A review on sustainable metrics for Sustainability Measurement in Supply Chain

V H L Saputri1, M Hisjam2, and W Sutopo3

1 Master Program of Industrial Engineering, Faculty of Engineering, Universitas Sebelas Maret Surakarta, Indonesia.
2 Department of Industrial Engineering, Faculty of Engineering, Universitas Sebelas Maret Surakarta, Indonesia.

Email: hisjam@staff.uns.ac.id

Abstract: This research analyzes the performance measurement in sustainable supply chain using sustainable triple bottom line aspects, namely environmental dimension, social dimension, and economic dimension. The analysis process is accomplished for 40 articles, which are from Scopus website related to sustainable supply chain. The focus in analysis process is the sustainable dimension that has been used in the previous research. Furthermore, the other focuses are the analysis processes about the journal name, organizations that fulfill the performance measurement, the utilized approach, and the type of research. Then, in the final research, there will be explanation about the metric that is utilized to be a tool for performance measurement of sustainable supply chain in the organization.

1. Introduction

The sustainable supply chain management (SSCM) is a topic that is being discussed currently. The SSCM has been a cornerstone for every organization that is trying to achieve the continual goal. Now, it continually becomes a requirement from all of stakeholders, such as government, non-governmental organization, consumer, community activist, and global competition. The SSCM comes along with the increasing of concerns about the impacts of environment and social in supply chain, so that, all of related stakeholders forces the companies to minimize the negative impacts of their own supply chain system [1], [2]. The SSCM focuses on creating the three pillars of sustainable development that emphasize on social, economic, and environment study, namely Triple Bottom Line (TBL) [3].

A lot of research that related to SSCM has been accomplished in every aspect and perspective. Molamohamadi, Ismail, Leman, & Zulkifli [4] performed a research that integrated the sustainable concept in supply chain to create a SSCM framework. Bendul, Rosca, & Pivovarova [5] accomplished a research that connected the SSCM with the study of Pyramid Base to develop the integrated sustainable model perspective in sourcing, making and delivering area. Tajbakhsh and Hassini [6] evaluated the operation of supply chain that maximized the return of economic, minimized the impact of environment, and fulfilled the social expectation by using data envelopment analysis model. Barbosa-Póvoa, da Silva, & Carvalho [7] reviewed the SSCM research based on Operations Research (OR) perspective which the optimization model was applied in strategic level decisions by assessing the economic, the environment, and social aspect. Qorri, Mujkić, & Kraslawski [8] suggested the new conceptual framework and provided a short guidance to assess the SSCM by using multi-
criteria decisions making method. Moreover, there are some research that conducted for sustainable wooden furniture industry using goal programming [9], [10], [11], [12], simulation [13], [14], and fuzzy Chance Constrained Model (CCM) [15].

A lot of SSCM research shows that SSCM has become a concern for many parties in the era of global competition today. For facing the global competition, the company needs to improve the competitive advantage. One of ways that can be used is by measuring and managing the sustainable performance of the company’s supply chain effectively and efficiently [16]. Measuring and improving the company’s performance certainly need a development of the supply chain performance measurement system. Performance metric and measurement tool/method are integral part of system. Finally, it is important to analyze the performance measurement approach that can help the manager to focus on the main decision that is related to the company’s SSCM [17].

Given the importance of measuring the SSCM’s performance, this research is aimed to find out and summarize the approach and metric that is used for performance measurement of the company’s supply chain that is related to “the sustainable” issue. Hereafter, the methodology that is applied in this research will be explained in the Chapter 2. Then, the understanding of existing SSCM literature and the detailed analysis of metric that is used in SSCM will be revealed in the Chapter 3. Lastly, the conclusion of the entire research, include the scope and the boundary of SSCM research study in the future will be explained in the Chapter 4.

2 Methodology

The method that was used in this study was by studying of the literature on the related research which discussed about SSCM. The literature study was conducted on five methodological steps from Tranfield et al. [18] as illustrated on Figure 1. The related articles was browsed on Scopus Website (www.scopus.com) that was one of the biggest database to examine and view trends of the related research over time.

The collecting data process was started by browsing documents/articles on Scopus database through the search field of title, abstract, and keyword using the search string as follows:

(“sustainable” OR “sustainability” OR “green”) AND (“environmental” OR “social”) AND “supply chain” AND “performance” AND (“management” OR “measurement” OR “assessment” OR “evaluation”) AND (“framework” OR “system” OR “method” OR “tool” OR “concept” OR “standard”) AND (“metric” OR “metrics”)

The article search process was only done for the articles that were published on Scopus from time range January 1, 2000 to June 20, 2018. As for the document type which was used was the journal articles that published in English, the other journal articles were not reviewed. The collecting data process was continued by reading the abstract of every article. The illustration of the article search process was presented on Figure 2. Based on the search, it could be
recognized that there were 40 related article documents from Scopus. Then from those articles, it could be done the dimension analysis of Triple Bottom Line (TBL) that related to the sustainable and the performance measurement in supply chain.

![Fig. 2 The article search process](image)

3 Results and Discussions

3.1 Descriptive Analysis

The research study on SSCM performance measurement tends to increase every year. It can be proved based on the search result on Scopus that is illustrated on Figure 3 which shows that the research study on SSCM has increased in the last 5 years.

![Fig. 3 Distribution of the number of research study by published year (n=40)](image)

Those research studies have been scattered in several journals, as illustrated in Figure 4 which shows the top 10 of journal names. The most widely published journal about SSCM is Journal of Cleaner Production. Furthermore, there are several other journal names such as Energy Conversion and Management, Environmental Science and Technology, International Journal of Global Energy Issues, International Journal of Logistics Management, etc. They have at least one published article about SSCM.

![Fig. 4 Distribution of the number of research study by journal name](image)
The articles that fit the criteria, which are articles that discuss about Sustainable Supply Chain Management (SSCM) are analyzed based on the industries studied, sustainable dimension, approach method for problem solving, and type of data processing that is used. The result of data analysis is showed in Figure 5, 6, 7 and 8.

![Fig. 5 Distribution of the number of research study by industries studied](image1)

The five industries that are used as the research object in SSCM is manufacturing [19], [20], [21], energy [22], [23], [24], automotive/electronic [25], [26], [27], food/agriculture [28], [29], [30], and water industry [31], [32], [33].

The dimension of sustainability measured that is including the dimension of the environment [34], [35], [36], social [37], economy [38], as well as its third integration about TBL [39], [40], [41]. From the result, can be seen that the dimensions of the many studied are the environment. It is in accordance with the discussion of SSCM and GSCM which further highlight the environmental dimension in every aspect of sustainability.

![Fig. 6 Distribution of the number of research study by used sustainable dimension](image2)

In addition, five problem solving approaches that are widely used in research study include performance measurement frameworks [42], [43], LCA [44], [45], AHP [46], [47], MCDM [48], NSGA-II [49], [50], TOPSIS [51], and behavior-based [29], [38]. Then, for the type of research is mostly done by way of survey. In addition, there are other ways that can be done such as the formulation of mathematical models, literature reviews, case studies, and conceptual frameworks of a study of SSCM.
3.2 Sustainable metrics

The sustainability considers three dimensions or aspects, namely economic, social, and environmental or often termed a triple bottom line. For measuring the performance of sustainability in the supply chain, it can use sustainability metric. Where the metric can be categorized based on each aspect in the dimension of sustainability. Based on the literature which has been analyzed can be made a metric that can be used to measure the performance of a sustainable supply chain of an organization. The proposed metric is presented in Table 1.
Table 1. The Sustainability Metric

| Dimension   | The Sustainability Metric |
|-------------|----------------------------|
| Environmental | Nature resources, solid waste, air emission and water, transportation modes and transportation distance, global warming, biodiversity, acid deposition, landscape, ultimate waste disposal, product recycling ability, restoration of forest and ecosystems, minimization of deforestation, conservation of primary forest, use of GMOs, use of chemicals, pest control, and fertilizer |
| Social     | Employment, salary, labour intensiveness or productivity, accident, risk, noise, welfare, education, resources, personal rotation rate, health and safety, human rights, legality verification, raw material/food security |
| Economical | Value added, output production, turnover, resources used as input, profitability, competitiveness, market shares, product durability, research and development efforts, business viability, economic stability, benefits sharing |

Fig. 9 The Framework for Sustainability Measurement of Supply Chain

Involved organizations in measuring sustainability performance of the supply chain may include governments, non-governmental organizations, corporations, media, research institutes, as well as the other parties that involved in decision-making related to the sustainability of an industry. The relevant parties can measure the sustainability performance based on metrics that are appropriate to the industry to be assessed. The approaches that can be used to perform the measurement namely, Life Cycle Assessment (LCA), Analytical Hierarchy Process (AHP), Multi Criteria Decision Making (MCDM), Non-dominated Sorting Genetic Algorithm (NSGA), TOPSIS, Behavior-based, Supply Chain Operations Reference (SCOR), Data Envelopment Analysis (DEA), Structural Equation Model (SEM), Fuzzy-based, and Multi-objective Optimization.

After measuring the performance of sustainability, the involved parties can perform a monitoring and standard setting mechanism, so that, the sustainability carried out by an industry can be monitored. The mechanism may include the application of the complaint procedure, trademark protection, label, assessment result publication, regular 3rd party assessment, 3rd party certification and accreditation processes. From all those processes can then be described a performance measurement framework of the supply chain as in Figure 9.

4. Conclusion

The review process of the previous literature has been done by analyzing based on the published year, the journal name, the used sustainable dimension, the industries that performs the performance measurement process, and the approach used in conducting the research. Then based on the results of the analysis, can be made a framework that can be used to measure the
performance of supply chain sustainability in an industry. Where the framework describes the involved organization, the dimensions and sub-dimensions of sustainability that can be used, the approach that can be used as a method of performance measurement, as well as monitoring mechanism and standard measurement of the process of measuring the performance of the sustainable supply chain.

Acknowledgements

The research is supported by Institute for Research and Community Service, Sebelas Maret University with Hibah Penelitian Mandatory UNS (PM-UNS) Research Program (Contract No. 543/UN27.21/PP/2018).

References

[1] Delai, I. and Takahashi, S.: “Sustainability measurement system: A reference model proposal,” Soc. Responsib. J., Vol. 7, pp. 438-471 (2011)
[2] Hassini, E., Surti, C., and Searcy, C.: “A literature review and a case study of sustainable supply chains with a focus on metrics,” Int. J. Prod. Econ., Vol. 140, pp. 69-82 (2012)
[3] Joyce, A. and Paquin, R. L.: “The triple layered business model canvas: A tool to design more sustainable business models,” Journal of Cleaner Production, Vol. 135, pp. 1474-1486 (2016)
[4] Molamohamadi, Z., Ismail, N., Leman, Z., and Norzima, Z.: “Developing a framework for sustainable supply chain management,” Applied Mechanics and Materials, Vol. 564, pp. 661-666 (2014)
[5] Bendul, J. C., Rosca, E., and Pivovarova, D.: “Sustainable supply chain models for base of the pyramid,” Journal of Cleaner Production, Vol. 160, pp. S170-S120 (2017)
[6] Tajbakhsh, A. and Hassini, E.: “A data envelopment analysis approach to evaluate sustainability in supply chain networks,” Journal of Cleaner Production, Vol. 105, pp. 74-85 (2015)
[7] Barbosa-Póvoa, A. P., da Silva, C. and Carvalho, A.: “Opportunities and challenges in sustainable supply chain: An operations research perspective,” European Journal of Operational Research, Vol. 268, No. 2, pp. 399-431 (2018)
[8] Qorri, A., Mujkić, Z. and Kraslawski, A.: A conceptual framework for measuring sustainability performance of supply chains,” Journal of Cleaner Production, Vol. 189, pp. 570-584 (2018)
[9] Habibie, A., Hisjam, M., Sutopo, W., and Widodo, K.H.: “A relationship model between supplier and manufacturer for securing availability of teak log in export oriented furniture industry with sustainability considerations,” Lecture Notes in Engineering and Computer Science Proceedings, pp. 1292-1297 (2012)
[10] Devi, R.A., Hisjam, M., Sutopo, W., and Widodo K.H.: “A relationship model between manufacturer and buyer for order fulfillment in export oriented furniture industry with sustainability considerations,” Lecture Notes in Engineering and Computer Science Proceedings, pp. 1407-1411 (2012)
[11] Hisjam, M., Habibie, A., Sutopo, W., and Widodo K.H.: “A supplier-manufacturer model for procurement plan in export oriented furniture industry with sustainability considerations,” Lecture Notes in Electrical Engineering Proceedings, pp. 247-260 (2013)
[12] Hisjam, M., Sutopo, W., Devi, R.A., and Widodo K.H.: “A manufacturer-buyer relationship model in export oriented furniture industry with sustainability considerations,” Proceedings - Joint International Conference on Electric Vehicular Technology and Industrial, Mechanical, Electrical and Chemical Engineering, ICEVT 2015 and IMECE 2015, pp. 298-303 (2015)
[13] Putri, D.N.E., Hisjam, M., Sutopo, W., and Widodo, K.H.: “Simulation of supplier-manufacturer relationship model for securing availability of teak log in furniture industry with sustainability consideration,” IEEE International Conference on Industrial Engineering and Engineering Management Proceedings, pp. 367-371 (2014)
[14] Herjuna, S.A.S., Hisjam, M., Putri, D.N.E., Sutopo, W., and Widodo K.H.: “A decision support application for teak log supplier to simulate scenarios of utilizing forest resources by considering the sustainability of teak log supply,” Lecture Notes in Engineering and Computer Science Proceedings, pp. 938-941 (2015)
[15] Kurniawan, B., Hisjam, M., and Sutopo, W.: “Integration of production and supply chain strategic planning for renewable resources under sustainability considerations: Teakwood case study,” IEEE International Conference on Industrial Engineering and Engineering Management Proceedings, pp. 433-437 (2011)
[16] Shepherd, C. and Günter, H.: “Measuring supply chain performance: current research and future directions,” Int. J. Product. Perform. Manag., Vol. 55, pp. 242-258 (2006)
[17] Bai, C. and Sarkis, J.: “Determining and applying sustainable supplier key performance indicators,” Supply Chain Manag. An Int. J., Vol. 19, pp. 275-291 (2014)
[18] Tranfield, D., Denyer, D. and Smart, P.: “Towards a methodology for developing evidence-informed management knowledge by means of systematic review,” Br. J. Manag., Vol. 14, pp. 207-222 (2003)
[19] Alsaffar, A. J., Raoufi, K., Kim, K. Y., Kremer, G. E. O., and Haapala, K. R.: “Simultaneous consideration of unit manufacturing processes and supply chain activities for reduction of product environmental and social impacts,” Journal of Manufacturing Science and Engineering, Transactions of the ASME, Vol. 138, No.10 (2016)
[20] Entezaminia, A., Heydari, M., and Rahmani, D.: “A multi-objective model for multi-product multi-site aggregate production planning in a green supply chain: Considering collection and recycling centers,” Journal of Manufacturing Systems, Vol. 40, pp. 63-75 (2016)
[21] Egilmez, G., Kucukvar, M., and Park, Y. S.: “Supply chain-linked sustainability assessment of the US manufacturing: An ecosystem perspective,” Sustainable Production and Consumption, Vol. 5, pp. 65-81 (2016)
[22] Garofalo, P., Campi, P., Vonella, A. V., and Mastorrelli, M.: “Application of multi-metric analysis for the evaluation of energy performance and energy use efficiency of sweet sorghum in the bioethanol supply-chain: A fuzzy-based expert system approach,” Applied Energy, Vol. 220, pp.313-324 (2018)
[23] Sluka, C. and Peck, P.C.: “Stakeholder dynamics in the EU forest energy sector: Key issues to manage and ways forward,” Biofuels, Bioproducts, and Biorefining, Vol. 9, No. 1, pp. 51-71 (2015)
[24] Halog, A.: “Models for evaluating energy, environmental and sustainability performance of biofuels value chain,” International Journal of Global Energy Issues, Vol. 32, pp.83-101 (2009)
[25] Schoggl, J. P., Fritz, M.M.C., and Baumgartner, R. J.: “Toward supply chain-wide sustainability assessment: A conceptual framework and an aggregation method to assess supply chain performance,” Journal of Cleaner Production, Vol. 131, pp. 822-835 (2016)
[26] Sahu, N. K., Datta, S., and Mahapatra, S. S.: “Green supplier appraisement in fuzzy environment,” Benchmarking, Vol. 21, No. 3, pp. 412-429 (2014)
[27] Olugu, E. U., Wong, K. Y., and Shaharoun, A.M.: “Development of key performance measures for the automobile green supply chain,” Resources, Conservation and Recycling, Vol. 55, No. 6, pp. 567-579 (2011)
[28] Mohammed, A., Setchi, R., Filip, M., Harris, I., and Li, X.: “An integrated methodology for a sustainable two-stage supplier selection and order allocation problem,” Journal of Cleaner Production, Vol. 192, pp. 99-114 (2018)
[29] Lengnick, L., Miller, M., and Marten, G.G.: “Metropolitan foodsheds: a resilient response to the climate change challenge?,” Journal of Environmental Studies and Sciences, Vol. 5, No. 4, pp. 573-592 (2015)
[30] Cao, L., Diana, J. S., Keoleian, G.A., and Lai, Q.: “Life cycle assessment of Chinese shrimp farming systems targeted for export and domestic sales,” Environmental Science and Technology, Vol. 45, No. 15, pp. 6531-6538 (2011)
[31] Balfaqih, H., Nopiah, Z. M., Al-Nory, M. T., and Saibani, N.: “Sustainable framework for water desalination supply chain: Delphi-AHP technique,” Advanced Science Letters, Vol. 23, No. 5, pp. 4721-4724 (2017)
[32] Hoekstra, A.Y.: “A critique on the water-scarcity weighted water footprint in LCA,” Ecological Indicators, Vol. 66, pp. 564-573 (2016)
[33] Huysveld, S., Schaubroeck, T., De Meester, S., Sorgeloos, P., Van Langenhove, H., Van Linden, V., and Dewulf, J.: “Resource use analysis of Pangasius aquaculture in the Mekong Delta in Vietnam using Exergetic Life Cycle Assessment,” Journal of Cleaner Production, Vol. 51, pp. 225-233 (2013)
[34] Tuni, A., Rentizelas, A., and Duffy, A.: “Environmental performance measurement for green supply chains: A systematic analysis and review of quantitative methods,” International Journal of Physical Distribution and Logistics Management, doi:10.1108/IJPDLM-02-2017-0062 (2018)
[35] Aymard, V. and Botta-Genoulaz, V.: “Normalisation in life-cycle assessment: consequences of new European factors on decision-making,” Supply Chain Forum, Vol. 18, No. 2, pp. 76-83 (2017)
[36] Raoufi, K., Haapala, K.R., Jackson, K.L., Kim, K.-Y., Kremer, G.E.O., and Psenka, C.E.: “Enabling non-expert Sustainable Manufacturing Process and Supply Chain Analysis During the Early Product Design Phase,” Procedia Manufacturing, Vol. 10, pp. 1097-1108 (2017)
[37] Alsaffar, A. J., Raoufi, K., Kim, K. Y., Kremer, G. E. O., and Haapala, K. R.: “Simultaneous consideration of unit manufacturing processes and supply chain activities for reduction of product environmental and social impacts,” Journal of Manufacturing Science and Engineering, Transactions of the ASME, Vol. 138, No. 10, doi:10.1115/1.4034481 (2016)

[38] Kirchoff, J.F., Omar, A., and Fugate, B.S.: A “Behavioral Theory of Sustainable Supply Chain Management Decision Making in non-exemplar Firms,” Journal of Supply Chain Management, Vol. 52, No. 1, pp. 41-65 (2016)

[39] Laguna-Salvado, L., Lauras, M., Okongwu, U., and Comes, T.: “A multicriteria Master Planning DSS for a sustainable humanitarian supply chain,” Annals of Operations Research, pp. 1-41 (2018)

[40] Gong, M., Simpson, A., Koh, L., and Tan, K.H.: “Inside out: The interrelationships of sustainable performance metrics and its effect on business decision making: Theory and practice,” Resources, Conservation and Recycling, Vol. 128, pp. 155-166 (2018)

[41] Abidi, N., Bandyopadhayay, A., and Gupta, V.: “Sustainable supply chain management: A three dimensional framework and performance metric for Indian IT product companies,” International Journal of Information Systems and Supply Chain Management, Vol. 10, No. 1, pp. 29-52 (2017)

[42] Ahi, P. and Searcy, C.: “An analysis of metrics used to measure performance in green and sustainable supply chains,” Journal of Cleaner Production, Vol. 86, pp. 360-377 (2015)

[43] Halog, A. and Manik, Y.: “Advancing integrated systems modelling framework for life cycle sustainability assessment,” Sustainability, Vol. 3, No. 2, pp. 469-499 (2011)

[44] Huysveld, S., Schaubroeck, T., De Meester, S., Sorgeloos, P., Van Langenhove, H., Van Linden, V., and Dewulf, J.: “Resource use analysis of Pangasius aquaculture in the Mekong Delta in Vietnam using Exergetic Life Cycle Assessment,” Journal of Cleaner Production, Vol. 51, pp. 225-233 (2013)

[45] Neupane, B., Halog, A., and Lilieholm, R.J.: “Environmental sustainability of wood-derived ethanol: A life cycle evaluation of resource intensity and emissions in Maine, USA,” Journal of Cleaner Production, Vol. 192, pp. 99-114 (2018)

[46] Entezaminia, A., Heydari, M., and Rahmani, D.: “A multi-objective model for multi-product multi-site aggregate production planning in a green supply chain: Considering collection and recycling centers,” Journal of Manufacturing Systems, Vol. 40, pp. 63-75 (2016)

[47] Mansoornejad, B., Pistikopoulos, E.N., and Stuart, P.: “Metrics for evaluating the forest biorefinery supply chain performance,” Computers and Chemical Engineering, Vol. 54, pp. 125-139 (2013)

[48] Rabbani, M., Navazi, F., Farrokh-Asl, H., and Balali, M.H.: “A sustainable transportation-location-routing problem with soft time windows for distribution systems,” Uncertain Supply Chain Management, Vol. 6, No. 3, pp. 229-254 (2018)

[49] Moslemi, S., Zavvar Sabegh, M.H., Mirzazadeh, A., Ozturkoglu, Y., and Maass, E.: “A multi-objective model for multi-production and multi-echelon closed-loop pharmaceutical supply chain considering quality concepts: NSGAI approach,” International Journal of Systems Assurance Engineering and Management, Vol. 8, pp. 1717-1733 (2017)

[50] Sahu, N. K., Datta, S., and Mahapatra, S. S.: “Green supplier appraisement in fuzzy environment,” Benchmarking, Vol. 21, No. 3, pp. 412-429 (2014)