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Sustainable Supply Chain Network Design: A Review on Quantitative Models Using Content Analysis

Ezzatollah Asgharizadeh [a,*], S. Ali Torabi [b], Ali Mohaghar [a], Mohammad Ali Zare-Shourijeh [a]

[a] Department of Industrial Management, Faculty of Management, University of Tehran, Tehran, Iran.
[b] School of Industrial Engineering, College of Engineering, University of Tehran, Tehran, Iran.

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Abstract

The purpose of this paper is to develop a systematic literature review on the subject of sustainable supply chain network design during 1990-2016, through a review of 261 papers. In this study, qualitative technique for conducting a systematic literature review was used. To systematize and make the literature review more accurate, content analysis method was used that include data collection, coding, analysis and interpretation of data. Several tables and figures were developed to provide a better interpretation of the literature. The results show that: 1. Researches has been growing dramatically in this field, especially since 2008; 2. Most research has been conducted in five countries; 3. The most of quantitative models of SCND have published respectively in five top journals; 4. Generally, the researchers were more interested in: single-objective, linear programming, single-period, multi-product, capacity-limited facilities, multi-mode, reverse and environmental models, than other types of models and considerations; 5. In phase of modeling and solving, the authors have used more of mathematical programming (specifically MILP) and commercial solvers. The general contribution of this paper is in its addressing the topic of Sustainable Supply chain Network Design. Supply chain network design (SCND) is one of the strategic problems at the intersection of disciplines such as management, strategy, logistics, and operational research. Moreover, this work specifically contributes to understanding sustainability and identifies research gaps and characteristics of the scientific papers on this topic.

Keywords: Supply Chain Network Design, Quantitative Models, Sustainability, Systematic Literature Review, Content Analysis.

Introduction

Supply chain has several issues that can be classified in three levels (Simchi-Levi et al., 2000): 1. Operational level, such as scheduling that refers to the daily decisions, 2. Tactical level that includes decisions is usually being updated seasonally or annually such as purchasing and production decisions and 3. Strategic level that deals with decisions have long-lasting effects on the firm and supply chain. Decisions like number, location and product/material flow through the logistics network are of this type. The supply chain network design (SCND) is one

* Corresponding author E-mail: Asghari@ut.ac.ir

of the issues at strategic level that creates a network of supply chain entities, and includes a set of decisions about location and role of supply chain entities, products allocations, capacity planning at the strategic level and the establishment of transportation and informational links between these entities (Chandra and Grabis, 2007). The structure of SCND will have a significant impact on the performance and future cost of the chain (Farahani et al., 2014). May be able to say the most important decision of SCND is locating of facilities in different supply chain tiers. Traditionally, the base of all SCND decisions is economic optimization and paying attention to higher profits or lower cost. Recently, according to the sustainability and resiliency considerations, making decision and the way of looking at SCND problem has changed. These considerations, however, takes decisions out of economically optimal condition but it will result in long-term competitive advantage and enhance the ability of supply chain continuity which is more important in the new paradigms of supply chain design. The remaining sections of this article are as follow: in the next section, theoretical principles and previous reviews will be examined. In third section, methodology of the research is described. The selected articles based on the research methodology will be analyzed and the result of these reviews is reported in section four and finally the section five is dedicated to conclusion and in introducing some paths for future researches.

Theoretical Principles and Previous Literature Reviews

Nowadays, decisions related to supply chain network design are strongly influenced by trends such as rapid changes in customer demand, increased competition, and appearance of sustainable development literature and extension of social and environmental requirements of stakeholders, crisis and unforeseen events (Eskandarpour et al., 2015). The green supply chain, the sustainable supply chain and resilience supply chain are of the most important reactions in response to these trends. Green supply chain in order to reduce environmental problems and industrial waste, emphasizes on product design and design of product recovery networks- called reverse or backward networks- and will ensure the reduction of the negative effects of the waste on the environment (Farahani et al., 2014). But concept of sustainability derives from the term of sustainable development. The world commission on environment and development (WCED) defines sustainable development as: *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (World Commission on Environment and Development, 1987). In its modern sense, Elkington (1998) for the first time introduced the concept of sustainability in triple bottom line (TBL). TBL is a tool that gains the essence of sustainability by measuring the organization’s activity on the world. These include economic, social and environmental impacts (Slaper and Hall, 2011). According to the WCED's definition, we can place green supply chain issues, recycling and reproduction of products under the theme of sustainable supply chain issues. Resources conservation, protecting the environment and social development are three essential part of sustainable development. Nowadays, many companies due to economic motivations and growing concerns of communities about environmental problems attempt to reuse and remanufacture products (Amin and Zhang, 2012b). Most companies that get involved in reverse logistics and closed-loop in their supply chain consider it as a way to meet social expectations and economic benefits of recycled items (Das and Chowdhury, 2012 and Özkır and Başlıgil, 2013). Reverse and closed-loop logistics emphasize on decreasing and reusing waste. Reverse logistics means moving products, materials and information in the opposite direction in order to create or regain value or dispose of wastes in a suitable way (Amin and Zhang, 2012a). Due to systematic nature of supply chain and in order to keep consistency of the value added of members, supply chain risks must be managed. Based on the classification of Tang (2006), supply chain risks include two types: operational risks and disruption risks. Operational risks related to inherent uncertainties such as customer uncertain demand, uncertain supply and uncertain costs. Disruption risks refer to major disruptions and shocks that come from nature or human disasters such as earthquakes, hurricanes and terrorist attacks (Tang, 2006). Based on the literature, the success of supply chains in disruptions management can be measured through resiliency of supply chain. Tukamuhabwa et al. (2015) presented a comprehensive definition for resilience:

The adaptive capability of a supply chain to prepare for and/or respond to disruptions, to make a timely and cost effective recovery, and therefore progress to a post-disruption state of operations – ideally, a better state than prior to the disruption.

Christopher and Peck (2004) believe that it is necessary to accept some principles and strategies to reduce negative effects of disruptions on supply chain: 1. supply chain reengineering, 2. collaboration, 3. agility, and 4. culture of supply chain risk management. Flexibility and redundancy are strategies to reduce risk by reengineering of supply chain. Flexibility is the ability to adopt different situation for better response to unusual situation and rapid adaption with dramatic changes in supply chain. Having different transportation systems, flexible production facilities, flexible supply base, flexible capacity and flexible labor arrangement and postponing demands are examples of flexibility to enhance resilience. Collaboration in the supply chain means the ability to work more effective with other chain member for common profits in areas such as predicting, postponing and risk sharing (Pettit et al., 2013). Supply chain agility is also defined as: the ability to respond quickly to unpredictable changes in demand and supply. The agility has two dimensions: visibility and velocity. Finally, it is necessary that organizations accept a culture for supply chain risk management to create resilient organizations (Kamalahmadi and Parast, 2016). Here the most important previous reviews on SCND are mentioned briefly to clarify the position of present literature review. In one of the first literature reviews which is done in this field, Vidal and Goetschalckx (1997) conclude that published works only addressed simply issues and the real world problems has not been considered. In their review, they focus on strategic design of global supply chains. Fleischmann et al. (2000) identify and define general characteristics of product recycling networks and compare them with the characteristics of traditional logistics networks, by reviewing some case studies in the field of logistics network design in various industries. Beullens (2004) describes some of frameworks, models and important concepts -which developed until 2004. Melo et al. (2009) are classified available literature about location problem in supply chain management based on: 1. supply chain structure, 2. decision variables in SCND, 3. performance criterions, 4. solution methods and 5- applications. Also performance criterions are classified into three analytical classes: a. cost minimization, b. profit maximization, and c. multiple objectives. Multiple objectives is the smallest class and includes varied range of criterions such as responsiveness, resources consumption, delay minimization in product delivery and environmental measures. They also concluded that studies in which uncertainty has merged with location decisions are rare. Klibi et al. (2010) focused on integration of uncertainty in SCND models. In recent years (2014-2016) also some review articles has published in field of SCND focusing on specific dimensions. Farahani et al. (2014) also reviewed the literature of the area focusing on competitive SCND. They classified the literature into: 1. network characteristics and SCND decisions, 2. performance measures, 3. uncertainty considerations and 4. solution methods. Govindan et al. (2015b) are analyzed and classified studies with the aim of surveying researches in field of reverse supply chain and logistic, closed-loop supply chain and logistic between 2007 March to 2013 and showed some directions for the future research. Eskandarpour et al. (2015) investigated 87 articles in the field of SCND with focus on different dimension of sustainability. Their emphasis was on optimization models and classification of articles based on mathematical models. Fahimnia et al. (2015) in a study with the aim of reviewing quantitative and analytical models, concluded that quantitative analysis of supply chain risk and sustainability risk analysis are of emerging and fast-growing research topics. As mentioned before, many articles that has published recent years, reviewed only one topic such as sustainable supply chain or reverse supply chain or closed-loop supply chain. According to the original definition of sustainable development and the impacts of sustainable, green, reverse and closed-loop approaches on supply chain models (Amin and Zhang, 2012a, 2012b; Das and Chowdhury, 2012 and Özkır and Başlıgil, 2013), we can place all of these approaches under this key term: *sustainable supply chain*. To the best of our knowledge, there is lack of a comprehensive and broad review on quantitative researches in the field of sustainable SCND. Therefore, in this article we tried to do a comprehensive review that has not seen in the previous reviews yet to illustrate more research gaps through answering these research questions: Which dimensions of sustainability have been considered more in quantitative SCND modeling? In reviewed articles, what characteristics did quantitative models address (objectives, transportations modes, periods, products, capacity limitations)? Which modeling and optimization approaches have used more? What solution approaches and methods are more prevalent? How much is the contribution of forward, reverse, closed-loop SCND in the literatures? How much is the contribution of certain and uncertain models? Which supply chain resiliency strategies are more considerable in quantitative researches of sustainable SCND? And according to the findings, which directions do we can suggest for the future researches? It is worth mentioning that main contributions of this paper are as follow:

1. We considered a suitable set of articles related to green supply chain, sustainable supply chain, environmentally conscious supply chain, reverse supply chain and closed-loop supply chain and so on under the topic of sustainable supply chain network design.
2. The timeframe considered in this literature review (i.e. 1990-2016) is a unique or perhaps unparalleled in this field of research.
3. To the best of our knowledge, the number of articles reviewed in this review is not seen in any other review article (i.e. 261 articles).
4. Comparing with other reviews, this paper addressed more structural dimensions and analytic categories at the same time. This provides more cross-analyses.
5. We made an attempt to use and aggregate the strengths of the past review articles here.
6. We also examined whether resiliency considerations are addressed in the field of quantitative models of SCND alongside sustainability considerations or not.

Research Method

Fink (2005) defined literature review as *"a systematic, explicit, and reproducible design for identifying, evaluating, and interpreting the existing body of recorded documents"*. Gathering related data to the field and investigating and evaluating it from different aspects is the most accepted method in reviewing literatures (Ansari and Kant, 2017). This article aims to investigate quantitative and analytic models of SCND (mathematical, optimization and simulation models) with a comprehensive literature review using *content analysis method*. To describe details of research method, we use research onion terminology of Saunders et al. (2012). The philosophy of this research is more realistic and somewhat pragmatic, because we want to check out the previous researches independent of our present knowledge. Our research approach is induction because we intend to identify gaps and trends by analyzing collected data; the research strategy is survey that involves collecting data from a population and structured observations; the time horizon of research is longitudinal and to ensure the methodological accuracy of literature review, we use systematic techniques of content analysis. Content analysis has 4 steps (Mayring, 2002; Brandenburg et al., 2014; and Ansari and Kant, 2017):

• *Material collection* (collecting articles and documents and defining analysis unit);
• *Descriptive analysis* (assessing formal characteristics of the material);
• *Category selection* (selection of structural dimensions and related analytic categories which will be applied to the collected material);
• *Material evaluation* (analyzing the material according to the structural dimensions and analytic categories).

Material collection

The most common method of obtaining publications and articles for studying literature is keyword-based searching on electronic databases and library services (Seuring and Gold, 2012). In order to review the literature, we consider online scientific articles published between 1990 and 2016. An article is selected when its content is related to quantitative modeling and sustainable SCND and also wrote in English and published within the mentioned time period. Therefore, different dual words combinations and multi-words combinations of keywords and phrases were used to find suitable material, which come as follow: "network design", "design", "designing", "configuration", "strategic", "supply chain", "logistics", "optimization", "quantitative", "mathematical", "simulation", "modeling", "programming", "sustainable", "sustainability", "green", "recycling", "environment", "environmental", "reverse", "closed-loop", "carbon-footprint", "social" and "societal". Finally, the articles were searched, gathered and selected through all following procedures and resources:

a. *Searching in scientific databases*: By using of above key words and focusing on the title, abstract and key words of indexed articles, the best scientific databases were searched such as: *Science Direct*, *Taylor and Francis*, *Springer*, *Emerald*, *Wiley*, *IEEE Xplore* and *JSTORE*;

b. *Searching in Google Scholar*: To ensure accuracy and access to more documents especially conference articles and other databases, we also searched Google Scholar;

c. *Exploiting previous review article*s: To prevent of ignoring most relevant articles and getting indirect help from other researchers, we referred to 20 surveys published in SCND area and related fields previously.

In addition, it should be noted that in many cases we also access to some other new articles by source tracking through the references of the existing articles.

Descriptive Analysis

After refining search result, according to the selection conditions mentioned before in material collection section, 261 articles which had the most relation to the purpose of research out of 81 journals and about 20 scientific conferences were selected as a set of articles. Before making a structural analysis, selected articles are analyzed from descriptive aspects through these *official dimensions*: articles distribution during the time (years), frequent publishing journals, authors, universities and countries in sample (selected articles). Fig. 1.a and 1.b show distribution of selected articles based on the year of publication and publishers. Publication frequency showed the trend which increased relatively during desired period of time and especially from 2008. Between all publishing journals, *"Journal of Cleaner Production"* is the most frequent one. Almost 30% of sample articles have been published in 5 first journals and 60% of published articles have been published in top 20% journals. 21 articles that is presented in international scientific conferences.

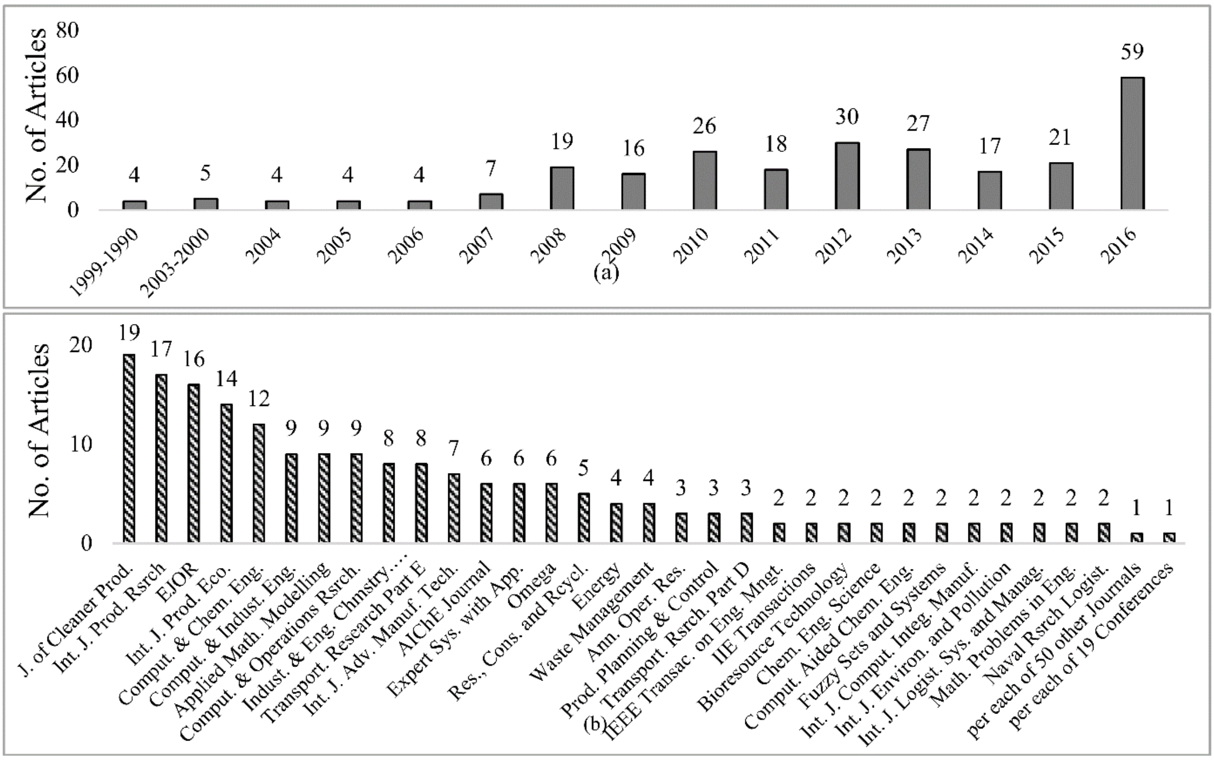

Figure 1. Distribution of collected articles a) over time; b) by journals

Between all authors, *Kannan Govindan* (South Denmark University, Denmark), *Seyed Ali Torabi* (University of Tehran, Iran) and *Gonzalo Guillén-Gosálbez* (URV University, Spain) are the most frequent researchers in our sample (See Fig. 2.a). Also between the reviewed articles, the authors correspond to theses five universities respectively, have the most frequencies: University of Tehran, Amir Kabir University of Technology, South Denmark University, URV University and New University of Lisbon. These five countries: USA, Iran, China, Canada and Turkey respectively have the most contribution of publishing articles and totally they owned 64% of all written articles. It should be noted that 9 authors out of 28 top authors are from Iranian's Universities and specially half of them are from Tehran University which shows the relatively low distribution authors of this field on the other Iranian's universities. In contras of t although USA rank first in the list of repetitive countries, relatively low presence of USA's universities in the upper half of the list of 40 repetitive universities illustrated more dispersion of researchers between USA's universities (See Fig. 2.b and 2.c).

Category Selection (Structural Dimensions)

To meet the purposes of the research, the categories and dimensions of content analysis should be determined according to the research questions. To do so, it can be use deductive and inductive approach (Ansari and Kant, 2017). Based on the research questions and different characteristics of quantitative models of SCND (Brandenburg et al., 2014), seven structural dimensions are defined and analysis categories were determined deductively and developed inductively by reviewing articles. The structural sub-dimensions of model characteristics include: number of objective functions, linearity, capacity limitation of facilities, number of time periods, number of products and number of transportation modes. The flow dimension in supply chain network includes forward, reverse (backward) and closed-loop. Also studied models may have non-deterministic parameters or not. Because of reviewing sustainable models in this research, along with economic considerations, articles can be noted to one of considerations environmental and social or both of them at the same time. In a small section of selected articles, attention has been paid to supply chain resiliency against strategic risks and disruption. The dimension of modeling approaches includes mixed integer linear programming, mixed integer non-linear programming, linear programming, non-linear programming, fuzzy approaches, simulating approaches and finally sub-dimensions of solution methods involve commercial solver software, approximate algorithms, heuristic and meta-heuristic, exact algorithms, analytical and multi-criterion approaches, simulation approaches and so on.

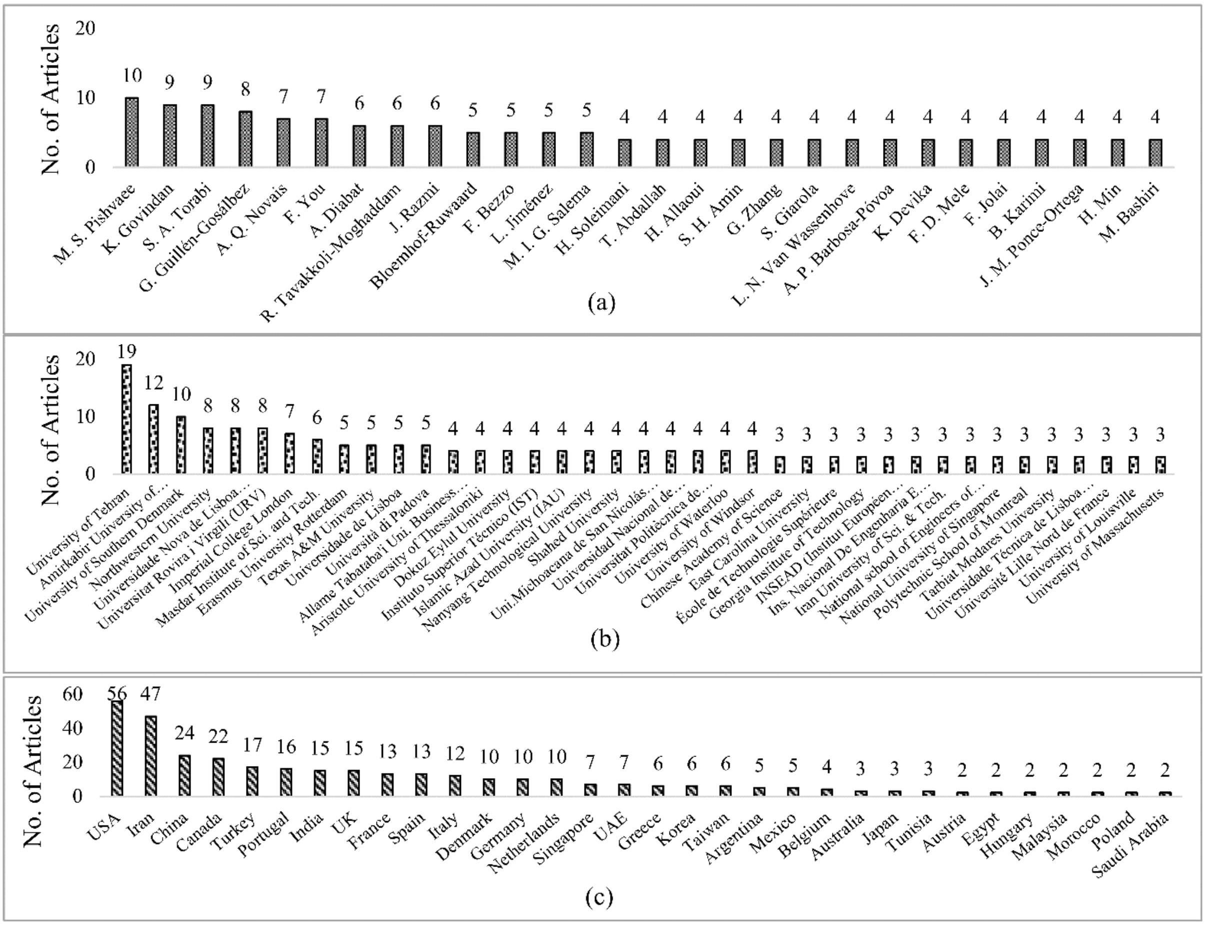

Figure 2. a) Researchers, b) Universities and c) Countries which have the most articles in the set of study

Material Evaluation

In this phase, each of selected articles were assessed and analyzed according to structural dimensions and analytical categories. In phase of categories selection also with combination of two approaches of deductive and inductive a suitable classification was obtained. To ensure research enrichment and verification of characteristics which assigned to the articles, the results was compared with other review articles. Also to minimize errors and analyzing different aspects we used Microsoft Excel 2013. Finally the results were shown in the Graphs. The reviewed references and structural characteristics for each article can be found at the appendix. In the next section the results will be discussed.

Findings and Discussion

To achieve a comprehensive view in review of quantitative models of sustainable SCND, the selected articles will be discussed based on structural dimensions. The result of this survey can clarify the existing gaps and future research directions.

Model Characteristics

Single-objective models obtain only an optimal solution while multi-objective ones consider different and conflicting objectives, so yield a set of Pareto solutions. In multi-objective models of SCND, the objectives are usually either economic-environmental or economic-environmental-social (Ghaderi et al., 2016). Fig. 3.a and 4.a respectively illustrate the percentage and trend of single-objective models and multi-objective ones in the set of reviewed articles. According to this, almost 54% and 45% of reviewed models respectively are single-objective and multi-objective ones and approximately in 1% of all articles single and multi-objective models have been employed at the same time. Also it was distinguished that near 78% and 20% of all articles which have mathematical models, employed linear and nonlinear models (See Fig. 3.b). This shows a higher number of linear models during over the past two decades, however, both trends are ascending (Fig. 4.b). Due to the complexity and non-linear nature of real world issues, it can be expected the growth of non-linear models by moving researchers from charity theoretical articles to practical articles in the future. The mentioned trend also shows it by the end of 2016. Breaking the time horizon in to a few time periods will lead to improve decision-making process (Ghaderi et al., 2016). Notwithstanding to the growth of multi-period models, 65% of reviewed models are single-period (See Fig. 3.c). Fig. 4.c shows the trends of using single-period models and multi-period in different years within the selected sample. Complexity of modeling and difficulty of solving multi-period models could be cause of fewer tendencies of researchers to these models. The supply chains use one transportation mode or combination of transportation modes to move materials and productions between chain members.

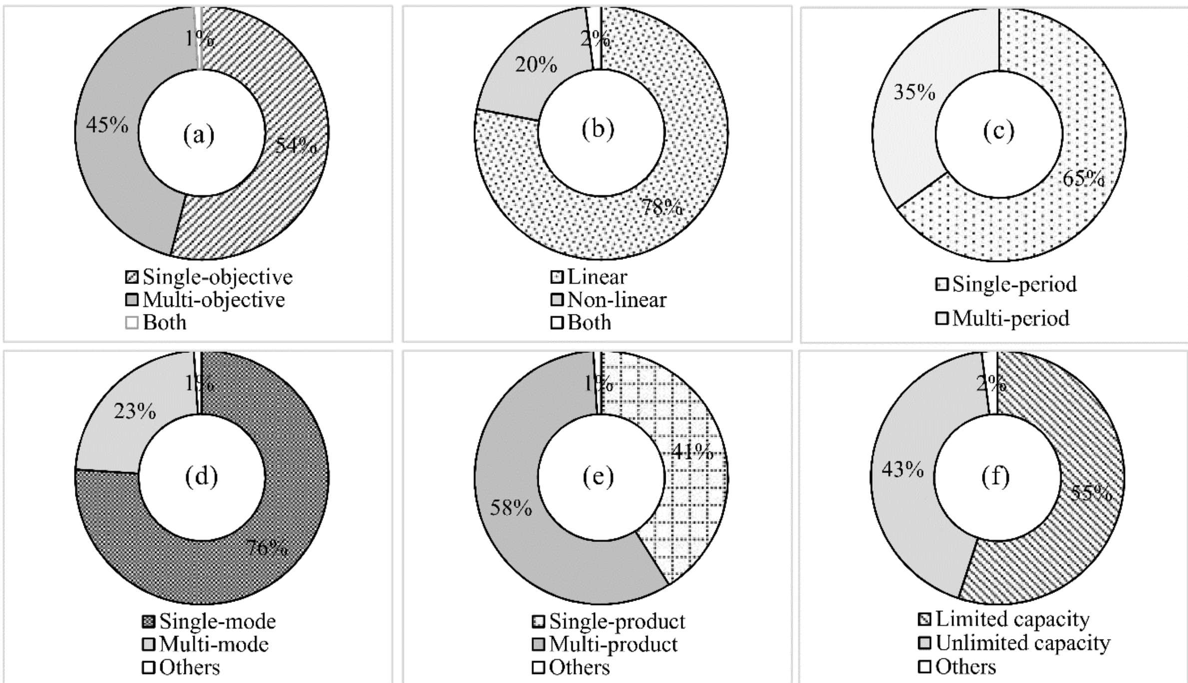

Figure 3. The portion of selected articles in each of sextet characteristics

Regardless of whether the transportation mode in SCND belongs to set of decision variables or one of the problem's assumptions, SCND models can be divided to two models categories of single-mode and multi-mode models. Review of selected articles showed that 76% of models have one and 23% of models have multiple transportation modes and the remaining 1% whether unknown or transportation considerations have not been seen in the models (See Fig. 3.d and Fig. 4.d). In addition, the majority of reviewed models have considered more than one product (about 58%). the growth rate of considering multiple products (especially from 2008 to 2016) has been higher than single product (See Fig. 3.e and Fig. 4.e). Regardless of whether the capacity of facilities belongs to set of decision variables or not, SCND models can be divided to capacity-constrained models and without capacity limitations. The review of selected articles showed more researchers' tendency of employing models with capacity limitations (See Fig. 3.f and Fig. 4.f).

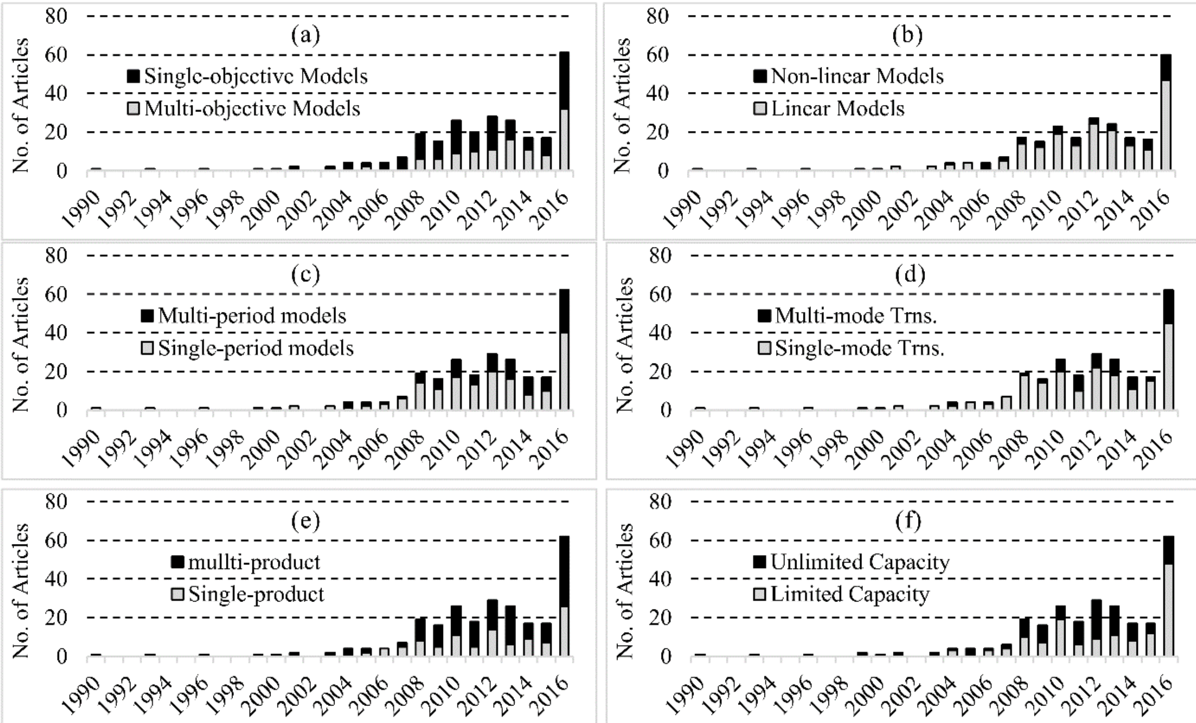

Figure 4. Frequencies of selected articles in each of sextet characteristics of model in desired horizon

Supply Chain Network Flow

Generally, supply chain has two types: *forward* and *reverse* (backward) supply chain. A supply chain in its traditional form (forward supply chain), is a combination of processes to meet customer demands and includes carriers, warehouses, retailers and customers (Chopra and Meindl, 2007). According to definition of American Reverse Logistics Executive Council, *"The process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal "*. If forward and reverse supply chains consider at the same time, the obtained network is named *closed-loop supply chain* (Govindan et al., 2015b). As shown in Fig. 5, approximately 54% of the articles have reverse supply chains (i.e. reverse and closed-loop).

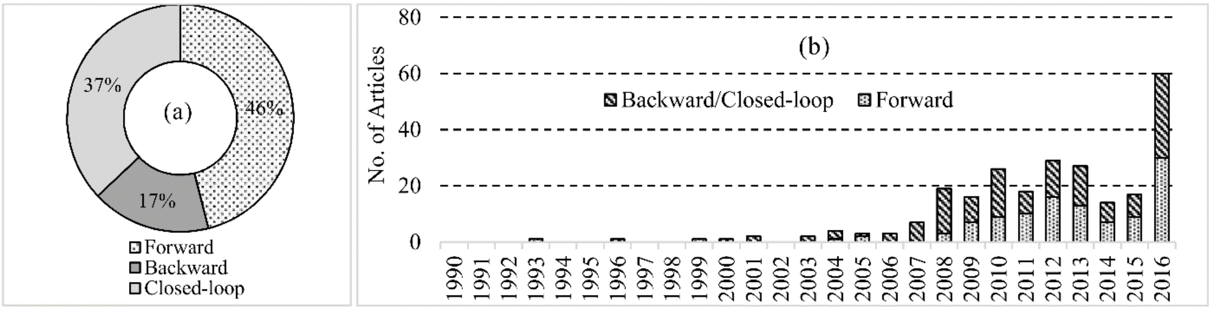

Figure 5. Portion of forward, reverse and closed-loop supply chains in the reviewed articles and their frequencies in desired horizon

Sustainability

Environmental and social considerations in the time of facilities locating, logistics and transportation planning, are important. Optimal use of available resources and used products and wastes management are more important in reverse SCND. In the field of SCND, every effort is being made to help the environment and society, is considered a positive action toward sustainability.

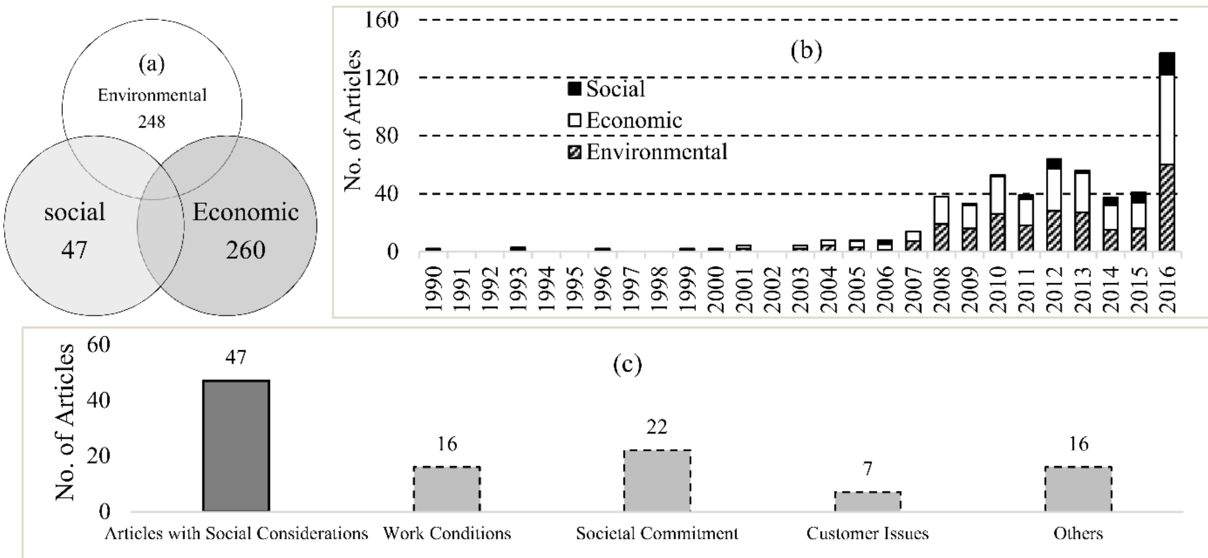

Figure 6. a) The portion of different dimensions of sustainability b) the frequency of each dimension in desired horizon; c) The frequency different social sub-dimensions in the reviewed articles

As can be seen in Fig. 6.a, most of selected articles have focused on environmental sustainability (248 articles) and a small number of articles (47 articles) have focused on social dimension. Only 33 articles have considered all of three dimensions economic, environmental and social. In the recent years, sustainability issues especially environmental ones have grown rapidly in SCND. Although the attention of social issues has been increased recently, but this is still scrimp (See Fig. 6.a and Fig. 6.b). It can be said that the abundance of reserve supply chain concerns and their close relationship with sustainability are also the reason for growth of sustainable considerations in the recent decades in SCND articles. Improvement in work conditions (such as workers' work life), societal commitment, customer issues are of the main social sub-dimensions. Fig. 6.c shows the frequency of different social considerations.

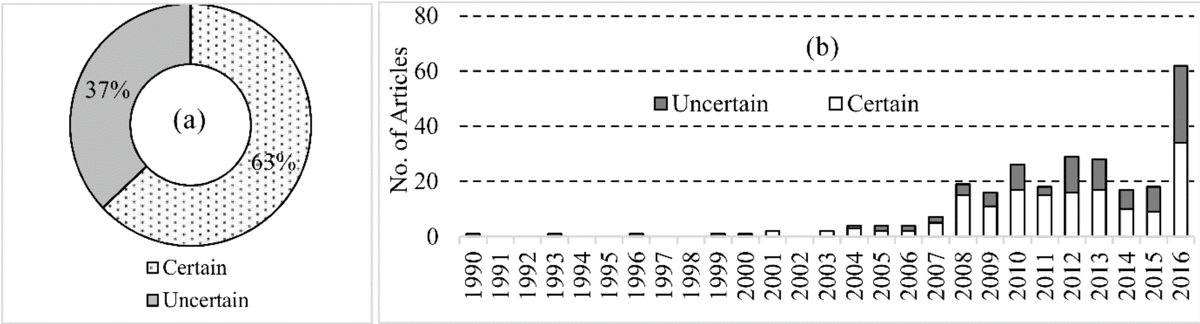

Figure 7. Contribution of certain and uncertain models in the reviewed articles and their frequencies over time

Uncertainty Consideration

There are several approaches to deal with uncertainty which include stochastic programming approaches, possibilistic programming, fuzzy logic, interval programming, chaos theory or combination of aforementioned approaches (Ghaderi et al., 2016; Govindan et al., 2015b). The distribution of selected articles and their frequency trends can be seen in Fig. 8. The real world problems are usually associated with uncertainty, so programming challenges in these situations can be one of the reasons why researchers are less likely to be involved with such problems.

Resilience

Although resilience is not a subset of sustainability issues and it is discussed under the topics of risk and uncertainty in supply chains, in this article we evaluated it separately because of its importance. Like sustainability, resilience issues are also including the topics that encourage moving from economic optimality paradigm to business continuity paradigm. The aim of different resilience strategies is reducing the effects of operational and disruption risks which constantly are threatened the supply chain structure and its continuity. Before this, different type of resilience strategies has been presented in section 2. In the set of selected articles which are related to the field of quantitative models of sustainable SCND, only 21 articles have taken into consideration resiliency strategies. Among all type of strategies, redundancy and flexibility have been employed more. The historical trend shows that attention to the resiliency in SCND are growing and specifically has grown dramatically in 2014 (See Fig. 8.a and Fig. 8.b).

Modeling approaches

There are different approaches for making decision in the SCND literature, like mathematical programming, simulating, multiple-criteria decision-making and so on. There may be some overlaps between different approaches (Ghaderi et al., 2016). Generally, the use of mathematical programming models is so common for SCND problems. The major decision variables in SCND models are binary variables which related to facilities location, sizing decisions, appropriate technology selection and selecting transportation modes between facilities (Eskandarpour et al., 2015). Here about 86% of reviewed articles have modeled with one of the types of mathematical programming. Fig. 9.a shows the distribution percentage of existing models in selected articles set. It should be noted that between mathematical programming models, MILP are the most common and attractive approach with the portion of 65%. Out of 8 articles which have simulation models, 5 of them have published in 2016 which can be a promising trend. About 66% and 15% of multi-objective articles have been finally modeled respectively by MILP and MINLP/NLP.

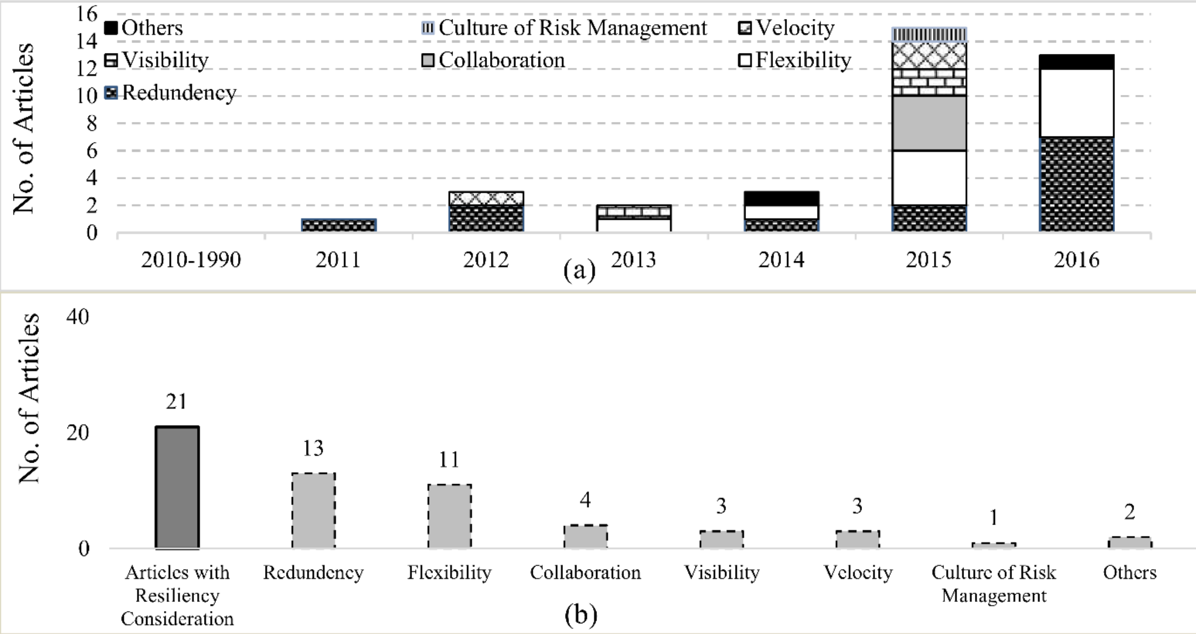

Figure 8. Frequency of different resilience strategies a) over time and b) by each strategy

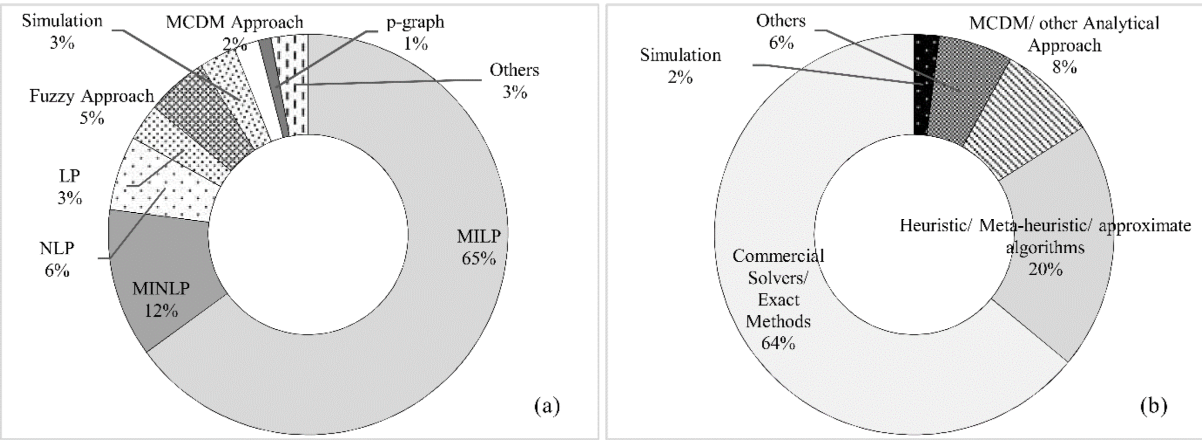

Figure 9. a) The portion of different employed modeling approaches; b) The portion of different solution methods employed in the reviewed articles

Solutions

Although SCND is generally a NP-hard problem (Pishvaee et al., 2010b; Devika et al., 2014 pand Saffar and Razmi, 2014); the cases with medium size are still solvable by commercial solvers (Eskandarpour et al., 2015). In this article the solutions are classified in five major categories: exact methods; commercial solvers; heuristic, meta-heuristic and approximate algorithms; simulation techniques; and analytical and multiple-criteria methods. Some others also have been employed that is placed in *other*s category. In some cases, solutions have overlaps with each other and may be used more than one solution. Fig. 9.b shows the portion of each aforementioned category among used solutions in selected articles. As it is clear, almost half of used solutions are commercial solvers. Our results showed that in almost 59% of cases of linear programming or mixed integer linear programming models, commercial solvers were employed and in 19% of these cases heuristic, meta-heuristic and approximate algorithms were used. In cases of NLP or MINLP models, 54% of cases have used commercial solvers and 38% of cases have employed heuristic, meta-heuristic and approximate algorithms. Since the large sizes of SCND problems are NP-Hard and cannot be solved by exact solutions and commercial solvers, it can be concluded that the number of large size problems between the articles are not so much. Commercial solvers and exact algorithms have been used in solving majority of the articles. In addition, near 54% of multi-objective articles finally have been solved by one of commercial solvers and 26% by heuristic algorithms and 14% by exact algorithms.

Conclusions and Implications for Further Research

It is not possible to achieve sustainable development without the contribution of supply chains to strengthening economic, environmental and social sustainability. The supply chain design is one of the first and important phases to accept such participation. This is where managers can prefer long-term benefits for chain/community and also long-term continuity of operations than common short-term economic benefits. This study is a comprehensive review on 261 articles related to quantitative models of sustainable SCND which published 1990 to 2016. In this literature review we were going to answer the research questions by conducting content analysis method and analyzing the articles in seven structural categories. The results can help researchers to build their new research program. First of all, time distribution of selected articles was presented and top journals, universities and countries in term of publication frequency introduced. This information is very useful for researchers whom interested in co-operating with other authors, professors and following this field of research at different universities in the world. Then trends and portion of sub-dimension were reviewed in each of structural dimensions. Findings showed that: 1. Researches has been growing dramatically in this field, especially since 2008; 2. Most research has been conducted in five countries; 3. the most of quantitative models of SCND have published respectively in five top journals; 4. the selected articles classified into 7 analytical categories. An Ascending trend is observed for multi-objective models. Also multi-period models and multi-mode models grow slowly. Although the growth of uncertain models is tangible, but it is still not much compared to certain models. In the sustainability category, models with economic considerations are saturated with economic considerations, environmental considerations are still growing, but social dimension has not been addressed much and has experienced little growth. The resilience considerations are an emerging topic and gradually grow in the field of quantitative models of SCND. In recent years, simulation attracted the attention of researchers, both as a modeling approach and as one of the solutions methods; 5. Generally, the researchers were more interested in: single-objective, linear programming, single-period, multi-product, capacity-limited facilities, multi-mode, reverse and environmental models, than other types of models and considerations; 6. In phase of modeling and solving, the authors have used more of mathematical programming and commercial solvers; 7. Only in 47 articles (about 18%) of selected articles social sustainability considerations have been addressed. In contrast, 95% of the selected articles have taken into consideration environmental issues. But only in 33 articles at the same time all sustainability dimensions were addressed. Difficulty of quantifying and modeling social factors can be considered as one of the main reasons for neglecting them. In some cases, social factors are indirectly considered in assessment of economic and environment factors; 8. Only 21 articles have addressed supply chain resilience but the trends are promising to bring these issues to SCND. Most of researchers have emphasized on two resiliency strategies, i.e. redundancy and flexibility which one of its reasons can be the ease of quantifying them; 9. Since problems with multi-period modeling, multi-mode modeling, uncertain modeling and non-linear programing are more complex, they are not so attractive to scholars. This is while most of real-world problems have such situations and dimensions. The analyses of this study draw some insights and propose several extensions for future research as follows:

1. It is necessary to transit from small academic problems to large real problems. Strengthening the link between practitioners and scholars can help understanding current questions and problems of industries.

2. Due to the inability of common algorithms in solving many real-world problems, there is a need to develop new algorithms such as decomposition-based, approximation, heuristic or hybrid ones.

3. Most of sustainability studies are poor in addressing social issues. The results of the research emphatically insist on increasing social considerations in supply chain network design for future researches. Also developing new methodologies to quantify social dimensions is still a challenging issue. Determining the depth and breadth of social impacts of supply chains is another issue that needs to be discussed more.

4. The integration of social consideration in SCND should not be regarded as an outward beauty for sustainability articles. In order to make it more serious and effective, employing the new research methodologies of *soft OR* is suggested, such as *critical systems heuristic*, especially in the process of defining and extracting different impacts of supply chain on society and stakeholders.

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