Multi-Objective Optimization for Sustainable Supply Chain and Logistics

Subjects: Operations Research & Management Science

Contributor: Chamari Jayarathna

There are several methods available for modeling sustainable supply chain and logistics (SSCL) issues. Multi-objective optimization (MOO) has been a widely used method in SSCL modeling (SSCLM), nonetheless selecting a suitable optimization technique and solution method is still of interest as model performance is highly dependent on decision-making variables of the model development process.

multi-objective optimization   sustainable supply chain   sustainable logistics

1. Introduction

Supply chain modeling has become more applied and feasible in supply chain management and logistics research as it facilitates decision-making to achieve various objectives, including economic, environmental, and social [1]. Traditional supply chain models have focused only on operational efficiency by reducing the total cost, lead time, defective items, unused capacity, and processing time [2][3][4], but novel supply chain models incorporate environmental and social objectives in addition to economic performance [5][6][7][8]. This phenomenon is evident by the growing research on sustainable supply chain and logistics modeling (SSCLM) [9][10]. SSCLM is aimed at optimizing economic, environmental, and social objectives simultaneously. SSCLM is a complex process as it involves diverse stakeholders from suppliers to customers for managing products and services accounting for economic, environmental, and social impacts [11]. This complexity becomes more emphasized when different phases of the supply chain (sourcing, manufacturing, warehousing, distribution, and transportation), different types of a supply chain (forward, reverse, and close loop), different levels of decision-making (strategic, tactical, and operational), and supply chain environment (certainty or uncertainty) are considered.

In this study, the authors explore the scholarly literature to identify the research gaps in multi-objective optimization (MOO) for SSCLM and to assist decision-makers in selecting suitable optimization techniques and solution methods based on various SSCL issues. Numerous review studies are currently available; however, they are limited to certain factors. Some have concentrated more broadly on operational research (OR) methods not specific to MOO [11][12] while others have focused on limited aspects of different sustainability dimensions [4][13] or have not considered decision levels and supply chain phases [14][15][16]. Further, most of these research efforts did not take uncertainty into account [17][18][19].

2. Recommendations

This study provided a review of 95 published papers in the field of MOO for SSCLM. The review aimed to identify the research gaps in MOO for SSCLM and to assist decision-makers in selecting suitable MOO methods and solutions in developing SSCLM. These purposes were achieved through different research questions covering sustainability dimensions, indicators, supply chain phases, decision levels, optimization techniques, solution methods, and uncertainty in SSCLM. The results revealed that the economic and environmental aspects of sustainability still dominate in the SSCLM, and they are limited to a few indicators. Sourcing, distribution, and transportation issues in the supply chain were not adequately addressed. Most of the models used classical methods of optimization of which the epsilon constraint (e-constraint) method is widely used and from metaheuristics methods, hybrid metaheuristics methods were highlighted. Less than 50% of the reference papers considered uncertainty in the models, and fuzzy programming was commonly used to address the uncertainty. There are several optimization techniques and solution methods available but selecting one of them depends on several factors such as the purpose of the decision-maker, nature of the problem, and availability of the data. This study has presented a comprehensive analysis of the MOO of SSCLM, and the results of the study significantly contributed to the development of the field of sustainable supply chain and logistics modeling. Specifically, the current study provided the research gaps in the MOO of SSCLM from sustainability dimensions, sustainability indicators, different supply chain phases, decision levels, optimization techniques, and solution methods. Accordingly, future researchers and decision-makers can use the following key considerations for their potential works in modeling sustainable supply chain and logistics issues.

- In the absence of broad indicators of sustainability assessment and limited focus on the social dimension, the authors suggest incorporating more social aspects and integrating economic, environmental, and social indicators into the future of SSCLM. For example, innovation can be considered as an economic indicator in addition to cost, quality, and delivery flexibility to maximize competitive advantage [20], which is one of the main economic objectives in supply chain modeling. As indicated in the GRI (Global Reporting Initiative) standard [21], indirect economic impact, anti-corruption, and anti-competitive behavior from economic aspects, the material used, biodiversity, supplier environmental assessment from environmental aspects, training and development, non-discrimination, human rights, and supplier social assessment from social aspects can be considered as sustainability indicators. Comprehensive economic, environmental, and social indicators proposed by [22] can also be used in SSCLM.

- To incorporate the sustainability indicators into the optimization models, quantification is a barrier. Direct and indirect economic benefits can be quantified using the cost of implementing green practices, cost savings of using reverse logistics practices, and return on environmental and social investment. Social impact can be quantified using factors, including the number of health and safety training, cost of health and safety training, average hours of training on anti-corruption policies and procedures, reported cases of corruption and bribery, employee happiness index, community satisfaction rate, and number of CSR initiatives. The use of comprehensive techniques, including LCA and S-LCA, for measuring environmental and social impact have more research potential in this case. The authors propose to combine social science research techniques, including surveys and case research, especially for social sustainability assessment in optimization models, to avoid its limitations and ensure data quality.

- More SSCLMs for sourcing, distribution and transportation phases of the supply chain are required. Of these phases, the transportation phase requires more focus on strategic decisions, for example, a decision to use electric vehicles to reduce Co2 emissions. The integration of all levels of decision with uncertainty factors to the model is also emphasized as a solution method to address uncertainty is limited to fuzzy programming. Incorporating more demand and supply-related uncertainty factors in a model can lead to exploring other solution methods, such as simulation, scenario and robust programming. Dividing the optimization model into different phases, including decision levels or supply chain phases, is recommended as it will help reduce problem space and the solution time. As all these considerations make optimization models more complex and larger, more sophisticated techniques and solution methods, the inclusion of hybrid metaheuristics approaches will be more useful in SSCLM. Furthermore, the authors propose the use of more hybrid and decomposed optimization methods that have direct implications for solving many real-world cases. Other OR methods, including simulation and system dynamics modeling, can also be applied and combined in future research, which facilitates decision-makers to acquire a more comprehensive picture of the sustainable supply chain and logistics issues.

References

1. Naidelage, C.; Agdas, D.; Rose, T.; Yigitcanlar, T. Stakeholder perception of reverse logistics practices on supply chain performance. Bus. Strategy Environ. 2020, 30, 60–70.
2. Zandieh, M.; Aslani, B. A hybrid MCDM approach for order distribution in a multiple-supplier supply chain: A case study. J. Ind. Inf. Integr. 2019, 16, 100104.
3. Liu, S.; Papageorgiou, L.G. Multi-objective optimization of production, distribution and capacity planning of global supply chains in the process industry. Omega 2013, 41, 369–382.
4. Dekker, R.; Bloemhof, J.; Mallidis, I. Operations Research for green logistics-An overview of aspects, issues, contributions and challenges. Eur. J. Oper. Res. 2012, 219, 671–679.
5. Darestani, S.A.; Hemmati, M. Robust optimization of a bi-objective closed-loop supply chain network for perishable goods considering queue system. Comput. Ind. Eng. 2019, 136, 277–292.
6. Mota, B.; Gomes, M.I.; Carvalho, A.; Barbosa-Povoa, A.P. Towards supply chain sustainability: Economic, environmental and social design and planning. J. Clean. Prod. 2015, 105, 14–27.
7. Jassim, S.; Al-Mubarak, M.; Hamdan, A. The Impact of Green Supply Chain Management on Firm’s Performance. J. Inf. Knowl. Manag. 2020, 19, 2040026.
8. Tukamuhabwa, B.; Mutebi, H.; Isabirye, D. Supplier performance in the public healthcare: Internal social capital, logistics capabilities and supply chain risk management capabilities as antecedents in a developing economy. J. Bus. Socio-Econ. Dev. 2021.

9. Nasr, K.A.; Tavana, M.; Alavi, B.; Mina, H. A novel fuzzy multi-objective circular supplier selection and order allocation model for sustainable closed-loop supply chains. J. Clean. Prod. 2020, 287, 124994.
10. Resat, H.G.; Unsal, B. A novel multi-objective optimization approach for sustainable supply chain: A case study in packaging industry. Sustain. Prod. Consum. 2019, 20, 29–39.
11. Barbosa-Póvoa, A.P.; da Silva, C.; Carvalho, A. Opportunities and challenges in sustainable supply chain: An operations research perspective. Eur. J. Oper. Res. 2018, 268, 399–431.
12. Banasik, A.; Bloemhof-Ruwaard, J.M.; Kanellopoulos, A.; Claassen, G.D.H.; van der Vorst, J.G.A.J. Multi-criteria decision-making approaches for green supply chains: A review. Flex. Serv. Manuf. J. 2018, 30, 366–396.
13. Crainic, T.G.; Perboli, G.; Rosano, M. Simulation of intermodal freight transportation systems: A taxonomy. Eur. J. Oper. Res. 2018, 270, 401–418.
14. Chen, L.; Zhao, X.; Tang, O.; Price, L.; Zhang, S.; Zhu, W. Supply chain collaboration for sustainability: A literature review and future research agenda. Int. J. Prod. Econ. 2017, 194, 73–87.
15. Ahi, P.; Searcy, C. An analysis of metrics used to measure performance in green and sustainable supply chains. J. Clean. Prod. 2015, 86, 360–377.
16. Brandenburg, M.; Govindan, K.; Sarkis, J.; Seuring, S. Quantitative models for sustainable supply chain management: Developments and directions. Eur. J. Oper. Res. 2014, 233, 299–312.
17. Rajeev, A.; Pati, R.K.; Padhi, S.S. Sustainable supply chain management in the chemical industry: Evolution, opportunities, and challenges. Resour. Conserv. Recycl. 2019, 149, 275–291.
18. Taticchi, P.; Garengo, P.; Nudurupati, S.S.; Tonelli, F.; Pasqualino, R. A review of decision-support tools and performance measurement and sustainable supply chain management. Int. J. Prod. Res. 2015, 53, 6473–6494.
19. Seuring, S. A review of modeling approaches for sustainable supply chain management. Decis. Support Syst. 2013, 54, 1513–1520.
20. Tukamuhabwa, B.; Mutebi, H.; Kyomuhendo, R. Competitive advantage in SMEs: Effect of supply chain management practices, logistics capabilities and logistics integration in a developing country. J. Bus. Socio-Econ. Dev. 2021.
21. GRI Standard. GRI 103 Management Approach. 2016. Available online: www.globalreporting.org/standards/download-the-standards/ (accessed on 30 November 2021).
22. Jayarathna, C.P.; Agdas, D.; Dawes, L.; Miska, M. Exploring sector-specific sustainability indicators: A content analysis of sustainability reports in the logistics sector. Eur. Bus. Review. 2021. ahead-of-print.