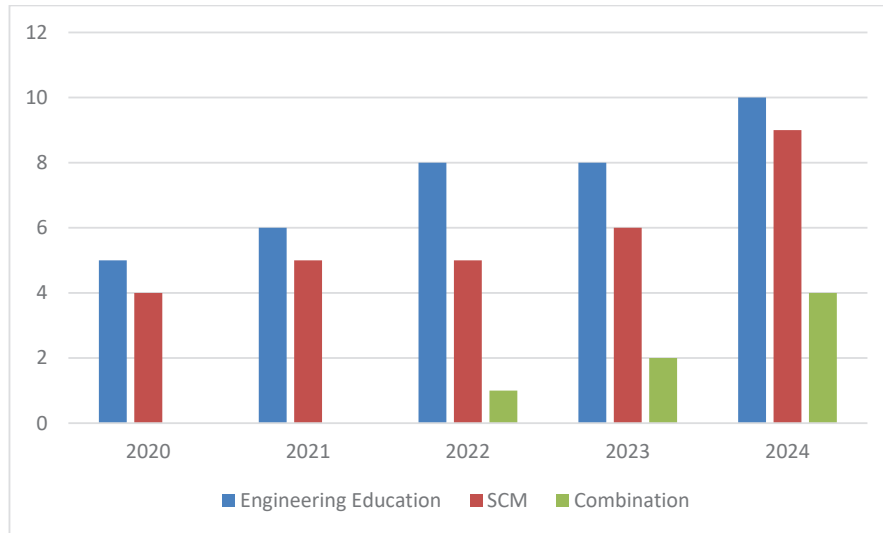


Figure 1: Number of reviewed articles on engineering education and SCM in 2020 to 2024

Combination Points between Engineering Education and SCM

Since it is a trend that applying SCM into engineering education, it is essential to explore how to combine two of them better. In this study, four potential combination points have been listed for future practice: curriculum integration; skill development; research and innovation and industry collaboration (Liu & Wen, 2024; Jebbor et al., 2024; Bandara et al., 2024). See Table 1.

From a curriculum incorporation perspective, SCM case studies can find a place in engineering education in providing real-world context, and SCM curricula can integrate engineering design principles for system optimization (Rahimi et al., 2024). Courses with a joint component and special courses, like supply chain analytics using engineering tools, further integrate the two fields. Skill development is a related area of importance as well, using engineering approaches for the development of problem-solving skills in the context of SCM problems, combined with the cultivation of skills in data analysis, simulation tools, and engineering software in the context of supply chain optimization (Khan et al., 2022; Lutz et al., 2022).

Research and innovation happen naturally as a part of joint efforts such as researching the engineering approach for solving SCM problems, investigating how engineering innovation applies in the context of SCM, and creating sustainable practices based on engineering ideas (Zhang et al., 2023). Industry collaboration is a key area as well with academia-industry collaborations with SCM-oriented companies or engineering firms providing opportunities for internships, capstones, and the deployment of innovative solutions (Pham, 2024). The joint efforts ensure that both streams are running in accordance with the needs of the industries with up-to-date curricula and improved learning with joint sharing of learning and practical implementation.

Table 1: Combination points between engineering education and SCM

Aspects	Engineering Education	SCM
Curriculum Integration	- Integrate SCM case studies into engineering courses to provide real-world context. - Develop joint courses focusing on both engineering principles and SCM applications.	- Incorporate engineering design principles into SCM curricula to enhance system optimization. - Offer specialized modules on supply chain analytics using engineering tools.
Skill Development	- Develop problem-solving skills for supply chain challenges using engineering methodologies. - Train students in data analytics and simulation tools relevant to SCM	- Enhance technical skills in supply chain process design and improvement. - Promote the use of engineering software for supply chain optimization.
Research and Innovation	- Conduct collaborative research on engineering solutions for SCM challenges. - Explore the application of emerging technologies in supply chain optimization.	- Investigate the role of SCM in driving engineering innovation. - Develop sustainable supply chain practices through engineering-driven solutions.
Industry Collaboration	- Partner with SCM-focused companies for internships and capstone projects. - Collaborate with industry experts to update engineering curricula relevant to SCM.	- Work with engineering firms to implement innovative supply chain solutions. - Engage in joint industry-academia projects to enhance SCM education through engineering insights.

Future Research Direction: The Application of Green Supply Chain in Engineering Education

The natural environmental issues have been values in recently years. Especially the global warming helps the public and governments realize the danger of the world’ s sustainability (Parmawati et al.,2023). In 2015, all the members of the United Nations totally agreed and promoted 17 Sustainable Development Goals (SDGs) which involved in Society, Economic and Environmental aspects to achieve sustainable development (Al-Raeei,2024). With the popularization of the low-carbon economy and sustainable development, future studies are encouraged to explore how to combine engineering education with sustainable elements (Chen et al., 2021; Qadir, 2023). Green supply chain management (GSCM) brings sustainability into mainstream supply chain practices with the aim of reducing waste, lowering carbon emissions, and optimizing the utilization of resources throughout procurement, production, and logistics (Broo et al., 2022). The internal and external GSCM can enhance the effectiveness of ecological and operating benefits (Javed et al.,2024). For example, Kholaiif et al. (2022) states that the implementation of GSCM can reduce the risks associated with the COVID-19 pandemic, because it can provide a prerequisite for the green and safe supply of relevant healthcare products and services (Kholaiif et al., 2023)

Education could grow the updated competencies and skills to achieve a high sustainable performance to meet the requirements of sustainable business (Al-Kasasbeh et al., 2024). The quality of education within communities has been demonstrated to directly influence the achievement of SDGs (Rathnayake et al., 2024). GSCM's incorporation into engineering education is essential in preparing engineers for sustainability problems. By incorporating GSCM into curricula as a fundamental part of engineering education, students develop practical experience with eco-efficient production methods, circular economizing practices, and life-cycle analysis that guides them toward the incorporation of sustainability within the same level of technical performance (Hadgraft & Kolmos, 2020). Not only does this enable engineers to become capable of innovating in green manufacturing and logistics but it also enables them to engage with industries in putting green technologies into practice (Almetov et al., 2023). Finally, the incorporation of GSCM into engineering education ensures that graduates have the ability to solve the immediate problems of climate change as demand for more sustainable engineering practices rises in the employment arena. It deserves deeper investigation to move toward a more circular and sustainable ecosystem in universities.

Conclusion and Suggestion

The paper shows the significance and trend of combination between engineering education in manufacture level with SCM. By integrating theoretical foundations using SCM practice through four points, curriculum integration (e.g., offering specialized modules on supply chain analytics using engineering tools), skill development that data analytics for supply chain forecasting, research collaboration such as exploring the application of emerging technologies in supply chain optimization, and industry collaboration such as engaging in joint industry-academia projects to enhance SCM education through engineering insights, programs of instruction prepare graduates more effectively for the challenges of advanced manufacturing. The growing emphasis on GSCM reinforces the importance of infusing sustainability principles into engineering curricula as well. Research in the future needs to continue these interdisciplinary methods of approach towards innovation and to relate academic education with world sustainability objectives.

To bridge the gap between theoretical frameworks and practical implementation, the integration of specialized circular economy modules into engineering and business curricula is proposed. Combining with the study result of table 1, a course entitled "Circular Economy and Campus Governance" could encompass topics such as campus-wide sustainability governance, carbon footprint accounting, and multi-stakeholder engagement, enabling students to formulate actionable circular economy strategies. Another course, "Circular Design Thinking and Green Building," could employ life cycle assessment (LCA) and building information modeling (BIM) to illustrate eco-design principles applicable to build environments and educational infrastructures. Additionally, a module focusing on "Circular Business Models and Investment Recovery" might examine green financing mechanisms, asset repurposing strategies, and waste valorization, offering students practical experience in assessing reuse pathways for campus equipment. This cross-sectoral pedagogical approach holds significant potential for cultivating a generation of graduates proficient in applied circular economy principles, thereby accelerating the integration of sustainability into mainstream practice. Moreover, collaborative frameworks between industry and academia warrant further scholarly inquiry to advance the transition toward circular and sustainable ecosystems within higher education institutions.

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