Review

Evaluation mathematical models in SSCM and Gap analysis

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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 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 of researches. The methodology of research is Systematic Literature review through peer review papers which are published in high ranking journals. In this paper, First, we search all papers through scientific data bases like Scopus, science direct, MDPI, Springer, Google Scholar, then, screening papers based on the criteria such as subject of paper, journals impact factor which is published in-should be peer review journal- and relative content of the papers. Finally, we selected 245 papers with three steps screening through 2806 papers that they have enough quality and relative to our research goals for context analysis. Through context analysis, first we categorized the information of the papers and drew the current situation of researches in the framework of our topic. Then, we evaluate and compare the goals of sustainability and current situation and found the gapes, then, offered new suggestions like implementing SSCMs models in pollutant industries like 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.

0. 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

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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

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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: VlseKriterijuska 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 [1]. 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 refers to the area of research like development and developing countries and made some mathematical models, rules or new suggestions for developing countries [2]; [3]; [4]; [5]. 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 [6]; [7]; [8]; [9]. Unfortunately, the social aspect in majority of papers underrepresented in comparison with economic and environmental factors [10]. In addition, Governments and new policies set some rules for carbon cap and emission carbon for factories, suppliers and logistics companies [11]. Although, there are some suggestions to governments to define subsides for environmental friendly products in order to controlling pollution and carbon cap [12].

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 [13]; [14]; analysis evolution SSCM trends across industries and economics [15]; evaluation different opportunities and challenges for designing and implementing SSCM [16]; [17]; Mathematical and measurement tools for organization performance [18], evaluated the concept and thematic scope in theoretical point of view and in relation to its practical implementation [19], the role of governments for renewable energy usage [20], Using cleaner Production method for large energy intensive industries [21], Applying and implementing triple bottom line in SSCM [22]; [23] and the ways for quantitative social impacts [24].

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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 [25]. 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.

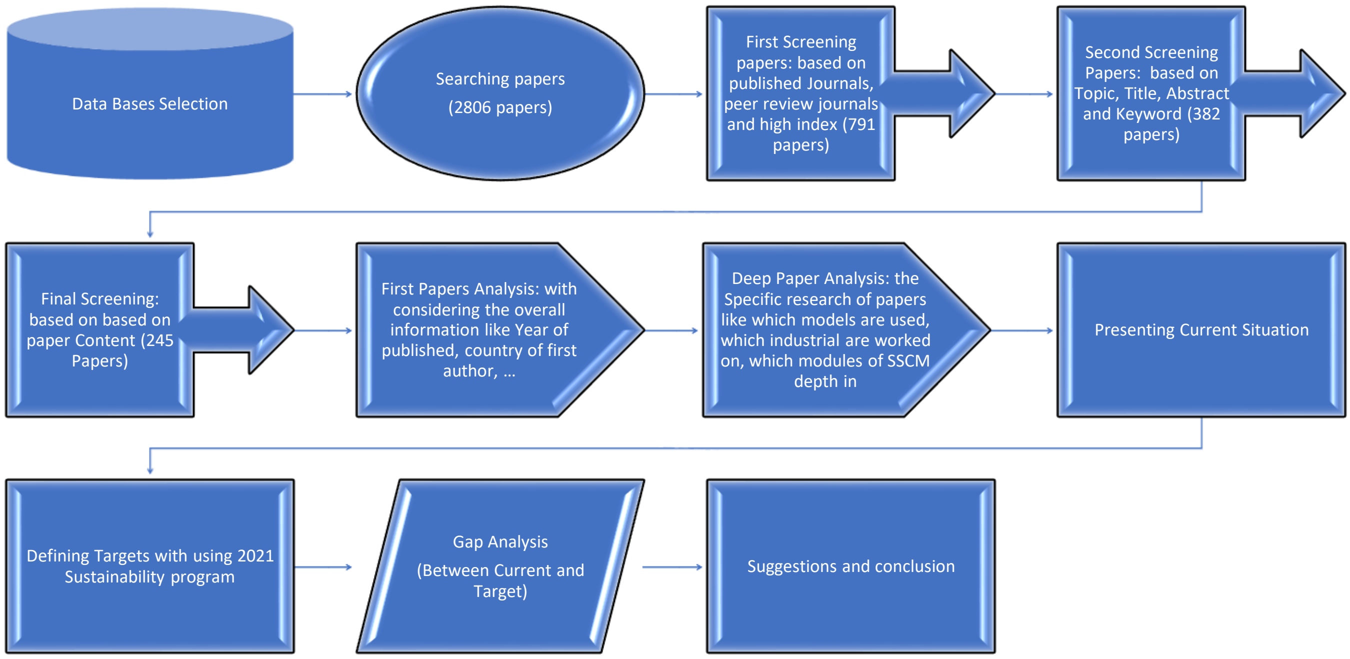

Figure 1: The flow chart of the Research Methodology

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

2.2. 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.

2.3. Third: Screening papers in three steps;

➢ Step one of screening is to evaluation the valid journals with criterias 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 evaluation 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.

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2.4. Forth: definning the target for SSCM according to 2021 Sustainabile Development Goals [25]. 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.

2.5. 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: Overal information

This Category analysis the overal 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.

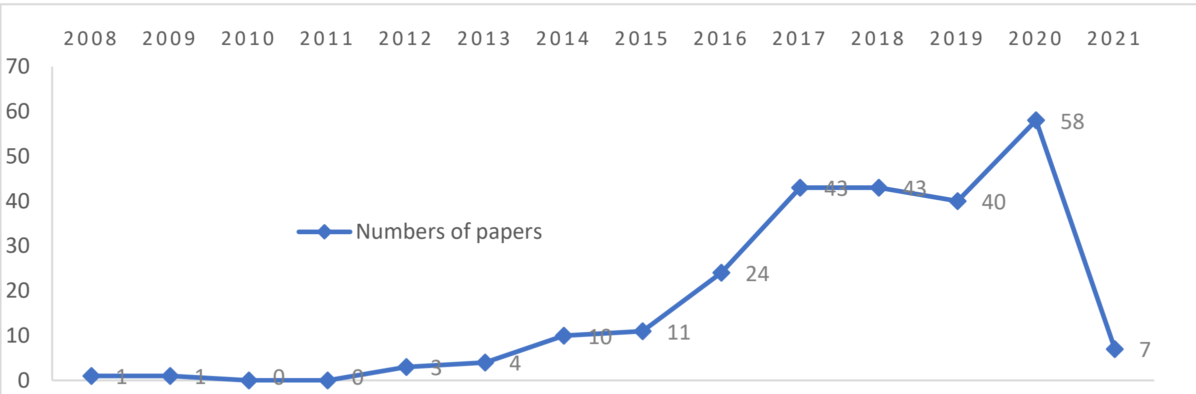

Figure 2: Distribution of published papers per year from 2018 to the end of March 2021

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.

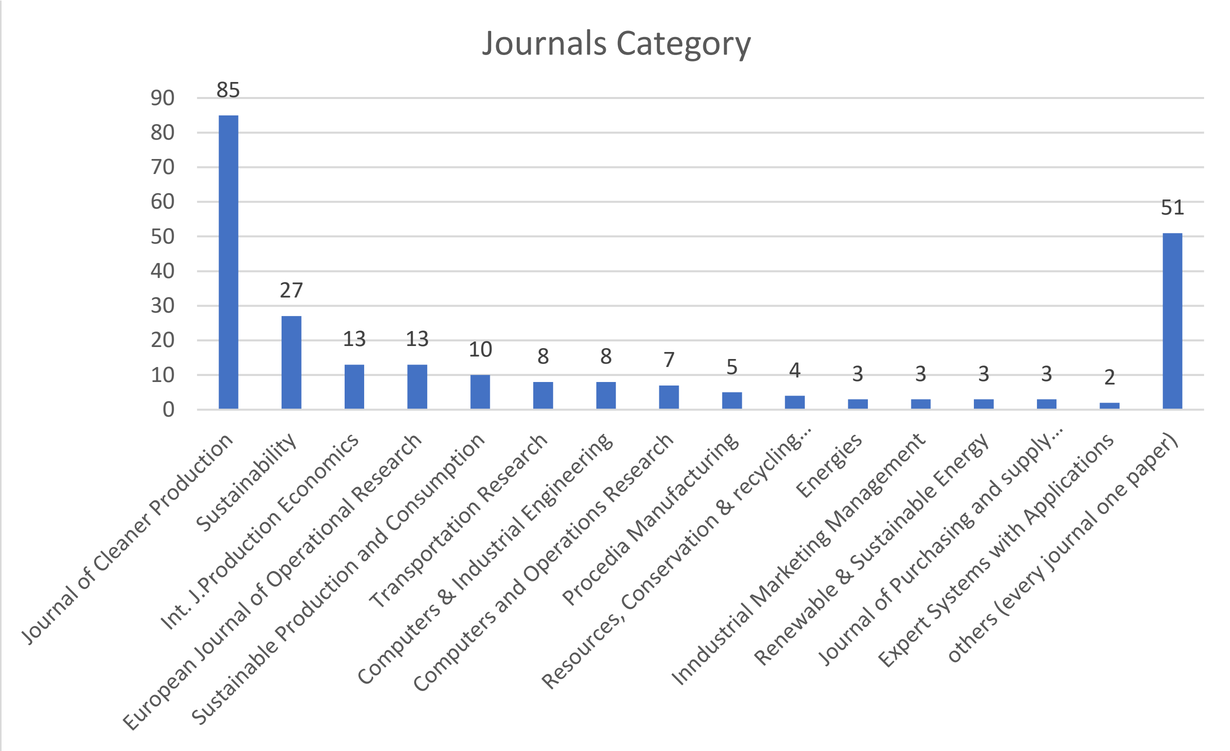

Figure 3: Number of papers by Journal

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.

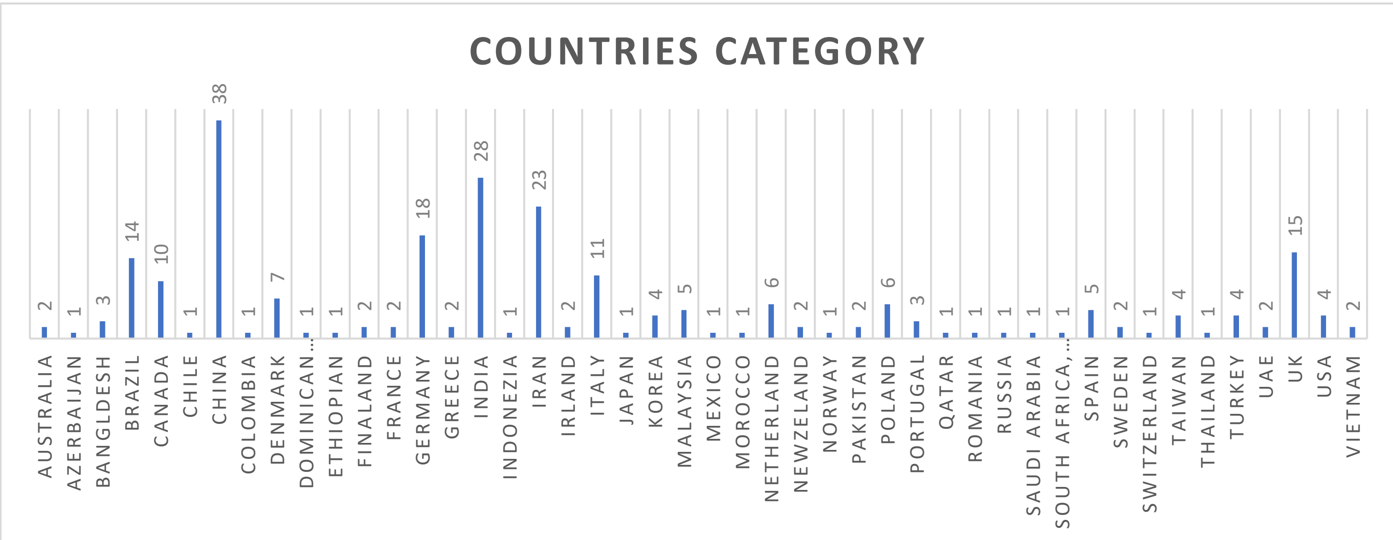

Figure 4: The quantity of papers per first author's country

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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 implement 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.

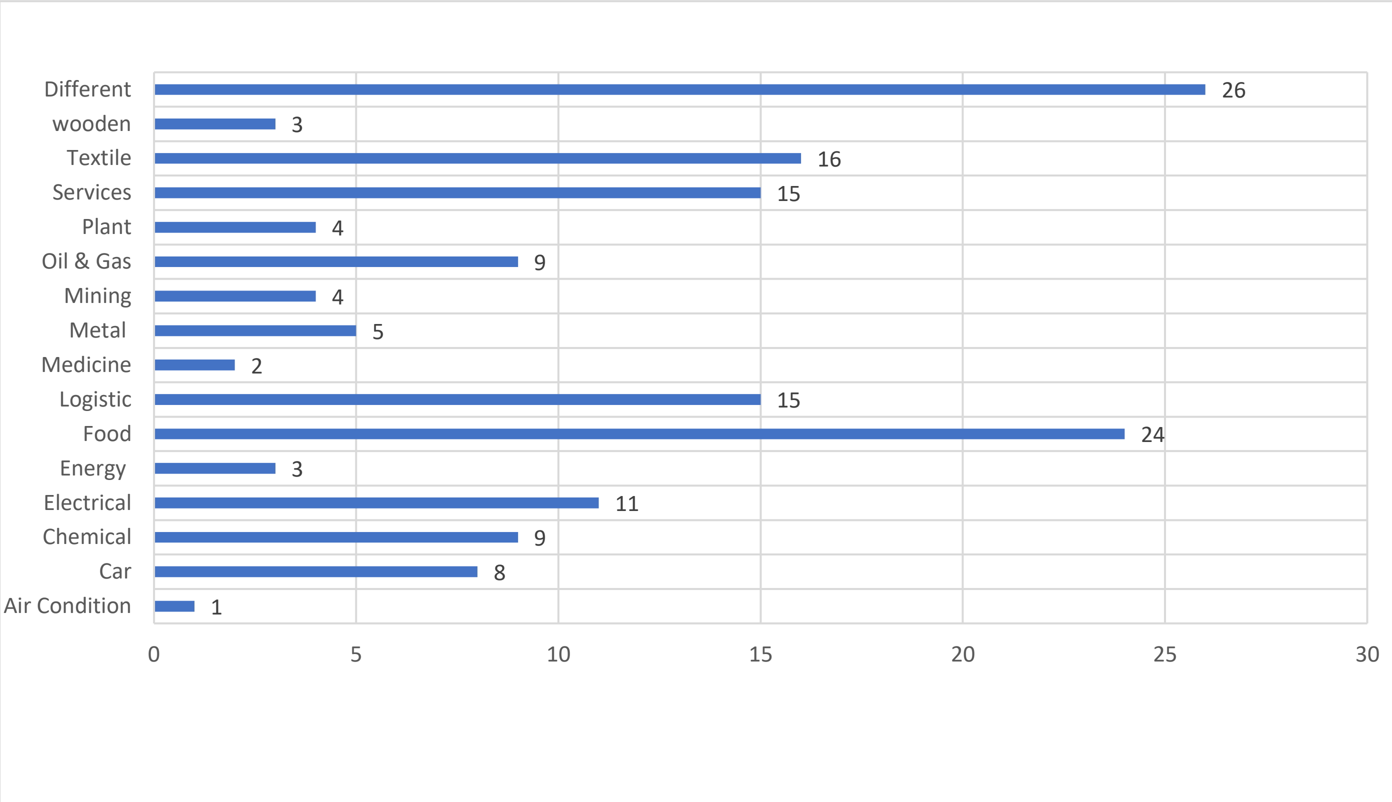

Figure 5: The number of papers for each Industry

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.

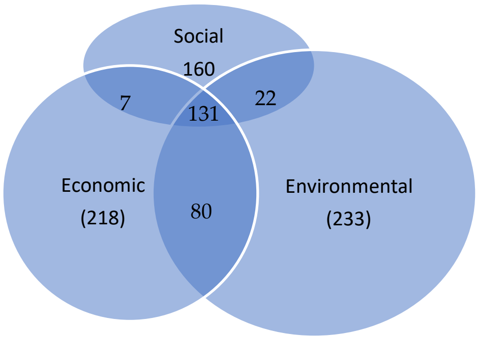

Figure 6: The quantity of papers per SSCM Dimensions

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 definning 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.

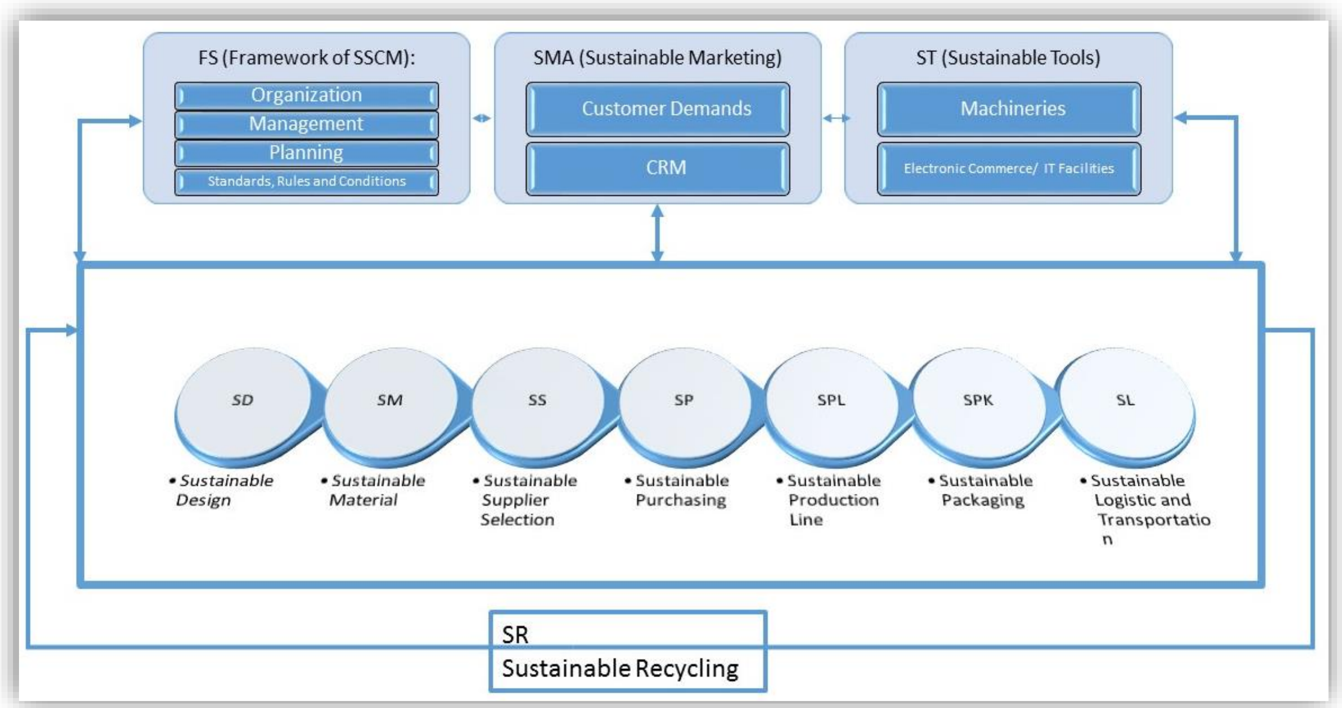

Figure 7: The modules of SSCM

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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 amont 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.

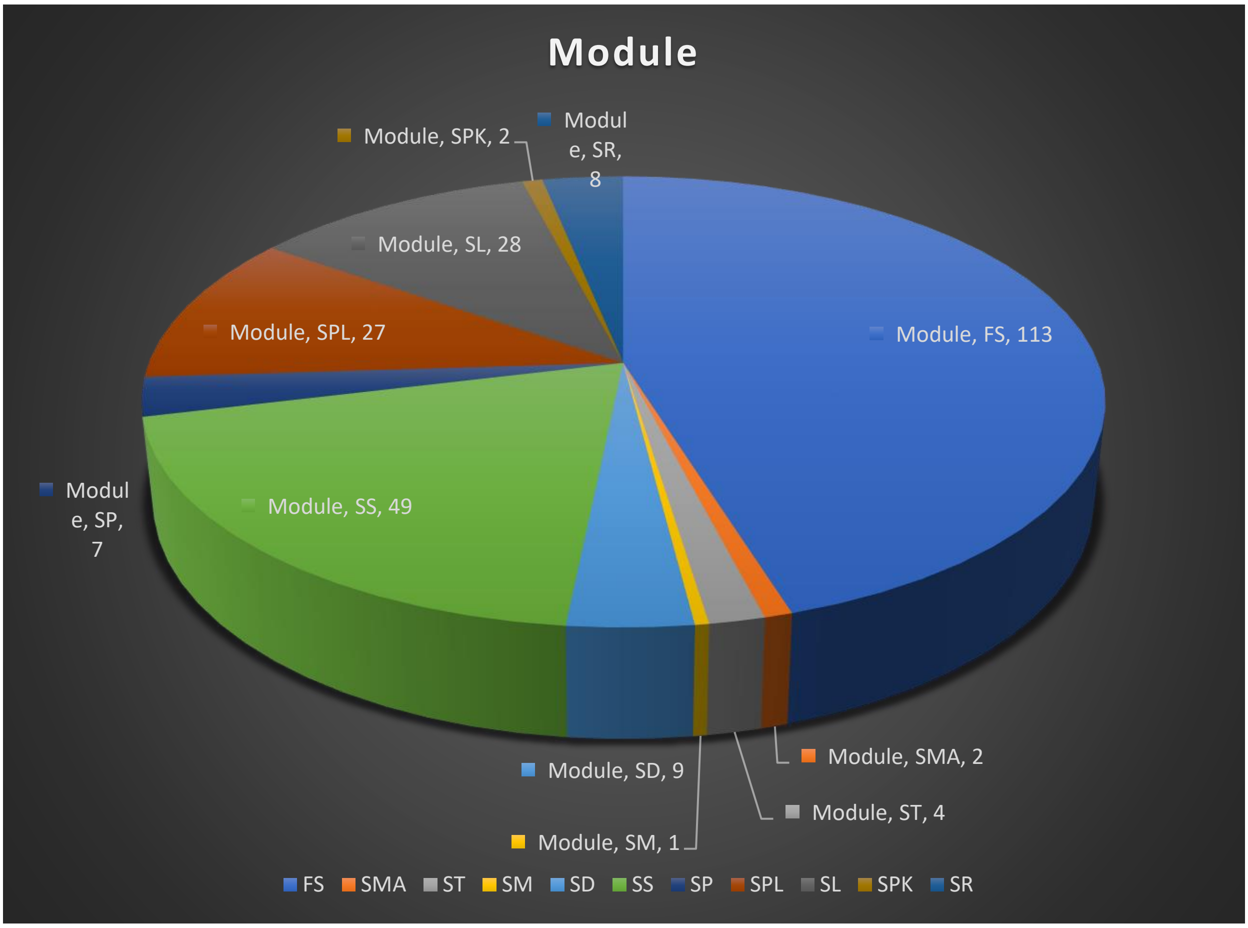

Figure 8: The number of papers for every modules

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

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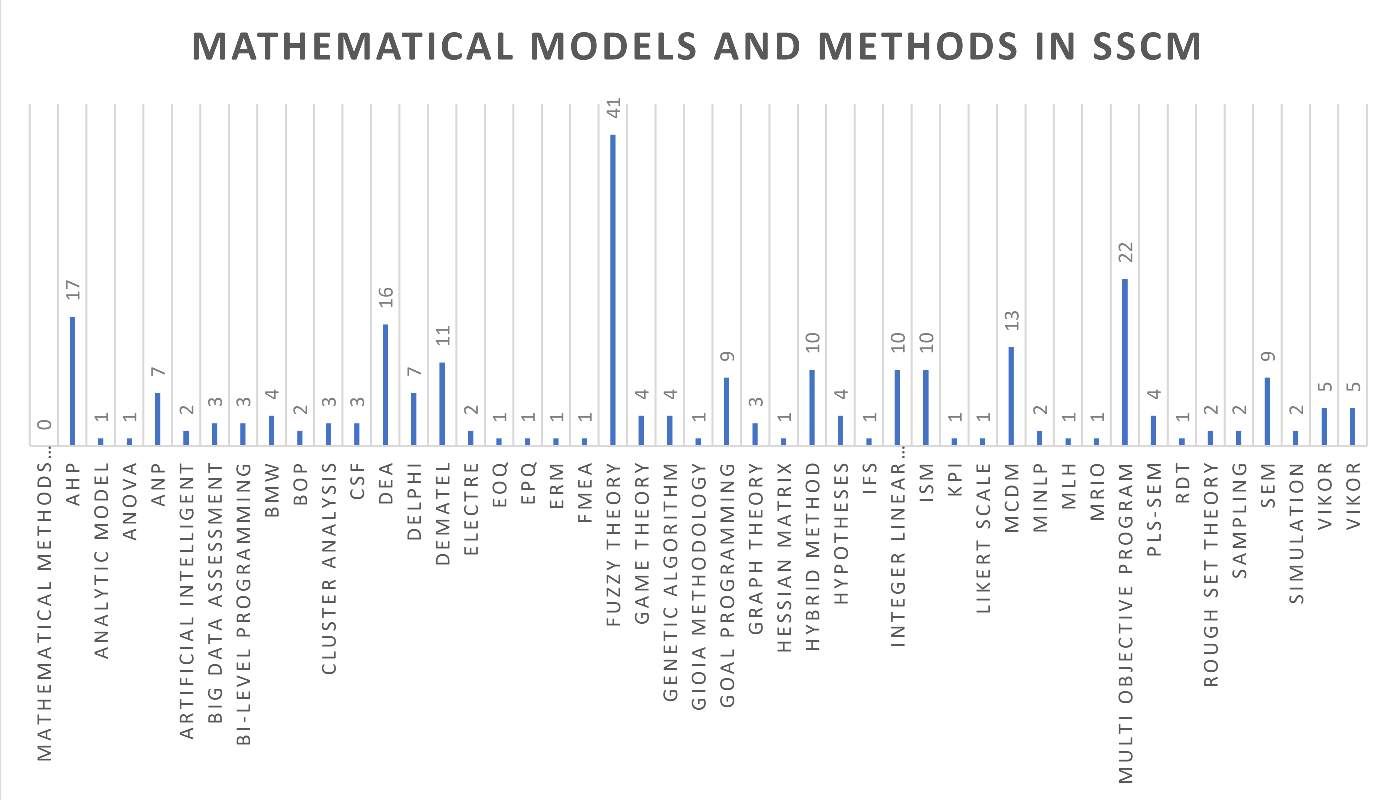

Figure 9: The chart of mathematical models for SSCM

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 usefule mathematical method for making models and solving problems in SSCM models. Fuzziy 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 intresting 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.

Table 1: The Authors who have more researchs in the field of mathematical application for SSCM

Raw	**Authors**	**As First Author**	**As Co-Author**	**Models which are used**	**Module**	**Ref.**
1	Huiping Ding	4	-	Multi-Objective Programming	SS, SPL, FS	[26]; [27]; [28]; [29]

2	Kannan Govindam	3	6	integrated fuzzy AHP-VIKOR approach-based, Multi Criteria Decision Making (MCDM) tool a combination of Analytical, Hybrid MCDM, DEMATEL-ANP (DANP). Fuzzy Delphi Method, Multiple-objective optimization Vehicle routing problem Swarm intelligence algorithms hybrid of genetic algorithm (GA) and VNS as the benchmark algorithm, Augmented 3-constraint (AUGMECON) method	FS, SS, SL, SD, SMA	[17]; [30]; [31]; [32]; [33]; [34]; [35]; [36]; [37]
3	Devika Kannan	3	5	Structural Equation Modelling (SEM), the combination of the Fuzzy DELPHI approach and the hybrid MCDM techniques, Critical success factor (CSF) theory, Fuzzy set theory, TOPSIS, Triangular fuzzy number, sensitivity analysis, Continuous approximation CA, Stochastic mixed integer programming SMIP, Fuzzy mixed integer programming FMIP, Mixed integer non-linear programming (MINLP), Mixed integer linear programming, Hybrid MCDM, DEMATEL-ANP (DANP). Fuzzy Delphi Method, analytical hierarchical process (AHP)- VIKOR	FS, SS, SD, SR, SL	[38]; [39]; [6]; [40]; [22]; [32]; [34]; [36];
4	Stefan Seuring	2	3	base-of-the-pyramid (BoP),	FS	[41]; [35]; [42]; [1]; [43];
5	Payman Ahi	2	-	probabilistic approaches to SSCM performance measurement	FS	[44]; [14]
6	Mohammad Izadibakhsh	2	-	Data envelopment analysis (DEA), Fuzzy Data, Fuzzy Screening System	SL, SS	[45]; [46]
7	Eleonora Bottani	2	-	Analytic model, Fuzzy Model	SPL	[47]; [48]
8	Chong Wu	2	-	systematic four-stage model based on Dempster-Shafertheory, the improved non-dominated sorting genetic algorithm-II (NSGA-II), and thedecision-making trial and evaluation laboratory (DEMATEL) method	SS	[49]; [50]
9	Ali Esfandi	2	-	resource dependence theory(RDT)lens, structural equation modelling (SEM) method	FS, SP	[3]; [51]

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10	Adel Hatami	2	-	Cross-efficiency evaluation, Data envelopment analysis (DEA), Fuzzy data, Lexicographic multi-objective linear programming, Fuzzy targets, Super-efficiency	FS, SS	[52]; [53]

As it is clearly seen in Table 1, the modules that the authors intrested 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 refrences 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	[30]; [54]; [55]; [31]; [56]; [57]; [22]; [32]; [58]; [59]; [36]; [60]; [61]; [62]; [63]; [64]
2	Analytic Model	1	[47]
3	ANOVA	1	[65]
4	ANP	7	[66]; [67]; [39]; [32]; [68]; [69]; [70]
5	Artificial Intelligent	2	[71]; [72]
6	Big Data Assessment	3	[73]; [74]; [75]
7	Bi-level Programming	3	[76]; [77], [69]
8	BMW	4	[78]; [79]; [80]; [81]
9	BOP	2	[82]; [42]
10	Cluster Analysis	3	[73]; [83]; [84]
11	CSF	3	[39]; [85]; [86];
12	DEA	16	[53]; [73]; [87]; [88]; [89]; [45]; [46] ; [90]; [91]; [92]; [75]; [93]; [94]; [95]; [61]; [63]
13	Delphi	7	[39]; [96]; [32]; [97]; [98]; [99]; [100]
14	DEMATEL	11	[101]; [50]; [67]; [102]; [7]; [103]; [32]; [104]; [105]; [69]; [106];
15	ELECTRE	2	[78]; [107];
16	EOQ	1	[108]
17	EPQ	1	[108]
18	ERM	1	[109]
19	FMEA	1	[110]
20	Fuzzy Theory	41	[53]; [52]; [111]; [101]; [30]; [112]; [113]; [49]; [39]; [6]; [40]; [47]; [67]; [102]; [114]; [115]; [22]; [32]; [79]; [109]; [116]; [97]; [45]; [46]; [98]; [117]; [69]; [118]; [119]; [120]; [121]; [122]; [100]; [94]; [123]; [61]; [62]; [124]; [63]; [125]; [64]
21	Game Theory	4	[126]; [127]; [128]; [129]
22	Genetic Algorithm	4	[130]; [50]; [72]; [34]

23	Gioia Methodology	1	[131];
24	Goal Programming	9	[132]; [133]; [125]; [134]; [135]; [92]; [59]; [89]; [67]
25	Graph Theory	3	[52]; [136]; [137]
26	Hessian Matrix	1	[138]
27	Hybrid Method	10	[73]; [111]; [39]; [139]; [57]; [22]; [32]; [33]; [92]; [100]
28	Hypotheses	4	[140]; [141]; [142]; [143];
29	IFS	1	[69]
30	Integer Linear Programming	10	[40]; [139]; [114]; [77]; [144]; [60]; [133]; [132]; [145]; [146];
31	ISM	10	[147]; [66]; [39]; [7]; [27]; [137]; [148]; [149]; [150]; [86]
32	KPI	1	[47]
33	Likert Scale	1	[151];
34	MCDM	13	[111]; [112]; [147]; [31]; [39]; [114]; [32]; [69]; [152]; [153]; [62]; [63]; [18]
35	MINLP	2	[40]; [114]
36	MLH	1	[154]
37	MRIO	1	[88]
38	Multi Objective Program	22	[53]; [130]; [155]; [113]; [156]; [146]; [157]; [139]; [57]; [26]; [33]; [34]; [158]; [105]; [59]; [159]; [160]; [161]; [94]; [123]; [95]; [37]
39	PLS-SEM	4	[162]; [140]; [163];
40	RDT	1	[3];
41	Rough Set Theory	2	[107]; [164];
42	Sampling	2	[165]; [166];
43	SEM	9	[38]; [162]; [147]; [49]; [140]; [167]; [98]; [163]; [168];
44	Simulation	2	[169]; [170];
45	VIKOR	5	[30]; [102]; [69]; [119]; [36]

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 [125];[59]; [67] or Multi Object Program [53]; [130]; [94] for best solution. Also, AHP method is used for weighting variables, priorities as an auxilary methods for definning variabled and normalizing them for using in the mathematical models, beside to AHP, authors offer another mathematical model for completed SSCM model like AHP-VIKOR [30]; AHP -MCDM and Gray Theory [31]; AHP-Multi Objective program [57]; 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, Environmet, 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

One of the main involving partners is Government who is responsible for Control environmental and social impacts. In 2015, The responsible representatives of 193 countries of the world held a meeting and set sustainable development goals till year 2030 *[25]*. The limitation of carbon cap and carbon credit is a good constraint for controlling carbon caps and protecting environment. Every country can make their own constraints 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 *[51]*; *[107]*; *[4]*. On the other hand, customer's demands are an important cause for producing the environmental unfriendly products (EUFP). For controlling the carbon cap and green environment, the training people for choosing the environmental friendly product (EFP) *[34]*; *[107]*.

4.Conculation and Sugesstions:

Although gainning 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. We defined these modules with using different papers conclusions and contents and 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 gainning 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 *[25]*, 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 *[25]* like casting, steel, and so on, need more research.

After analysis the gap between current situations and goals, we found to need more research on different modules of SSCM, different industries, different countries no matter developed or undevelopped 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.

6. Acknowledgment

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