Evaluation of Mathematical Models in Sustainable Supply Chain Management: Gap Analysis

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Received: July 20, 2021 Accepted: August 23, 2021 Online Published: August 31, 2021
doi:10.5539/ibr.v14n10p25 URL: https://doi.org/10.5539/ibr.v14n10p25

Abstract
The main purpose of this paper is to present a comprehensive view of the application mathematical models in the designing and implementing SSCM beside to solving problems and making decision. The research questions are: what kind of mathematical models are used for designing and implementing sustainable supply chain management, how to use them, which industries implemented in, what modules of SSCM depth in and finally finding the gaps between the goals of Sustainable development and current researches and suggestions for further researches.

The methodology of the research is Systematic Literature review and evaluation peer review papers which are published in high ranking journals: First, we gather all papers through scientific data bases like Scopus, science direct, MDPI, Springer, Google Scholar. Then, screening papers based on the criteria such as object of paper, subject of paper, journals impact factor, peer review paper, and relative content of the papers. Finally, we selected 245 papers through three steps screening from 2806 papers that they have enough quality and relative to our research goals for context analysis.

For context analysis: First we categorize the information of the papers and draw the current situation of researches in the framework of our topic. Then, we evaluate and compare the goals of sustainability and current situation and find the gaps, then, offer suggestions required researches for pollutant industries such as Casting Industry, Heavy Industry, Coal Industry and so on. On the other hand, there are gaps in researches in some modules of SSCM such as packaging, designing products, etc.

Keywords: SSCM, mathematical model, systematic literature review, SSCM modules, sustainable development goals, gap analysis

List of acronyms
2E-LRP: 2(Two) Echelon Location Routing Problem
ACO: Ant Colony Optimization
AHP: Analytic Hierarchy Process
AI: Artificial Intelligence
AMOVNS: Adapted Multi Objective Variable Neighborhood Search
ANOVA: one-way statistical analysis
ANP Technique: Analytic Network Process Technique
ANP: Analytic Network Process
BMW: Best Worst Method
BOP: Base Of the Pyramid
CI: Composite Indicator
CLSC: Closed Loop Supply Chain
CSF: Critical Success Factor
CSR: Corporate Social Responsibility
CSS: Corporate Sustainability Standard
DC: Dynamic Capabilities
DEA: Data Envelope Analysis
DEMATEL: DEcision-MAking Trial and Evaluation Laboratory
DMUs: Decision Making Units
EFP: Environmental Friendly Products
ELECTRE: ELimination Et Choix Traduisant la REalité
EOQ: Economic Order Quantity
EPQ: Economic Production Quantity
ERM: Enhanced Russell Measure
EUFP: existing environmental unfriendly product
EWH: European Waste Hierarchy
FIS: Fuzzy Inference System
FMEA: Failure Mode and Effects Analysis
FSSD: Framework for Strategic Sustainable Development
GA: Genetic Algorithm
GLM: Green Logistic Management
GRI: Global Reporting Initiative
GSCM: Green Supply Chain Management
GVC: Global Value Chain
IE: Industrial Ecology
IFS: Intuitionistic Fuzzy System
IS: Industrial Symbiosis
ISM: Interpretive Structural Modeling
KPI: Key Performance Indicators (KPIs)
LCA: Life Cycle Assessment
LCIA: Life Cycle Inventory Assessment
LRPTW: Location Routing Problems with Time Windows
LSP: Leader Selection Procedure
MCDM: Multiple-Criteria Decision-Making
MHPV: Multi-objective Hybrid Metaheuristic Algorithm
MILP: Mixed Integer Linear Programming
MINLP: Mixed Integer Non Linear Program
MLH: maximum likelihood estimation
MOGA: Multi-Objective Genetic Algorithm
MOMIP: Multi Objective Mixed-Integer Programming
MOOP: Multi Objective Optimization Problem
MOPSO: Main Loop Particle Swarm Optimization
MOPSO: Multi Objective Particle Swarm Optimization
MP: Mathematical Programming
MRIO: Multi-Region Input-Output
NGO: Non-Government Organization
NIS: Negative Ideal Solution
NRGA: Non-dominated Ranked Genetic Algorithm
NSERC: Natural Science and Engineering Research Council
NSGAII: Non-dominated Sorting Genetic Algorithm II
OEM: Original Equipment Manufacturer
PIS: Positive Ideal Solution
QFD: Quality Function Developed
RDT: Resource Dependence Theory
RFID: Radio Frequency Identification Technology
SA: Simulated Annealing
SCM: Supply Chain Management
SCND: Supply Chain Network Design
SEM: Structural Equation Modeling
SMP: Sustainable Manufacturing Practice
SNSF: Swiss National Science Foundation
SPL: Sustainable Production Line
SS: Scatter Search
SSCM: Sustainable Supply Chain Management
SSHRC: Social Science and Humanities Research Council
SWOT: Strength, Weakness, Opportunity and Threat
TBL: Triple Bottom Line
TFN: Triangular Fuzzy Number
TOPSIS: Technique for Order of Preference by Similarity to Ideal Solution
TS: Tabu Search
TSP Model: Two Stage Programming Model
VIKOR: ViseKriterijuska Optimizacija I Komoromisno Resenje
VRP: Vehicle Routing Problems
WCED: World Commission on Environment and Development

1. Introduction

SSCM refers to implementing all sustainable goals via Triple Bottom Line which are economic, environmental and social dimensions. In parallel, SSCM define as management of information, capital, and materials through cooperation and collaboration of Supply chain partners, stakeholders, customers, and people (Seuring and Müller 2008). In two last decades the numbers of scholars and academic researchers made different conceptual and mathematical models for SSCM and used a several of tools for decision makings. Some papers evaluated sustainability in the wide range of supply chain referred by the area of research like development and developing countries and made some mathematical models, rules or new suggestions for developing countries (Sánchez-Flores, et al. 2020); (Ali, Yufeng and Glyn, Sustainable supply chain management in emerging economies: Trade-offs between environmental and cost performance 2016); (Köksal and Müller 2018); (Jia, et al. 2018). Because of rapid changing in environmental conditions and a number of alarming for warming world and environment protection, recently, the scholars and researchers take more attention on environment dimension of sustainability and green sustainable supply chain management (Kannan, Jabbour and Jabbour 2014); (Fang, Wang and Song 2020); (Rinib 2015); (Agi and Hazır 2020). Unfortunately, the social aspect in majority of papers underrepresented in comparison with economic and environmental factors (Martins and Pato 2019). In addition, Governments and new policies set some rules for carbon cap and emission carbon for factories, suppliers and
logistics companies (Zhang and Yixiang 2017). Although, there are some suggestions to governments to define subsidies for environmental friendly products in order to controlling pollution and carbon cap (Li, Chen and Hou 2018).

Through literature review, we found that papers present different kind of literature review and state of art for SSCM such as: offering various tools and methods for SSCM performance measurement (Tundys and TomaszWi´sniewski, The Selected Method and Tools for Performance Measurement in the Green Supply Chain—Survey Analysis in Poland 2018); (Ahi and Searcy 2015); analysis evolution SSCM trends across industries and economics (Rajeev, et al. 2017); evaluation different opportunities and challenges for designing and implementing SSCM (Barbosa-Póvoa, Silva and Carvalho 2018); (A, Pati and Padhi 2019); Mathematical and measurement tools for organization performance (Ansari and Kant 2017), evaluated the concept and thematic scope in theoretical point of view and in relation to its practical implementation (Tundys, Sustainable Supply Chain Management – Past, Present and future 2020), the role of governments for renewable energy usage (Cucchiella and D’Adamo 2013), Using cleaner Production method for large energy intensive industries (G. and Nagesha 2018), Applying and implementing triple bottom line in SSCM (Rashidi, et al. 2020); (Matos, et al. 2018) and the ways for quantitative social impacts (Messmann, et al. 2020).

In this paper, we evaluate different mathematical models which are used in SSCM in order to decision support system, design and modeling, implementing, development, Environmental protection and social responsibility. First we define the sources of recently researches from 2008 to now, then we find proper papers and analysis the current researches which are related to our subjects. After that, we define a target for achievement to an ideal SSCM structure with use of 2021 Sustainable Development Goals (United Nation 2015). Finally, we compare the current situation and Target, the results of comparison are shown the gaps.

2. Materials and Methods

In this paper, we use different researches, papers, protocoles and manifests which are related to Sustainability, SSCM and future plan of the world. As it shows in Figure (1), we use a systematically paper review and gap analysis in our research.

First: choosing valid data bases: Scopus, Science Direct, Emerald, Springer, Taylor & Francis, JSTORE, Wiley Online library, SAGE Publication.

Second: searching and gathering papers through the key words which are “SSCM” + “Mathematic”, “Sustainability Supply Chain Management” + “math”, “SSCM” + “Model”, “Sustainability” + “Supply chain” + “math”. In this step, the number of papers with mentioned key words are 2806. Also, Only papers written in English considered and, The range of data was the year from 2008 to May 2021.

Figure 1. The flow chart of the Research Methodology

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Third: Screening papers in three steps;

- Step one of screening is to evaluate the valid journals with criteria like peer review, ranking and index; After finishing first screening, the number of papers are 791. These papers are published in peer review, high index journals.
- Step two of screening is to evaluate the topic and abstract of journals; After finishing the second screening, the number of papers are 382. These papers are selected based on the relevant topic and abstract to the objectives of paper and research questions.
- Step Three of Screening is to use the systematically content analysis for selecting relevant papers. After final selection and content analysis, the number of papers are 245 which are published in international, peer review and high index journals, have relevant topic, abstract, keyword and content with the research objectives and questions.

Forth: defining the target for SSCM according to 2021 Sustainabile Development Goals (United Nation 2015). Based on Sustainable Development Goals, Goals numbers 9 and 12 is related to our topic. For every module of SSCM and partners we define the Target for research.

Fifth: with using gap analysis, find the gaps in several categories like Industries, module of SCM and responsibilities of different partners.

3. Review and Results

For review and analysis selected papers, we categorized selected papers in four categories. Every categories, first the existing situation of papers and researches are presented, then evaluate and analysis the gaps.

- Category one: overall information like as Year of published, Journals, Country of first author, Industrial, Dimension of SSCM;
- Category two: SSCM modules that the papers depth in;
- Category Three: Mathematical models and methods which are used for SSCM;
- Category Four: The roles of parties in SSCM modeling.

After reviewing and analysis the papers and categorizing in four main categories, the existing situation of recently researches is recognized. These categories present the current situation of researches of mathematical models which are used for SSCM. For gap analysis and propose new idea, the depth of information in this step is very important. Then, we analysis the papers in different point of view.

3.1. Category One: Overall Information

This Category analysis the overall information of the papers like year, journals, country, Industrial and dimension of SSCM. The figure 2 shows the distribution of papers between 2008-End of March 2021 and presents the numbers of papers which are published in every year.

![Figure 2. Distribution of published papers per year from 2018 to the end of March 2021](image)

The curve (Figure 2) presents that the quantity of papers increases every year from 2012 to 2017. As clearly seen in figure 2, the quantity of papers in 2017, 2018 and 2019 are near together and after that in 2020, the quantity is increased. Overall, it means that there are enough interests for researchers to do research on applications of
mathematical methods and using different tools and methods for modeling and solving problems in the field of sustainability and SCM.

The Figure 3 shows the distribution of journals which published more than two relative papers.

As clearly seen in the figure 3, the cleaner production Journal has the most quantity of papers in the territory of our research by 85 papers. After that the sustainability Journal is the second journal which published relative papers by 27. The 51 journals published only one paper related to the research scope.

The Figure 4 shows the numbers of published papers per country of author. The papers which have several authors from several countries, only the country of first authors are considered.

The most papers are published by authors from china by 38 papers. As it is clear, china pollution is very serious and because of that there is a big effort from Chinese government side for finding solutions. After china, India, Iran and Germany are 28, 23, and 18 papers respectively.
Figure 5 presents the mathematical models which are implemented in industries as case study. This statistics help us to find gaps in the industries that there is no research for them. Although, we can use the existing research for development.

![Figure 5. The number of papers for each Industry](image)

The researches had more attention on food industry and maximum papers and case studies are related to Food industry by 24 papers. Then the papers in the field of Textile, Services, Logistics, Electrical, Chemical and oil and Gas industries are 16, 15, 15, 11, 9, and 9 respectively. The different is refer to the other papers which are concentrated in several industry or case study or services.

Figure 6 presents the quantity of each papers which are distinguished in every dimensions of SSCM: Social, Economic and environmental.

![Figure 6. The quantity of papers per SSCM Dimensions](image)

Figure 6 illustrate the number of papers for dimensions of sustainability which are social, environmental and economic in SCM modeling. The most striking feature of the picture seems to the environmental dimension is more interesting in the researches. However, the social dimension is needed to be research more.

3.2 Category Two: Modules of SSC and Papers for Every Category

First of all, the modules of SSCM are defined. For defining SSCM Modules, we defined level one of process of SSCM in two kind of process: Main Process and Supporting process. The main process are the process to involve
for producing the products and delivery to customers and recycling the products for protecting environment. The supporting process are the process which are needed for the best services to customers and social responsibility or needed for better performance in main process. The main and supporting process devided to modules. The figure 7 shows the modules of SSCM modeling that it presents level two of process.

![Figure 7. The modules of SSCM](image)

As it can clearly seen in figure 7, The modules of main process are SD, SM, SS, SP, SPL, SPK, SL, and SR. And modules for supporting process are FS, SMA, and ST. For supporting process and modules, we define sub-modules as show in Figure 7.

For every modules, we have some papers which are depth in. Figure 8 shows the number of papers for every modules of SSCM. The big amount of papers are focused on model FS which are related to Structure, Frame work, Management, Standards, Rules and conditions, planning and organization for SSCM modeling.

![Figure 8. The number of papers for every modules](image)
The figure 8 indicates the number of papers which are depth in every modules of SSCM. The most notable feature of the graph concerns the less research on some important modules like SM, SPK and SP. These pile represents the gap of researches clearly.

3.3 Category Three: Mathematical Models and methods Which Are Used for SSCM

![Figure 9. The chart of mathematical models for SSCM](image)

The figure 9 represents the mathematical tools and models which are used for making SSCM modeling. As a general overview, it can be said that the Fuzzy theory is a useful mathematical method for making models and solving problems in SSCM models. Fuzzy theory is used as a single method for solving problem or combine with other mathematical models for making SSCM models. After that, the multi objective programming is the second mathematical model which is used for SSCM. One of the main reason of used multi objective programming is thriple bottom line in SSCM and need to offer the optimum solutions for supporting decision making.

Table 1 shows the authors who have more researchs and papers for using mathematical models and methods in SSCM modeling and problem solving. As it can clearly seen, they also used fuzzy theory with combination of other methods, Multi-Objective Programming as a mathematical methods and models in their papers more than other methods. Although, Supplier Selection module and Framework of Sustainable SCM are more interesting for authors and they focused on these two modules more than others.

Table 1 shows the authors who have more than one research in the fireld of application mathematical models for SSCM modeling, solving problems and decision suport system. Prof. Kannan Govindan, Prof. Devika Kannan, and Prof. Stefan Seuring have the more researches in this field.

| Rank | Authors       | As First Author | As Co-Author | Models which are used | Module | Ref.                                                                 |
|------|---------------|-----------------|--------------|-----------------------|--------|----------------------------------------------------------------------|
| 1    | Huiping Ding  | 4               | -            | Multi-Objective Programming | SS, SPL, FS | (Huiping, Wang and Zheng 2018); (Huiping, Liu and Zheng, Assessing the economic performance of an environmental sustainable supply chain in reducing environmental externalities 2016); (Ding, QilanZhao, et al. n.d.); |
As it is clearly seen in Table 1, the modules that the authors interested in are SS and FS, which are supplier selection and Framework Structure for SSCM.

Table 2 presents the mathematical models, methods and tools which are used for SSCM, the number of papers and references of them.
### Table 2. The papers for every mathematical models which are used in SSCM modeling

| Raw | Mathematical methods and models | Numbers of papers | Ref. |
|-----|--------------------------------|-------------------|------|
| 1   | AHP                            | 17                | (Awasthi, Govindan and Gold 2018); (Azimifard, Moosavirad and Ariaifar 2018); (Gulyeyva and Lis 2020); (Mathivathanan, Govindan and Haq 2017); (Ernesto, et al. 2020); (Hamid, et al. 2018); (Rashidi, et al. 2020); (Govindan, Madan and Devika, Supplier selection based on corporate social responsibility practices 2018); (MahathirMohammad, et al. 2019); (Renato, et al. 2020); (Sunil, et al. 2017); (Tülin and Zeynep 2016); (Yan, et al. 2019); (YogeshKumar, et al. 2018); (Yun and Yang 2020); (Zhou, et al. 2019) |
| 2   | Analytic Model                 | 1                | (Eleonora, Maria and Marta 2017) |
| 3   | ANOVA                          | 1                | (Tamara, et al. 2018) |
| 4   | ANP                            | 7                | (Abhijeet, et al. 2020); (Erfan, et al. 2020); (K. Devika 2018); (Govindan, Madan and Devika, Supplier selection based on corporate social responsibility practices 2018); (Mohammad, Anjali and + 2016); (Patchara and Chunjiao 2019); (Xiaole, et al. 2021) |
| 5   | Artificial Intelligent         | 2                | (Frank and Bramwel 2020); (Jose-Antonio, Rocio and Jorge 2016) |
| 6   | Big Data Assessment            | 3                | (Akash, Arun and Simar Preet 2020); (Malin, et al. 2017); (Taliva, Reza and Tahmoures 2017) |
| 7   | Bi-level Programming           | 3                | (Che-Fu 2015); (Mazyar and Jose e-Fernando 2019); (Patchara and Chunjiao 2019) |
| 8   | BMW                            | 4                | (Gunjan, et al. 2020); (Amiri, et al. 2020); (WanNurul, et al. 2017); (Saima, et al. 2020) |
| 9   | BOP                            | 2                | (JuliaC., Eugenia and Darima 2017); (Stefan, Carolin and Raja 2019) |
| 10  | Cluster Analysis               | 3                | (Akash, Arun and Simar Preet 2020); (Roya and Markus 2017); (UalisonRebulade, et al. 2018) |
| 11  | CSF                            | 3                | (K. Devika 2018); (Jörg H., Joerg and Joseph 2018); (Rakesh, Balkrishna and Bhaskar 2017) |
| 12  | DEA                            | 16               | (Hatami-Marbini, Ali and Sebastián 2017); (Akash, Arun and Simar Preet 2020); (Elaehe and Reza 2018); (Wang, et al. 2020); (Hadi, Saeed and Reza 2017); (Izadikhah, Reza and Kourosh, How to assess sustainability of suppliers in volume discount context? A new data envelopment analysis approach 2017); (Izadikhah, et al. 2020); (Mohammad, Reza and Reza 2020); (S.Motevali, S.A. and Ghasemi 2016); (Saeed, et al. 2017); (Taliva, Reza and Tahmoures 2017); (Xiang, Jie and Qingyuan 2016); (Xiaoyang, et al. 2016); (Yadong, et al. 2020); (Yan, et al. 2019); (Yun and Wang 2020) |
| 13  | Delphi                         | 7                | (K. Devika 2018); (Hendrik and David 2017); (Govindan, Madan and Devika, Supplier selection based on corporate social responsibility practices 2018); (Ming-Lang, et al. 2020); (Nejah 2021); (Omid, Ali and Saber 2019); (Tat-Dat, et al. 2021) |
| 14  | DEMATEL                        | 11               | (Anil, et al. 2020); (Chong, Yi, et al. 2020); (Erfan, et al. 2020); (Fuli, et al. 2018); (Fang, Wang and Song 2020); (Jing, Marco and Miguel 2016); (Govindan, Madan and Devika, Supplier selection based on corporate social responsibility practices 2018); (Mahtab, Sara and Joseph 2021); (Morteza, et al. 2017); (Patchara and Chunqiao 2019); (Zhigang, et al. 2016); |
| 15  | ELECTRE                        | 2                | (Gunjan, et al. 2020); (Huiyun, et al. 2018) |
| 16  | EOQ                            | 1                | (Noraaida, et al. 2018) |
| 17  | EPQ                            | 1                | (Noraaida, et al. 2018) |
| 18  | ERM                            | 1                | (Majid, et al. 2015) |
| 19  | FMEA                           | 1                | (Fatemeh and Donya 2018) |
| 20  | Fuzzy Theory                   | 41               | (Hatami-Marbini, Ali and Sebastián 2017); (Adel, Per, et al. 2017); (Alireza, et al. 2017); (Anil, et al. 2020); (Awasthi, Govindan and Gold 2018); (Aydin, Ehsan and Rene 2018); (Adenso-Díaz, S.Lozano and PMoreno 2016); (Chong, Chuanlin, et al. 2020); (K. Devika 2018); (Kannan, Jabbour and Jabbour 2014); (Devika, Alireza and Nourbaksh 2014); (Eleonora, Maria and Marta 2017); (Erfan, et al. 2020); (Fuli, et al. 2018); (Harpreet, et al. 2020); (John and Sheila 2020); (Rashidi, et al. 2020); (Govindan, Madan and Devika, Supplier selection based on corporate social responsibility practices 2018); (Amiri, et al. 2020); (Majid, et al. 2015); (Md Maruf, et al. 2020); (Ming-Lang, et al. 2020); (Izadikhah, Reza and Kourosh, How to assess sustainability of suppliers in volume discount context? A new data envelopment analysis approach 2017); (Izadikhah, et al. 2020); (Nejah 2021); (Ozden, et al. 2017); (Patchara and Chunqiao 2019); (Pezhman, Ahmad and Cathal 2017); (Phommaly, et al. 2019); (Pratibha, et al. 2020); (Ravi, Divya and Sanjay 2018); (Sumit and Neeraj 2020); (Tat-Dat, et al. 2021); (Xiaoyang, et al. 2016); (Xin, et al. 2019); (Yan, et al. 2019); (Yun and Wang 2020) |
| No. | Methodology                                      | References                                                                 |
|-----|------------------------------------------------|---------------------------------------------------------------------------|
| 21  | Game Theory                                    | (Azadeh, et al. 2017); (Chong, Yi, et al. 2020); (Jose-Antonio, Rocio, et al. 2016); (Kannan, A. Jafarian, et al. 2014) |
| 22  | Genetic Algorithm                              | (Asad, et al. 2019); (Bisheng, Qing, and Guiping 2017); (Shekarian 2020); (Wenge and Yuanjie 2017) |
| 23  | Gioia Methodology                              | (B.Gardas, D.Raut, and Narkhede 2019); (Abbas, et al. 2020); (Kostera, Vos, and Schroeder 2017) |
| 24  | Goal Programming                               | (Devika, Alireza, and Nourbakhsh 2019); (Goodarzian, Hosseini-Nasab, and M.B.Fakhrzad 2020); (Hatami-Marbini, Ali, and Saeed 2021); (Fang, Wang, and Song 2020); (Hashmi, et al. 2020); (Vergara-Valderrama, et al. 2020) |
| 25  | Graph Theory                                   | (Kostera, Vos, and Schroeder 2017); (Vafaeenezhada, Tavakkoli, and Shojaeian 2019) |
| 26  | Hessain Matrix                                 | (Azadeh, et al. 2017); (Chong, Yi, et al. 2020); (Jose-Antonio, Rocio, et al. 2016); (Kannan, A. Jafarian, et al. 2014) |
| 27  | Hybrid Method                                  | (Kostera, Vos, and Schroeder 2017); (Vafaeenezhada, Tavakkoli, and Shojaeian 2019) |
| 28  | Hypotheses                                     | (Asad, et al. 2019); (Bisheng, Qing, and Guiping 2017); (Shekarian 2020); (Wenge and Yuanjie 2017) |
| 29  | HFS                                           | (Abbas, et al. 2020); (Kostera, Vos, and Schroeder 2017); (Muchaendepia, et al. 2019); (Kostera, Vos, and Schroeder 2017) |
| 30  | Integer Linear Programming                     | (Alok, Indranil, and Samir 2018); (Bisheng, Qing, and Guiping 2017); (Shekarian 2020); (Wenge and Yuanjie 2017) |
| 31  | ISM                                           | (Alok, Indranil, and Samir 2018); (Bisheng, Qing, and Guiping 2017); (Shekarian 2020); (Wenge and Yuanjie 2017) |
| 32  | KPI                                            | (Kostera, Vos, and Schroeder 2017); (Vafaeenezhada, Tavakkoli, and Shojaeian 2019) |
| 33  | Likert Scale                                   | (Kostera, Vos, and Schroeder 2017); (Vafaeenezhada, Tavakkoli, and Shojaeian 2019) |
| 34  | MCDM                                          | (Ali, Yufeng, and Glyn 2018); (MuhammadShahid, et al. 2020); (Hamia, RazaliMuhamad, and Ebrahimpour 2015); (Fang, Wang, and Song 2020); (Huiping, Liu, and Zheng 2017) |
| 35  | MINLP                                         | (Alok, Indranil, and Samir 2018); (Bisheng, Qing, and Guiping 2017); (Shekarian 2020); (Wenge and Yuanjie 2017) |
| 36  | MLH                                            | (Asad, et al. 2019); (Bisheng, Qing, and Guiping 2017); (Shekarian 2020); (Wenge and Yuanjie 2017) |
| 37  | MRIO                                          | (Ali, Yufeng, and Glyn 2018); (MuhammadShahid, et al. 2020); (Hamia, RazaliMuhamad, and Ebrahimpour 2015); (Fang, Wang, and Song 2020); (Huiping, Liu, and Zheng 2017) |
| 38  | Multi Objective Program                        | (Ali, Yufeng, and Glyn 2018); (MuhammadShahid, et al. 2020); (Hamia, RazaliMuhamad, and Ebrahimpour 2015); (Fang, Wang, and Song 2020); (Huiping, Liu, and Zheng 2017) |
| 39  | PLS-SEM                                       | (Ali, Yufeng, and Glyn 2018); (MuhammadShahid, et al. 2020); (Hamia, RazaliMuhamad, and Ebrahimpour 2015); (Fang, Wang, and Song 2020); (Huiping, Liu, and Zheng 2017) |
| 40  | RDT                                           | (Ali, Yufeng, and Glyn 2018); (MuhammadShahid, et al. 2020); (Hamia, RazaliMuhamad, and Ebrahimpour 2015); (Fang, Wang, and Song 2020); (Huiping, Liu, and Zheng 2017) |
| 41  | Rough Set Theory                              | (Ali, Yufeng, and Glyn 2018); (MuhammadShahid, et al. 2020); (Hamia, RazaliMuhamad, and Ebrahimpour 2015); (Fang, Wang, and Song 2020); (Huiping, Liu, and Zheng 2017) |
| 42  | Sampling                                      | (Ali, Yufeng, and Glyn 2018); (MuhammadShahid, et al. 2020); (Hamia, RazaliMuhamad, and Ebrahimpour 2015); (Fang, Wang, and Song 2020); (Huiping, Liu, and Zheng 2017) |
| 43  | SEM                                           | (Ali, Yufeng, and Glyn 2018); (MuhammadShahid, et al. 2020); (Hamia, RazaliMuhamad, and Ebrahimpour 2015); (Fang, Wang, and Song 2020); (Huiping, Liu, and Zheng 2017) |
The most notable feather of the table 2 concerns some papers and authors used several mathematical models and methods together for making a model or solving problems in SSCM. For example, majority of papers used the fuzzy logic method for normalizing variables, or balancing parameters and enablers in the mathematical models as primary method, then used another model such as Goal programming for finding the optimum solution (Zainab, Syed and Shakeel 2019); (Renato, et al. 2020); (Erfan, et al. 2020) or Multi Object Program (Hatami-Marbini, Ali and Sebastián 2017); (Azadeh, et al. 2017); (Xiaoyang, et al. 2016) for best solution. Also, AHP method is used for weighting variables, priorities as an auxiliary methods for defining variables and normalizing them for using in the mathematical models, beside to AHP, authors offer another mathematical model for completed SSCM model like AHP-VIKOR (Awasthi, Govindan and Gold 2018); AHP-MCDM and Gray Theory (Mathivathanan, Govindan and Haq 2017); AHP-Multi Objective program (Hamid, et al. 2018); and etc.

3.4 Category four: The Roles of Parties in SSCM Modeling

For SSCM modeling, there are different parties which are involving and have roles who are Stakeholders, Governments, People, Social, Environment, Factories, Logistics Companies and resources. Figure 10 represents the different parties and the relative effects.

![Figure 10. The parties which are involved for SSCM modeling](image)

One of the main involving partners is Government who is responsible for Control environmental and social impacts. In 2015, The representatives of 193 countries of the world held a meeting and set sustainable development goals by the year of 2030 (United Nation 2015). The limitation of carbon cap and carbon credit is a constraint for controlling carbon caps and protecting environment. Every country can define their own limitations for factories, companies, transportation and so on, and control the pollutions. The different researches are investigate how to control carbon cap through different partners and rules which are set by governments (Esfahbodi, et al. 2017); (Huiyun, et al. 2018); (Köksal and Müller 2018). On the other hand, customer’s demands are an important cause for producing the environmental unfriendly products (EFP) (Kannan, A.Jafarian, et al. 2014); (Huiyun, et al. 2018).
4. Conculation and Suggestions

Although gaining increased attention on SSCM, the using mathematical methods and models for solving problems and designning new models relative to SSCM frames and modules are increased. In this paper, we conducted a systematic litrature review to identify the current situation of using mathematical models and methods for SSCM and finding the gaps. The Gaps between the Current situation which are discussed in section three, and the ideal are divided in modules of SSCM, Partners who are involved in SSCM, Countries and area for SSCM and industries.

4.1 SSCM Modules

We divided the SSCM in eleven modules which are shown in Figure 7, then defined these modules with using different papers conclusions and contents and finally categorised them in eleven core of research in SSCM and named as modules of SSCM. The resulte of analysis papers and research contents showed that there is no balance for research in different modules. Some modules like SS (Supplier Selection) or FS (Frame work Structure) are evaluated in different papers and there are different mathematical models and methods for modeling these modules. However some modules like SR (Sustainable Recycling) and SPK (Sustainable Packaging) are needed more research. The new research is needed for evaluation the weight of every modules according to environmental impacts and social attention and how to optimum the current situation and gaining goals of sustainability in different modules.

4.2 Involved Partners in SSCM Mathematical Models

After analysis the paper contents, we offer a model of different partners who have an important role in SSCM (Figure 10). With content analysis of papers, we found that the changing approach for customer’s demand is needed. We suggest that the role of demand in designning products and EFP should be investigated. In the researches, the role of stakeholders and governments are more highlight. However other roles should be considered and need to add in the roles of SSCM models.

4.3 Countries or Area of Research

As it is clearly seen in the Figure 4, the research in some countries are a few. According to united nation definition for sustainability (United Nation 2015), different countries have different goals for sustainability. There is a gap between modeling SSCM in different countries and the defined goals. Some countries need more research which are clear in figure 4.

4.4 Industries as Case Study or Implementing Models

In the figure 5 ahows the industries which are investigated as case study or implementing SSCM models in them. As it is clearly seen, the heavy industries which have more weight on the sustainability (United Nation 2015) like casting, steel, and so on, need more research.

After analysis the gap between current situations and goals of sustainability, we found to need more research on different modules of SSCM, different industries, different countries no matter developed or undeveloped and differend involved partners in SSCM. The analysis presented in this paper enabled the authors to define SSCM models in different modules and categorised in different mathematical models. These categorizes and gap analysis can be helped future researches and designning new models.

Acknowledgment

This research is funded by National Natural Science Foundation of China under Grand Number: 71832001. Also, thanks Department of Logistics and Electronic Commerce, Glorious Sun School of Business and Management, Shanghai Donghua University for supporting us in this project.

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