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Supply Chain Network Design: A Comprehensive Literature Review

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Abstract:
Introduction: Supply chains are the integrated and coordinated flows of goods from source to destination, as well as the information and money flow associated with it. The management of supply chain aims at maximising the value of contribution to the customer while simultaneously optimising infrastructural and operational costs and also consists of firms collaborating to leverage strategic positioning and to improve operating efficiency. The introduction of multi-items and varied product lines and the growth of competitive pressure have forced firms to change the supply network design (SCN) quickly through innovation and improvements. This also allows the top management to rethink to create strategy, competitive advantages for the firms and their customers to achieve the overall objectives and goals.
Methodology: This study is focused on single optimum values and models of single objectives like minimum inventory cost, minimum total cost, minimum lead time etc. with liner programming model, mixed integer programming etc.
Results: The parameters focused for such analysis are time, asset productivity, use of technology and building relationship. The basic competitive operations for tomorrow existence depends on developing and executing value acquisition strategy, deliver value as quickly as possible within the cost parameters defined by the demand market and maximise the return to the firm which help to find and leverage external sources of innovation, contribute to revenue generation, expand efforts to manage costs and ensure business continuity and sustainability.
Conclusion: The paper highlighted the existing methods, models, sustainability, solution approaches and to identify the drawbacks, missing aspects of related literature and also forecast the future research direction to the researcher.

Introduction

The supply chain for a product is the network of organisations and activities involved in production and distribution process of a company. Traditionally, organizations in a supply chain have focused on their internal operations without worrying about coordinating their activities with supply chain partners. Even within an organisation, activities are often functioned such as procurement, manufacturing, sales, and distribution. Each functional manager focuses on improving the operations within his or her scope while taking the requirements of other supply chain members as given. To exert control over activities within their scope, organizations actively buffer themselves from suppliers and customers by establishing rigid policy on interaction. For example, they may set long lead times and minimum order size for customers so that their suppliers carry sufficient inventory. So, all organizations need effective supply chain management to coordinate across organizational and functional boundaries. The supply chain function is responsible for facilitating such coordination. It involves making decisions regarding integration of multi-echelon supply chain

for multi-items, sharing information about demand and product availability with other members, integrating production and distribution decisions, setting up long-term supplier relationships, publicity effort for moving fast of deteriorated item, preservation effort for deteriorating item, writing contracts to share the risks of demand and price uncertainty among organisations, reducing lead time, and so on.

Supply chain strategy will have a major impact on creating value for a company and its supply chain partners. Supply chain strategy is based on collaborative strategy, demand low strategy and customer service level strategy. An effective supply chain strategy may be formulated to meet the needs of the market and integrate them with technology to generate highest level of customer satisfaction while delivering the highest value to the shareholder. Collaboration enables partners to jointly gain a better understanding of future product demand and implement more realistic programmes to satisfy that demand. Close collaboration among supply chain partners can be to align the parties and then enhance the value of the networks' combined activities. Collaborating with suppliers, manufactures are the key activities as product development, order fulfillment and capacity planning. Collaborative product development enabled by sharing and modifying design documents will help manufactures develop products better and faster. The collaborative opportunities between manufactures and customers centre on demand planning and inventory replenishment. The focus is on jointly developing an understanding of demand at the point of consumption, followed by the creation o a mutually agreed upon replenishment plan. This helps to ensure that customer requirements are met efficiently. Collaboration between companies and third party logistics (3PL) providers will focus on jointly planning activities. Packaging is the potential area for logistics collaboration. Collaboration with 3PLs providing distribution centre (DC) services would focus on the productive use of facilities, labour and equipment .In supply chain management, the key focus and scope has been in managing the flows of materials and goods from suppliers through the manufacturing and distribution chain to customer. The key in demand management is the continuous flow of demand information from customer and end-users through distribution and manufacturing to suppliers. The most important controlling inputs are rolling forecasts and plans, point-of-sales, daily orders, management decisions ad performance feedback.

A key issue in SCM is then to develop an integrated multi-echelon supply chain model mechanism that can align the objectives of independent supply chain members and coordinate their decisions and activities so as to optimize system performance and profit. In the real world, procurement and inventory control are truly large scale problems, often involving more than hundreds of items. In a multi-item distribution channel, considerable savings can be realized during the replenishment by coordinating the ordering of several different items. Multi-echelon multi-item replenishment strategies are already widely applied in the real world, for example, the supplying of parts for computers and for automotive assembly or refrigerated goods to supermarkets. In these industries, a supplier normally produces different products for a single customer and ships to the customer simultaneously in a single truck. In the grocery supply industry or a fast moving consumer goods industry different types of refrigerated goods (General Mills yogurt, Derived Milk products etc.) can be shipped in the same truck to the same supermarket or retail stores. Because multi-echelon coordination is frequently applied in current business practice, it is an essential component in supply chain model. Hence the multi-echelon supply chain is the focus of the present study. In framing multi-echelon supply chain model, it is tacitly assumed that the retailer (buyer) must pay for the items as soon as he receives them from a supplier.

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Over the last four decades a lot of work has been published for controlling the inventory of deteriorating items. Products are assumed to deteriorate with time resulting in a decreasing utility or price from the original one. Some of the examples of perishable items are fresh sea foods, medicines, battery, volatile chemicals and semiconductor chips. For perishable items, such as medicine, volatile liquids, and food, product quantity decreases because of deterioration during a normal storage period. Ordering policies for deteriorating items under the condition of permissible delay in payments or ordering multi-items.

Literature Review

It focused on single optimum values and models of single objectives like minimum inventory cost, minimum total cost, minimum lead time etc. with liner programming model, mixed integer programming etc.

Azaron et al.(2008): *A Multi-Objective Stochastic Programming Approach for Supply Chain Design Considering Risk*

In this paper authors are focused on uncertainty, demand, supplies transport supply chain structure with multiple stochastic programming approach and also multi objective models like minimization of current investment cost and expected future processing, transport costs. They also use the goal attainment technique for finding Pareto-optimal result that can be applied in decision making.

Tsao, et.al.(2012):*A Supply Chain Network Design Considering Transportation Cost Discount*

This paper descried the two types of transport discount where one is quantity transport discount for inbound and another is distance discount for outbound. And also study focused on integrated and inventory facility location problem. Here supply chain network designused nonlinear optimization techniques.

Liu, et.al (2013): *Multi objective Optimization of Production, Distribution and Capacity Planning of Global Supply Chains in the Process Industry*

This paper address the production, distribution and capacity planning in supply chain and it measured by multiple criteria. Here author used mixed integer liner programming with total cost, total flow time and total lost time. Here the multi objective problem is solved by methods of mini- max and e-constraint and at last numerical example are applied in models.

Garcia-Herreros, et al. (2014): *Design of Resilient Supply Chains with Risk of Facility Disruptions*

Here authors used supply chain which formulated a two stage stochastic problem and it involves multiple commodities with distribution center location. The model emphasized to minimize the investment cost &expected distribution cost in finite time horizon. Now the model is used in large scale industries.

Nekooghadirli, et al. (2014): *Solving a New Bi-Objective Location-Routing-Inventory Problem in a Distribution Network by Meta-Heuristics.*

This paper included bi-objective location routing inventory model in multi–period and multi product problem in two –echelon distribution network. Here the key objectives are focused on to minimize the uses of vehicle, fuel consumption, holding cost, transportation cost etc. and to reduce the shortage of product using validity presented model.

Bojarski, et al. (2009*): Incorporating Environmental Impacts and Regulations in a Holistic Supply Chains Modeling*

This paper concerned in environmental performance and economic performance in supply chain planning and how the supply chain entities are impact on sustainability different strategic decision models are considers in location, technology selection, and production

distribution. Here a lifecycle assessment approach is used environmental aspects how reduced the value –subjectivity inherent to the assignment of weight in calculation by end point damage. This is considered as objective function. The mathematical formulation of this problem becomes a multi-objective MILP (MOMILP). Criteria selected for the objective function are damage categories impacts and net present value (NPV).here also considering a case study of distribution supply chain network and its distribution center.

Alçada-Almeida et al. (2009): *A Multi objective Modeling Approach to Locating Incinerators*

This paper identify the locations and capacities of facilities by introducing a mixed-integer, multi-objective programming approach. It incorporates a Gaussian dispersion model and a multi objective optimization model in a GIS-based interactive decision support system that planners can access via the Internet. This method is applied through a case study to locate larger facility of hazardous waste.

Lee, et al. (2009): *Network Model and Optimization of Reverse Logistics by Hybrid Genetic Algorithm.*

The study focused on three stages logistic network model for minimization the total cost to reverse logistics shipping cost and fixed opening cost .this paper considering a multi-stage, multi-product disassembly center and processing center. In 1st stage and 2nd stage used genetic algorithm with priority method. And 3rd stages used heuristic approach method to transportation of parts from processing center to manufacturer.

Wang, et al. (2011) : *A Multi-Objective Optimization for Green Supply Chain Network Design*

In this paper authors suggested a supply chain network design with environmental issues and proposed a multi-objective optimized model with investment decision in total trade-off cost and the environmental influence. Here models are applied in strategic planning for green supply chain and also sensitivity analysis provides managerial insights for organizations.

Pishvaee, et al. (2011): *A Robust Optimization Approach to Closed-Loop Supply Chain Network Design under Uncertainty*.

The study focused on a robust optimization for uncertainty input data in closed loop supply chain network problem and developed a deterministic mixed-integer linear programming model to apply in closed–loop supply chain network. Then, the robust counterpart of the proposed mixed-integer linear programming model is applied in recent extensions in robust optimization. At last, it assesses the robustness of the solutions obtained by the novel robust optimization model.

Chaabane, et al. (2012): *Design of Sustainable Supply Chains under the Emission Trading Scheme*

This paper presented in a mixed-integer linear programming for sustainable supply chain design that in life cycle assessment principles. The models are used to evaluate the tradeoffs between economic and environmental objectives with different cost and operating strategies in the aluminium industry. The results suggest the legislation and Emission Trading Schemes must be strengthened and harmonized at the global level for environmental issues, the model demonstrates that efficient carbon management strategies will help decision makers to achieve sustainability in a cost-effective manner.

Elhedhli, et al. (2012): *Green Supply Chain Network Design to Reduce Carbon Emissions*

This paper focused on emission cost with fixed and variable location and production costand CO2 emission on supply chain network design problems. Here authors are used lagrangian relaxation method for decompose problem into a capacitated facility location problem and also focused knapsack problem that solve easily. They also proposed lagrangian heuristics based on solution for sub problem the result indicating can change the optimal solution of supply chain.

Pérez-Fortes, et al. (2012): *Design of Regional and Sustainable Bio-Based Networks for Electricity Generation Using a Multi-Objective MILP Approach.*

Here the paper addresses traditional factors in optimal solutions in complex situation and represents of a multi-objective bio-based energy supply chain network subjected to multiple sources of uncertainty. So they proposed data–driven decision making strategy for current problem by using conventional optimization technique. The strategy explained here is to reduce the computational effort for future optimizations. Thus the use of the proposed data-driven decision tool promotes a time-effective optimal decision making, which represents a step forward to use data-driven strategy in large-scale/complex industrial problems.

Diabat, A. et.al (2013*): Strategic Closed-Loop Facility Location Problem with Carbon Market Trading*

In this paper addresses multi-echelon multi commodity facility location problem with a trading price of carbon emission and cost of procurement. Now days companies are forcing to green their supply chains by integrating business value–adding operation with minimize the impact on environment. A numerical study is presented which studies the impact of different carbon prices on cost and configuration of supply chains.

Amin, et al. (2013): *A Multi-Objective Facility Location Model for Closed-Loop Supply Chain Network under Uncertain Demand and Return.*

This paper focused on forward and reverse supply chain for a closed–loop supply chain network. It include multiple plants, collection center, demand markets, product in closed –loop supply chain (CLSC) and explained a mixed integer linear programming model is proposed to minimize the total cost. Authors also investigate the impact of demand and uncertainties on the network configuration by stochastic programming

Garg, et al. (2015): *A Multi-Criteria Optimization Approach to Manage Environmental Issues in Closed Loop Supply Chain Network Design*

In this paper deals with the environmental issues presented in the design of CLSC networks. The CLSC network proposed in the paper consists of four echelons in the forward chain and five echelons in the backward chain. Here they proposed a bi-objective integer nonlinear programming approach algorithm. This model determines the optimal flow of parts and products in the CLSC network and the optimum number of trucks hired by facilities in the forward chain of the network. A numerical experimentation of the proposed model to validate the applicability of the model is done with the help of data from a real life case study.

Chibeles-Martins, et al. (2016*): A Multi-Objective Meta-Heuristic Approach for the Design and Planning of Green Supply Chains*

The paper proposed an optimization model to support the associated decisionsand focused on the supply chain design and planning problem. The proposed model is a Mixed Integer Linear Multi-objective Programming model, which is solved through a Simulated Annealing based multi-objective meta-heuristics algorithm - MBSA. The algorithm explained the location and capacities of the supply chain entities (factories, warehouses and distribution centers) chooses the technologies to be installed in each production facility and defines the inventory profiles and material flows during the planning time horizon. Profit maximization and environmental impacts minimization are considered.

Taxakis et al. (2016): *A design model and a production-distribution and inventory planning model in multi-product supply chain networks*

In this paper the authors proposed two models. The first model is a mixed-integer linear programming model by concerning with the supply chain network design problem, whereas the second operational model is a mixed-integer non-linear programming model in respect to

the production-distribution and inventory planning problem in a supply chain network. By knowing the number of customers and suppliers as well as their demand and capacities two steady-state genetic algorithms is implemented in MATLAB in order to solve both the design and the operational model. By applying two genetic algorithms the multi-product supply chain network design problem, the multi-product, multi-time period production-distribution and inventory problem are solved. These two models could provide the practitioners with useful tools in making critical decisions for the supply chain at a strategic as well as at a tactical and operational level for perfection of their supply chain. The results are compared with GAMS for both first and second models. It is found that for some cases GA provides better results with accuracy than GAMS.

Babazadeh, et.al (2017*): A Sustainable Second-Generation Biodiesel Supply Chain Network Design Problem under Risk.*

This paper focused on possibilities multi-objective programming model to design a second-generation biodiesel supply chain network under risk. The proposed model minimizes the total costs of biodiesel supply chain from feedstock supply centers to customer centers besides minimizing the environmental impact (EI) of all involved processes under a well-to-wheel perspective. The performance of the proposed possibility programming method as well as the developed solution approach are evaluated and validated through conducting a real case study in Iran. The result of this study examined the high investment cost is required for improving the environmental impact and risk of sustainable biodiesel supply chain network design under risk.

Islam et al. (2017): *A joint economic lot size model for a supplier-manufacturer-retailer supply chain of an agricultural product*

This study presented a three-tier joint economic lot size supply chain model of delivering agricultural products which are comprising of a single seasonal supplier, a single manufacturer and multiple retailers. Demand is assumed as deterministic constant. The objective of this study is to find the number of shipments and shipments size in a cycle from the supplier to the recipient to minimize the total cost of ordering, setup, shipment and holding. Considering the strategic use of a seasonal supplier‘s time and the modern integrating tendency among the supply chain players for greater benefits, the authors have developed a new agro based joint economic lot sizing model. They have considered conversion ratio of raw materials to finished product. Both algebraic and the differential methods of solution to the model are employed to provide the results theoretically, which is also validate through many numerical example problems. By following the algorithm of parallel multiple jumps technique the integral number of shipments is calculated which is also found to be globally optimal. The sensitivity analysis on the results of the example problems is shown that the low shipment cost leads to frequent shipments of smaller sizes.

Analysis

The study illustrates the sustainability development of supply chains in the form of economic, environmental and social aspects. As sustainability becoming an important part of everyday decision making process of firms within local and global supply chains, the analysis is divided into three different aspects based on the area of interest i.e. economic sustainability deals with cost and financial stability of supply chains, environment sustainability deals with the impact of the supply chain on the environment and social sustainability studies the impact of supply chain on societies, human well beings and stakeholders. The outcome of modeling and sustainability of above literatures are shown in the Table 1.

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Table 1: Taxonomy of Approaches for Modelling and Sustainability of Supply Chain Models of the other recent research

Name of Author and Year	Modelling	Sustainability
Azaron et al.(2008)	HA	ECO
Tsao, et.al.(2012)	NLP	ECO
Bojarski.a.d,et.al (2009)	MILP	ECO
Alçada-almeida.et.al (2009)	MILP	Eco-Env-Soc
Wang, f.et.al (2011)	LP	Eco-Env
Pishvaee,m.s.et.al 2011)	MILP	Eco-Env
Chaabane, a.et.al. (2012)	MILP	Eco-Env
Elhedhli. S.et.al. (2012)	MILP	Eco-Env
Pérez-Fortes, M.et.al (2012)	MILP	Eco-Env
Diabat, A. et.al (2013)	MILP	Eco-Env
Amin, S. H.et.al. (2013)	GA	Eco-Env
Nekooghadirli, et.al (2014)	HA	Eco
Garg, K.et.al (2015)	MINLP	Eco-Env
Taxakis et al. (2016)	MINLP	Eco-Env-Soc
Chibeles-Martins,N.et.al (2016)	FA	Eco-Env
Babazadeh. R. et.al (2017)	MILP	Eco-Env
Islam et al. (2017)	MILP	Eco-Env

#MILP=Mixed Integer liner Programming
MINLP=Mixed Integer Nonlinear Programming
NLP= Non Liner Programming
LP= Liner Programming
HA= Harmonic Approach
SA= Stostatics Approach
GA= Geometric Approach
GA= Geometric Approach

Further the analysis also concludes the taxonomy of analytical approaches for production distribution system of supply chain models of the researchers on basis of objective, number of echelons, no. of commodities, demand, time period, deteriorated items, financing, publicity, preservation effects and their applications related to industries are shown in Table 2.

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Table 2: Taxonomy of Analytical Approaches for Production-Distribution System of Supply Chain Models of the other Recent Researches

Sl. No.	Authors' Detail	Objective Function (C/P/M)[1]	Number of Echelons in the Supply Chain	Number of Commodities (S/M)[2]	Demand (D/S)[3]	Number of Time-Periods (S/M)[2]	Deteriorated Items (+/-)	Forward Financing (+/-) & (F/P)[4]	Publicity Effect (+/-)	Preservation Technology Effect (+/-)	Industrial Applications (+/-)
1	Cohen (1977)	P	1	S	D	S	+	-	-	-	-
2	Graves (1979)	C	2	M	D	S	-	-	-	-	+
3	Kao (1979)	C	1	M	D	M	-	-	-	-	-
4	Khedher et al. (1994)	C	1	M	D &S	M	-	-	-	-	+
5	Hwang et al. (1997)	P	1	S	S	M	+	+ & F	-	-	+
6	Chung (1998)	C	1	S	D	M	-	+ & F	-	-	-
7	Chang et al. (2001)	C	1	S	S	M	+	+ & F	-	-	-
8	Yang et al. (2002)	C	2	S	D	M	+	-	-	-	+
9	Khouja (2003)	C	3	S	D	M	-	-	-	-	+
10	Chen et al. (2005)	C	2	M	D	M	-	-	-	-	+
11	Lee et al. (2006)	C	3	S	D	S	-	-	-	-	+
12	Huang (2007)	C	1	S	D	S	-	+ & P	-	-	+
13	Chen et al. (2007)	P	3	M	S	M	-	-	-	-	+
14	Tsao et al. (2008)	P	1	S	S	M	+	+ & F	+	-	+
15	Ouyang et al. (2009)	C	1	S	D	S	+	+ & P	-	-	+
16	Tsao (2010)	P	1	S	D	S	+	-	-	+	+
17	Tsao et al. (2012)	P	3	M	D	M	-	+ & F	-	-	+
18	Tsao et al. (2012)	P	3	M	D	S	-	+ & F	-	-	+
19	Dye et al. (2012)	P	1	S	D	M	+	-	-	+	-
20	Tsao et al. (2013)	C	1	M	D	S	-	+ & F	-	-	+
21	Present study (2020)	P	3	M	D / S	M	- /+	+ & F/P	+	+	+

1: C: Cost, P: Profit, M: Multiple
2: S: Single, M: Multiple
3: D: Deterministic, S: Stochastic
4: F: Fully Forward Financing,
5. P: Partially Forward Financing,

Conclusion

To optimize the channel profit, an integrated mechanism for a multi-echelon supply chain system of multi- item used an action plan that coordinates the decisions and activities of all supply chain members. However, this is inadequate for a disintegrated supply chain system whereby members are separate economic entities acting opportunistically to optimize their individual perspective and this happened because an action plan is often not in the best interest and hence unable to entice the cooperation, of all independent members. We can say that an integration mechanism for a multi-echelon supply chain of multi-item has to include the action plan to optimize the channel perspective model and also have collaborative approach to

distribute the benefits of coordination so as to entice their cooperation. In the same time the integration of a supply chain can also requires the accurate and timely information about their operational decisions and activities be shared among all members to reduce uncertainties.

In present scenario the retail business where many companies have a disintegrated supply chain model especially for the perishable products. When designing a perishable goods or durable goods optimized supply chain model under centralized policy by ordering multi-item jointly companies must cope with deteriorating inventory, product preservation efforts and product publicity efforts to maximize his total supply chain profit and also bring sustainability to the supply chain network. Decisions related to multi-item retail price, the optimal annual replenishment frequency, optimal preservation effort factor for multi-item, optimal order quantity for multi-item, optimal publicity effort factor for multi-item and the effects of the parameters on decision and profits under decentralized and centralized policies are the keys for success of an optimized sustainable supply chain network in a competitive market environment.

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