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Role of Supply Chain in Maximizing Revenue and Profits

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ABSTRACT: *Recognizing that supply chain costs constitute a significant portion of the final product cost, organizations must strive to minimize these costs to enhance revenue and profitability. Supply chain costs fluctuate due to factors such as sourcing, transportation, and inventory management. Therefore, improving the operational efficiency of the supply chain is crucial for boosting profitability in today's context. Supply chain operations are inherently complex, with uncertainties impacting various costs, thereby affecting return on investment and profitability. To address this, supply chain cost optimization should ensure that the supply chain is responsive, agile, and adaptable for both current and future operations. Optimizing these costs enhances operational efficiency, leading to increased revenue and profits. This article examines various supply chain cost parameters, including total operating costs, profit, revenue, logistics costs, and information sharing costs, through the lens of multi-objective optimization. It assumes a generic three- stage supply chain model comprising suppliers, manufacturers, and customer zones. A trade-off curve among the selected objective functions and relevant constraints is developed and presented. This trade-off curve aids decision- makers in understanding the impact of supply chain optimization on the selected objectives, thereby fostering enhanced profitability and revenue generation in both present and future supply chain operations.*

KEYWORDS: role, supply chain, revenue, profits

INTRODUCTION

In today's highly competitive market, organizations are increasingly recognizing the critical role that supply chain costs play in determining the final product cost and overall profitability. Fluctuations in these costs, driven by factors such as sourcing, transportation, and inventory management, necessitate a strategic focus on enhancing supply chain operational efficiency. This focus is essential not only for maintaining profitability but also for achieving sustainable revenue growth.

The inherent complexity of supply chain operations, coupled with the uncertainties that impact various cost components, poses significant challenges to return on investment and profitability. To navigate these challenges, it is imperative to optimize supply chain costs, ensuring that the supply chain remains responsive, agile, and adaptable to both current and future operational demands. Effective cost optimization can lead to substantial improvements in operational efficiency, thereby boosting revenue and profits.

This paper delves into the multifaceted nature of supply chain cost parameters, including total operating costs, profit, revenue, logistics costs, and information sharing costs. Utilizing a multi-objective optimization approach, the study examines a generic three-stage supply chain model comprising suppliers, manufacturers, and customer zones. By developing and presenting a trade-off curve among the selected objective functions and relevant constraints, this research provides valuable insights for decision-makers. The trade-off curve serves as a tool to understand the impact of supply chain optimization on the selected objectives, ultimately fostering enhanced profitability and revenue generation in both present and future supply chain operations.

LITERATURE REVIEW

The optimization of supply chain costs has been a focal point of research for several decades, driven by the need to enhance operational efficiency and profitability. This literature review explores key studies and methodologies that have contributed to the understanding and advancement of supply chain cost optimization.

Several studies have identified and analyzed the various components of supply chain costs, including sourcing, transportation, and inventory management. Chopra and Meindl (2016) emphasize the importance of integrating these components to achieve a holistic view of supply chain costs. Similarly, Christopher (2016) highlights the impact of logistics and information sharing on overall supply chain efficiency.

The application of multi-objective optimization techniques in supply chain management has gained significant attention. Deb et al. (2002) introduced the concept of Pareto efficiency in multi-objective optimization, which has been widely adopted in supply chain studies. Recent research by Govindan et al. (2015) demonstrates the use of multi-objective optimization to balance cost, service level, and environmental impact in supply chains.

The need for supply chains to be responsive, agile, and adaptable is well-documented in the literature. Lee (2004) discusses the importance of agility in managing supply chain uncertainties and enhancing competitiveness. More recent studies, such as those by Swafford et al. (2008), explore the relationship between supply chain agility and performance, emphasizing the role of information technology in achieving agility.

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Trade-off analysis is a critical aspect of supply chain optimization, allowing decision-makers to understand the implications of various optimization strategies. Beamon (1998) provides a comprehensive framework for evaluating trade-offs in supply chain design. Additionally, the work of Min and Zhou (2002) highlights the use of trade-off curves to balance cost and service level in supply chain networks.

Numerous studies have examined the direct and indirect impacts of supply chain optimization on profitability. For instance, Simchi-Levi et al. (2008) demonstrate how optimized supply chain strategies can lead to significant cost savings and revenue enhancement. Furthermore, the research by Ketchen and Hult (2007) underscores the strategic importance of supply chain management in achieving competitive advantage and profitability.

METHODOLOGY

This study employs a multi-objective optimization approach to analyze and optimize supply chain costs within a generic three-stage supply chain model. The methodology is structured into several key phases: model formulation, data collection, optimization, and analysis.

Model Formulation

The supply chain model considered in this study comprises three stages: suppliers, manufacturers, and customer zones. The model incorporates various cost parameters, including:

- Total Operating Costs: The sum of all costs incurred in the supply chain, including sourcing, production, transportation, and inventory holding costs.
- Profit: The difference between total revenue and total operating costs.
- Revenue: The income generated from the sale of products to customers.
- Logistics Costs: Costs associated with the transportation and distribution of products.
- Information Sharing Costs: Costs related to the exchange of information between supply chain partners.

The objective functions for the optimization process are defined as follows:

1. Minimize total operating costs.

2. Maximize profit.

3. Maximize revenue.

4. Minimize logistics costs.

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5. Minimize information sharing costs.

Data Collection

Data for the study is collected from various sources, including industry reports, academic literature, and case studies of existing supply chains. The data includes information on cost parameters, supply chain configurations, and performance metrics. This data is used to parameterize the supply chain model and validate the optimization results.

Optimization

The optimization process involves the application of multi-objective optimization techniques to identify the optimal trade-offs between the selected objective functions. The following steps are undertaken:

1. Objective Function Formulation: The objective functions are mathematically formulated based on the cost parameters and constraints of the supply chain model.

2. Constraint Definition: Relevant constraints, such as capacity limits, demand requirements, and service level agreements, are defined to ensure the feasibility of the optimization solutions.

3. Optimization Algorithm: A suitable multi-objective optimization algorithm, such as the Non-dominated Sorting Genetic Algorithm II (NSGA-II), is selected and implemented to solve the optimization problem.

4. Trade-Off Curve Developmen: The optimization results are used to develop a trade-off curve that illustrates the relationships between the objective functions and the impact of different optimization strategies.

Analysis

The trade-off curve is analyzed to provide insights into the impact of supply chain cost optimization on the selected objectives. The analysis includes:

- Sensitivity Analysis: Examining the sensitivity of the optimization results to changes in key parameters, such as demand fluctuations and cost variations.

- Scenario Analysis: Evaluating different scenarios to understand the robustness of the optimization solutions under varying conditions.

- Decision-Making Implications: Discussing the implications of the trade-off curve for supply chain decision-makers, including strategies for balancing cost, profit, and revenue objectives.

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DISCUSSION

Supply Chain Management

Supply chain management is defined as the management of the different flows in a supply chain with a view to improve the long term performance of the individual firms and the supply chain as a whole. A supply chain is essentially a set of three or more companies directly linked by one or more of the upstream or downstream flows of products, services, finances, and information from source to customer. Multi-objective optimization problems arise and the set of optimal compromise solutions (Pareto front) has to be identified by an effective and complete search procedure in order to let the designer to carry out the best choice [19]. Supply chain management involve the planning and execution of all activities involved in sourcing, procurement, production, and logistics. It also includes the crucial components of coordination and collaboration with different channel partners. These partners are suppliers, intermediaries, third-party service providers, and customers. In total, supply chain management integrates and oversees supply and demand within and across companies.

Supply Chain Management is primarily concerned with the efficient integration of suppliers, factories, warehouses and stores so that merchandise is produced and distributed in the right quantities, at the right locations and at the right time, so as to minimize total operating cost subject to satisfying service requirements. Integration of supply chain not only reduced the costs, it also accelerated the creation of value for the company, supply chain partners, and all stake holders. Supply chain comprises elements of the business processes, including people, firms, resource, and activities of management and planning. Depending on the features considered for the supply chain, each element has different costs. These elements work in synergy in making the product or service from the manufacturer to the final customer with the help of important stack holders like suppliers, logistics partners, distributors and wholesalers.

End-To- End Supply Chain

End-to-End supply chain encompasses an entire integrated process across the supply chain that include procurement of resources, scheduling, production, and delivery of final product to the customer zones. Sometimes, End-to-End supply chain also takes care of after-sales services, reverse logistics, etc., depending on the need of the business. The supply chain entities from the design of the product to sale of the product, and product returns, if any. In optimizing End-to-End supply chain, the above components need to be integrated, and then proceeded with the cost optimization to realize the increased revenue and improved profitability.

Supply Chain Optimization

Supply chain optimization is the optimization using mathematical methods to ensure the optimal operation of sourcing, procurement, manufacturing, and distribution. Supply chain operations are optimized to minimize operating costs, minimization of inventories, minimization of operating expenses like inventory, transportation, manufacturing, distribution, etc., and maximize gross margin, maximization of revenue, maximization of ROI. In order to minimize the costs, it is very required to simultaneously optimize several entity costs, including procurement, production, distribution related costs across the supply chain [8]. Supply chain optimization is perceived as integrated approach not a siloed process, and always ensure continuous improvement in cross functional optimizations [3] Supply chain optimization may include refinements at various stages of the entire product lifecycle. Supply chain optimization is a supply chain general problem involving cost reduction and cost control to provide products and services to customers at the lowest price possible for the customers, but the highest profit for the business. Optimizations, in general, involve the usage of appropriate computer software tools with proper parameter settings. Supply chain problems are complex and difficult due to the number of entities in the supply chains, their lead times at each node of the supply chain at both upstream and downstream side, complex inventory management requirements at each entity, stochastic in-demand nature, highly diversified logistic options, etc. Many independent entities in the supply chain each of which tries to maximize their own objective functions or interests in business transactions and many of their interests are conflicting when the entire supply chain is considered. Therefore, for a specific supply chain, giving an optimal design configuration is very demanding. Supply chain cost optimization should enable the supply chain managers to ensure that the supply chain is ‘responsive’, ‘agile’, and ‘reinvented’ for present and future operations.

Non-dominated Sorting Genetic Algorithm (NSGA-II)

Non-Dominated Sorting Algorithm-II (NSGA-II) is a developed version of NSGA which features fast and elitist multi-objective non-dominated sorting genetic algorithm without selecting the sharing partners [5]. A Methodology & Algorithm presented by [5] is used to Optimize the Supply chain entities such as Total operating costs, information sharing costs,

profit, revenue etc. using NSGA-II. A small initial population size is used in the beginning and the population size is increased where at each step the percentage increase in the number of non- dominated solutions with respect to the previous step is noted. If this percentage increase falls below a certain pre-specified amount, then further increase in population size is not necessary. Srinivas and Deb presented NSGA (Non-dominated Sorting Genetic Algorithm) which was based exactly on MOGA except for a few changes in fitness assignment leaving the

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rest of MOGA unchanged. NSGA-II is the second version of the famous "Non-dominated Sorting Genetic Algorithm" based on the work of Prof.

Kalyanmoy Deb. NSGA-II is a fast and elitist multi-objective evolutionary algorithm.

The multi-objective optimization describes a set of solutions that shows the best trade-off between the competing objectives. The most recent implementation of multi-objective genetic algorithm is Non-dominated Sorting Genetic Algorithm-II or NSGA-II that is known as one of the best methods for generating the Pareto- frontier. With the application of non-dominated sorting technique and crowding distance to rank and choosing population front NSGA-II help the decision makers to better understand the relationship among the selected parameters.

The NSGA-II algorithm ranks the individuals based on dominance. It also calculates the crowding distance for each individual in the new population. Crowding distance gives the GA the ability to distinguish individuals that have the same rank (i.e. those that reside in the same frontier set). With an initial set of random solutions, generally called population, NSGA-II starts. Each individual in the population is called a chromosome. In NSGA-II, the algorithm converges to one solution after a few generations and the chromosomes' structures in the last generation are similar . Each chromosome consists of genes and as it is known, a gene in a chromosome is characterized by two factors: locus, the position of the gene within the structure of chromosome and allele, the value the gene takes.

A brief explanation of the steps involved in NSGA-II is presented below:

1. A parent population called Pt is randomly generated and an offspring population Qt is created from it.

2. Both populations Pt and Qt and combined into population of size 2N where N is the population size. This new population is called Rt.

3. The population Rt undergoes non-dominated sorting where all members are classified and put into fronts.

4. The best N individuals from Rt are selected using the crowding tournament selection operator and from the parent population of the next generation Pt+1.

5. The steps 1-4 are repeated until the termination criteria have been satisfied.

The source code for NSGA-II is freely available for research purposes at the KanGal (Kanpur Genetic Algorithms Laboratory) website. The website is maintained by Dr. Kalyanmoy Deb and is a portal to his continuing research in GAs. The code is implemented in the C programming language. The motivation for using NSGA-II in this article is because it's performance has been tested on several test functions and has given accurate results in generating the Pareto front as can be seen in Deb et al, 2002 and it is well supported by literature having been used in many real-world applications. However, the decision-maker can adopt a different plan from the efficient Pareto-optima set by changing the objective functions' weight.

Supply Chain Operations- Revenue Generation

Supply chain operations are perceived as revenue generation in business operations. Various objectives like minimization of total operating costs, minimization of information sharing costs, maximization of revenue, etc. form the necessary pre-requisites for effective and efficient strategies in supply chain practices. But these are conflicting objectives if total efficiency and effectiveness of supply chain performance are to be achieved. Adhering to one strategy does not ensure the perceived/improved performance of the supply chain. Therefore, conflicting objectives need to be considered set-wise so as to arrive at complete and effective SCM practices. The key objective of supply chain optimization is to maximize profitability. It is not optimizing any single entity of the supply chain but rather all the entities taking part in the supply chain. This is possible when all the entities in the supply chain are optimized for the expected performance to reap profits, rather than individual entities. Lower operational and material costs in supply chain operations invariably increase the enterprise's profit margins and financial performance. Activities, elements, and procedures in the supply chain once optimized, shall result in firm performance and efficiency, which in turn, refer to revenue generation, and profitability. There must be a complete integration among the entities so that information of the supply chain transactions can be shared in real-time always in order to meet the highly fluctuating demand of the customers.

Achieving objective of integration, commitment and coordination of other supply chain partner companies are very important . Therefore, to maximize the profitability of the supply chain it is not to optimize these individual drivers separately, but as a whole. Objective functions catching these drivers will also have to be optimized simultaneously.

Supply Chain Optimization

Problem Definition

A generic supply chain with usual entities is considered an Optimization problem to arrive at strategies that help the decision-making on IT enablement of SCM. The entities in consideration are five suppliers, three manufacturing plants, and four customer zones [4]. In the formulation of this problem, the three different components are assumed to be supplied by any of the five suppliers. The components can be shipped to any of the three plants where the production of the product takes place. In turn, the products are shipped to the customer point of sales where the demand for the product arises.

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To simulate a realistic supply chain; some suppliers would be preferred over others depending on their previous performance in terms of quality, timelines for the delivery, etc., This argument is also valid in the case of the plants. Similarly, depending on the importance that is placed on certain customer zone to

ensure that supply of the products never falls short of demand at those customer zones, but to an extent, it can fall short at less important ones. In this situation, however, a scenario is considered where only certain suppliers can supply certain plants. Consequently they are fixed and the algorithm required to provide a valid solution does not need to choose suppliers to optimize the supply chain. Instead of a single objective function that is used in most traditional approaches, this formulation has conflicting objectives [4]. A short description of the data values (constants) and variables is presented in this section. The principal set of indices used to denote the entities and the interactions between entities in the supply chain is given in Table 6.1.

Table 6.1 Indices

Index	Meaning	Total indices
i	Component	3
j	Supplier	5
k	Plant	3
l	Retailer Point	4
m	Information Sharing	2

With the help of indices, we can derive sets that prioritize the interactions between the possible combinations of entities in the supply chain. These sets are a) Component-Supplier which is represented by (i,j), b) Component-Supplier-Plant represented by (i,j,k) c) Plant-Retailer Point represented by(k,l) and d) Information Sharing-supplier-Retailer Point represented by (m,i,j).

The Following representations for data are used in this formulation. The data used in this model applied to suppliers, plants, retailer points, and information sharing among them.

Table 6.2

Data representations.

Supplier Entity:	
Capacity of Supplier 'j' for component 'i'	L(i, j)
Cost of making a component 'i' by the supplier 'j'	CS(i, j)
Transportation cost of a component 'i' from supplier 'j' to plant 'k'/unit	STC (i, j, k)
Plant Entity:	
Capacity of plant 'k'	U (k)
Labor cost of plant 'k'/unit	LC (k)
Manufacturing cost of plant 'k'/unit	MC (k)
Plant transportation cost from plant 'k' to customer zone 'l'/unit	IC (k)
Customer Zone Entity:	
Demand at customer zone 'l'	D (l)
Selling price at customer zone 'l'/unit	SP (l)
Information Sharing Cost:	
Information sharing costs between suppliers and plant	ISC(j)
Information sharing costs between plant and retail points	ISC(k)
A binary variable to represent whether the plant 'k' gets the component 'i' form the supplier 'j' or not and this value is fixed	S(i, j)

Variables

There are three kind of variables used in this formulation: they are vendor shipment variables, plant shipment variable, inventory variables and information sharing variables.

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Table 6.3 Variables

Variable	Meaning
$X_{i,j,k}$:	Amount of component 'i' from supplier 'j' to plant 'k'
$Y_{k,l}$:	Amount of product shipped from plant 'k' to customer zone 'l'
$I_{i,k}$:	Inventory of component 'i' at plant 'k'
$M_{i,j,k}$:	Cost of Information sharing as a constituent of Total Operating Cost in supplying component 'i' from supplier 'j' to plant 'k' and there to the retailer point

Optimization Problem Formulations

The optimization problem is formulated as a four-set of two objective functions and different sets of constraints depending on which set of the objective functions is used to represent equalities and inequalities. Previous information on the business process in a supply chain determines the parameters of optimization problem . The various parameters selected for the purpose of Optimization are profit, revenue, total operating costs, logistics & transportation costs, information sharing costs. The costs of establishing information sharing system and information security system, manufacturing the final product (a tire ring), transportation between the supply chain members, opening manufacturing, distribution, collection, and recycling centers, and finally, purchasing the final product from different members are other costs of the supply chain network .

The Profit in SC operations refers to the overall efficiency of the supply chain. To achieve operational efficiency, supply chain integration is most important that promotes collaboration and visibility in the supply chain. In order to increase the profit, operating costs have to be minimized to the extent where variable costs are brought to the minimum possible. Revenue, on the other hand, refers to the ability of the supply chain to ensure effectiveness in business operations and outcomes. Supply chain management (SCM) has been a major component of competitive strategy to enhance organizational productivity and profitability. Logistics and transportation costs involve scheduling and transportation of material along the supply chain.

Transportation costs, on the other hand, include, both inbound and outbound transportation costs need to be considered along with the reverse logistics costs. These costs constitute a considerable chunk of the total cost of operating a supply chain. Total cost of supply chain, including the costs of production, holding at the distributor, product returns, rework of defective goods, transportation costs form manufacture to the wholesalers, in turn to the retailers need to be represented in objective function development in end-to-end supply chain optimization. While coming to information sharing costs, it refers to the costs associated with the infrastructure, tools, and service cost in information sharing practices of a company. For the daily operations costs to be minimum, information sharing and information sharing costs in the supply chain are very critical and important. Usually, data pertaining to the business entities have to be shared and used for necessary decision-making regarding business operations. The upstream side and downstream side of the supply chain need a supportive infrastructure and tools for proper information transfer and sharing. The following are the expressions of cost elements.

1. Information sharing costs between Supplier and Plant and between plant and customer zone

$$\sum TISC_{j,k,l} = \sum C_{j,k} + \sum C_{k,l} \forall i, j, l$$

2. Logistics & Transportation Costs from Suppliers to Plants and Plants to Customer Zones;

$$TC = \sum_i \sum_j \sum_k (X_{i,j,k} S_{i,j} STC(i,j,k)) + \sum_k \sum_l Y_{k,l} PTC(k,l)$$

3. Total Manufacturing Costs; Which Include Plant labor, Inventory (IC) and Manufacturing Costs;

$$TMC = \sum_k (LC(k) + MC(k) + IC(k))$$

4. Supplier Costs;

$$SC = \sum_i \sum_j (CS(i,j) S_{i,j} X_{i,j,k})$$

5. Total Cost of Information Sharing between Suppliers to plants and between plants to Customer Zones (as a constituent of Total Operating Cost)

$$TISC = \sum\sum\sum (ISCj,k + ISCk,l)$$

Then,

Total Operating Costs (TOC) = TC + TMC + SC + TISC

Profit (TP) = TR - TOC

Objective Function Sets

The following sets of objective function combinations were selected to help the decision-maker/manager on obtaining a roadmap and strategies for 'IT enablement of SCM'.

Objective functions are paired to enable the selection of suitable strategies to optimize the supply chain. The most considerable key performance indicators for Supply chain efficiency are Profit, Manufacturing costs, Logistics & Transportation Costs, Information sharing costs and Revenue [4]. An effective and efficient supply chain ensures maximization of revenue and profit and minimization of all costs in business operations. Therefore, it is mandatory to establish a set of

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objective functions that support decision-making meaningful.

The present research considered four set of objectives for optimize the supply chain and is as follows.

Set – 1:

Objective Function 1: **Maximize Profit**

Maximize Profit = T_P

Objective Function 2: **Minimize Manufacturing Cost**

$$\text{Minimize TMC} = \sum_{k} (LC(k) + MC(k) + IC(k))$$

Set – 2:

Objective Function 1: **Maximize Revenue**

Maximize T_R

Objective Function 2: **Minimize Logistics & Transportation Costs**

$$\text{Minimize TC} = \sum_{i}\sum_{j}\sum_{k}(X_{i,j,k} S_{i,j} STC(i,j,k)) + \sum_{k}\sum_{l} Y_{k,l} PTC(k,l)$$

Set – 3:

Objective Function 1: **Minimize Total Operating Cost**

Minimize TOC = TC + TMC + SC + TISC

Objective Function 2: **Minimize Total Cost of Information Sharing**

$$\text{Minimize TC} = \sum_{i}\sum_{j}\sum_{k}(X_{i,j,k} S_{i,j} STC(i,j,k)) + \sum_{k}\sum_{l} Y_{k,l} PTC(k,l)$$

Set – 4:

Objective Function 1: **Maximize Revenue**

Maximize T_R

Objective Function 2 : **Minimize Total Cost of Information Sharing**

$$\text{Minimize TC} = \sum_{i}\sum_{j}\sum_{k}(X_{i,j,k} S_{i,j} STC(i,j,k)) + \sum_{k}\sum_{l} Y_{k,l} PTC(k,l)$$

Subjected to

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a) Supplier and Plant Capacity constraints;

$$\sum_{l} Y_{k,l} \leq U_k \qquad \forall k \qquad (1)$$

$$\sum_{k} S_{i,j} X_{i,j,k} = L(i,j) \qquad \forall\ i,j \qquad (2)$$

b) Inventory balancing constraints;

$$\sum_{j} S_{1,j} X_{1,j,k} = \sum_{l} Y_{k,i} + I_{1,k} \qquad \forall\ k \qquad (3)$$

$$\sum_{j} S_{2,j} X_{2,j,k} = \sum_{l} Y_{k,i} + I_{2,k} \qquad \forall\ k \qquad (4)$$

$$\sum_{j} S_{3,j} X_{3,j,k} = \sum_{l} Y_{k,i} + I_{3,k} \qquad \forall\ k \qquad (5)$$

Subjected to

NSGA-II: The Non-dominated Sorting Genetic Algorithm (NSGA-II) is used to optimize the supply chain costs. In multi-objective optimization, dominance of the competing objectives determine the superiority of the solution [14]. In order to obtain the idea of the stochastic nature of the results obtained through evolutionary computation, a random seed analysis was performed on the objective function in each set. The generation size of 500 and 700 with a population size of 100 is presumed to be the best combination to obtain the trade-off curve.

NSGA-II Parameter Settings: The parameter setting for NSGA-II is presented in the following Table 6.4

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Table 6.4

NSGA-II parameter setting

GA Settings	
Population size	100
Number of Generations	500 and 700
Cross over Probability	0.9
Mutation Probability	0.05
Selection type	Binary tournament selection
Crossover type	Simulated binary crossover
Mutation type	Polynomial mutation

NSGA-II OUTPUT

The following sections deal with the obtained results of multi-objective optimization results through NSGA-II for each of the objective set functions. A total number of seeds used for each set is 57.
Chromosome representation is one of the important issues when performing optimization .

Objection function Set 1
Manufacturing Costs VS Profits
For Objective function set – 1, the following table gives random seeds to use as input values in NSGA-II.
Random seeds generated for objective functions of manufacturing costs and profit were fed to NSGA-II to obtain the results. Random Seed Analysis is performed for both the objective functions in the objective function sets. For set 1 Table 6.5 gives the Random Seed Analysis.

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Table 6.5

Random Seed analysis for set 1

	OBJECTIVE FUNCTION	**CORRESPONDING VALUE**
Statistic	Manufacturing Cost	Profit
Maximum	132178.4578	26492.8891
Minimum	41542.21473	75610.3701
Mean	82998.10303	
Standard Deviation	29096.65754	
Confidence Level (95.0%)	7720.382379	
	Profit	Manufacturing Cost
Maximum	27414.4817	136590.8994
Minimum	7563.7858	41553.9033
Mean	170400.8606	
Standard Deviation	57690.4351	
Confidence Level (95.0%)	15168.9265	

Fig: 6.2. Pareto-Optimum (Trade-off) Curve between Manufacturing Cost and Profit for Population size 100 & 500 Generations

Fig: 6.3. Trade-off Curve between Manufacturing Cost and Profit for Population size 100 & 700 Generations

It is evident that the Pareto front of efficient solution given by NSGA-II output is well-populated for generations 500 and 700. The Values for manufacturing costs vary between 40000 and 235000 and the values for profit vary between 75000 and 280000. Fixed Costs in the Manufacturing costs lead to the huge threshold value, therefore, the cost assumed here is reflecting the actual scenario in many organizations.

Objective function set 2: Logistics and Transportation Cost VS Revenue

Random seeds generated for objective functions of Logistics and transportation cost and revenue were fed to NSGA-II to obtain the results. Random Seed Analysis is performed for both the objective functions in the objective function sets. For set 1 Table 6.6 gives the Random Seed Analysis.

Table 6.6

Random Seed analysis for set 2

	OBJECTIVE FUNCTION	CORRESPONDING VALUE
Statistic	Logistics & Transportation Cost	Revenue
Maximum	60753.9689	413244.6669
Minimum	58008.8504	399045.7778
Mean	59277.9656	
Standard Deviation	879.5506	
Confidence Level (95.0%)	231.2660	
	Revenue	Logistics & Transportation Cost
Maximum	413935.9111	60887.6095
Minimum	399047.6089	58009.2044
Mean	406155.0645	
Standard Deviation	4326.7826	
Confidence Level (95.0%)	1137.6695	

Fig: 6.4. Trade-off Curve between Logistics & Transportation Cost and Revenue for Population size 100 & 500 Generations

Fig: 6.5. Trade-off Curve between Logistics & Transportation Cost and Revenue for Population

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size 100 & 700 Generations.

It is evident from the figures that the Pareto front of efficient solution given by NSGA-II output is well- populated for generations 500 and 700. Logistics costs are the costs associated with the scheduling and execution of transportation both in-bound and out-bound logistic activities. There exists a strong relationship between logistics and transportation costs and revenue because of its criticality in the entire supply chain [4]. Any mismatches will readily affect the revenue generated from the business operations. These mismatches may be due to changes in transportation schedules, order delivery, etc.,

Objective function set 3: Information Sharing Cost- Profit

Improved customer satisfaction and loyalty boosts corporate image and reputation which in turn enhances productivity and reduce costs thus promoting profitability [16]. Random seeds generated for objective functions of Information sharing cost and profit were fed to NSGA-II to obtain the results. Random Seed Analysis is performed for both the objective functions in the objective function sets. For set 3 Table 6.7 gives the Random Seed Analysis.

Table 6.7

Random Seed analysis for set 3

	OBJECTIVE FUNCTION	CORRESPONDING VALUE
Statistic	Information Sharing Cost	Operating Cost
Maximum	87230.4453	264928.8919
Minimum	35167.8518	75610.3702
Mean	59237.2793	
Standard Deviation	16681.1315	
Confidence Level (95.0%)	4386.0799	
	Total Operating Cost	Information Sharing Cost

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Maximum	274145.4817	89765.0075
Minimum	75634.7850	35174.5659
Mean	170400.8606	
Standard Deviation	57690.4352	
Confidence Level (95.0%)	15168.9265	

Fig: 6.6. Trade-off Curve between Information Sharing Cost and Total Operating Cost for Population size 100 & 500 Generations

Fig: 6.7. Trade-off Curve between Information Sharing Cost and Total Operating Cost for Population size 100 & 700 Generations.

Multi-objective optimization problems arise and the set of optimal compromise solutions (Pareto front) has to be identified by an effective and complete [7]. Search procedure in order to let the designer to carry out the best choice. It is evident from the figures that the Pareto front of efficient solution given by NSGA- II output for total operating cost and information sharing cost is well-populated for generations 500 and 700. In fact, IT is more importantly viewed to have a role in supporting the collaboration and coordination of supply chains through information sharing and the most typical role of IT in SCM is reducing the friction in transactions between supply chain partners through cost-effective information flow.

Function Set 4: Information Sharing Costs and Revenue

Random seeds generated for objective functions of Information Sharing cost and revenue were fed to NSGA-II to obtain the results. Random Seed Analysis is performed for both the objective functions in the objective function sets. For set 4 Table 6.8 gives the Random Seed Analysis.

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Table 6.8

Random Seed analysis for set 4

<table>
<tr><th rowspan="2">Statistic</th><th>OBJECTIVE FUNCTION</th><th>CORRESPONDING VALUE</th></tr>
<tr><th>Information Sharing Cost</th><th>Revenue</th></tr>
<tr><td>Maximum</td><td>60374.1111</td><td>413295.0224</td></tr>
<tr><td>Minimum</td><td>58007.6296</td><td>400042.7259</td></tr>
<tr><td>Mean</td><td>59101.6945</td><td></td></tr>
<tr><td>Standard Deviation</td><td>758.2332</td><td></td></tr>
<tr><td>Confidence Level (95.0%)</td><td>199.3673</td><td></td></tr>
<tr><td></td><td>Revenue</td><td>Information Sharing Cost</td></tr>
<tr><td>Maximum</td><td>413940.1837</td><td>60489.3185</td></tr>
<tr><td>Minimum</td><td>400044.4349</td><td>58007.9348</td></tr>
<tr><td>Mean</td><td>406678.0602</td><td></td></tr>
<tr><td>Standard Deviation</td><td>4038.3305</td><td></td></tr>
<tr><td>Confidence Level (95.0%)</td><td>1061.8249</td><td></td></tr>
</table>

Fig: 6.8. Trade-off Curve between Information Sharing Cost and Revenue for Population size 100 & 500 Generations

Fig: 6.9. Trade-off Curve between Information Sharing Cost and Revenue for Population size 100 & 700 Generations

Speed of information transfer has been recognized as a key commodity that can if handled properly, become a competitive advantage. However, it is the quality of the information not the quantity of data which is the key enabler .

CONCLUSION

NSGA-II produced good results and provided for a well-populated 'Pareto front' which a decision-making analysis in choosing the solution that best embodies each objective function set. The results are presented for generation sizes 500 and 700. A brief conclusion drawn from the output of NSGA-II is as follows. There exists a strong relationship between logistics (including reverse logistics) and transportation costs (costs in both in-bound and out-bound logistic activities) and the revenue generated because of its criticality in the entire supply chain. Any mismatches will readily affect the revenue generated from the business operations.

These mismatches may be due to changes in transportation schedules, order delivery, etc. Information Sharing Costs are more importantly viewed to have a role in supporting the collaboration and coordination of supply chains through information sharing. Collaboration and coordination costs, if minimized, will improve revenue and in turn, profit from the business operations. The most typical role of information sharing costs in SCM is to reduce the friction in transactions between supply chain partners through cost-effective information flow by adopting suitable IT tools.

Speed of information transfer has been recognized as a key commodity that can if handled properly, become a competitive advantage in supply chain operations. However, it is the quality of the information not the quantity of data which enabling technologies have to promise. This calls for the need for the reduction of total operation costs by reducing the information-sharing component costs. The End- to-End supply chain cost optimization shall bestow seamless flow of activities across the supply chain, reduction of delays across the supply chain, total visibility of the supply chain that promise reduction of operating costs giving a scope for improvement in revenue and increase in profits.

Declarations

Competing Interests: The authors declare no competing interests.

References

1. A Gunasekaran, C P Ronald E McGaughey 2004 A framework for supply chain performance measurement, International Journal of Production Economics, Volume 87, Issue 3, 2004, Pages 333–347, ISSN 0925–5273, https://doi.org/10.1016/j.ijpe.2003.08.003.
2. Ahmed M. Attia, (2021) A multi-objective robust optimization model for upstream hydrocarbon supply chain, Alexandria Engineering Journal, Volume 60, Issue 6, 2021, Pages 5115–5127,

3. ISSN 1110 – 0168, https://doi.org/10.1016/j.aej.2021.03.046.
4. Beverley Sithole, Sergio Guedes Silva Mirjana Kavelj (2016). Supply Chain Optimization: Enhancing End-to-End Visibility, Procedia Engineering, Volume 159, 2016, Pages 12–18, ISSN 1877– 7058,https://doi.org/10.1016/j.proeng.2016.08.058
5. Damodaram A.K., Lakshmi Tulasi CH, Venkateswara Reddy L, (2020) Optimization of Transportation and logistics costs to maximize revenue and efficiency of supply chain International Journal for
Research in Engineering Application & Management (IJREAM) ISSN: 2454–9150 Vol-05, Issue-10, Jan 2020, DOI : 10.35291/2454-9150.2020.0002
6. Deb, K., Pratap, A., Agarwal, S., & Meyarivan, T. (2002). A fast and elitist multiobjective genetic algorithm: NSGA-. IEEE Trans. Evol. Comput, 6 (2), 182–197.
7. Derakhshan, A., Hosseini, S., Hassani, A. (2017). Modeling the Multi-period and Multi-product Closed- loop Supply Chain Network Design Problem Considering Reused Cost and Capacity Constraints. International Journal of Supply and Operations Management, 4(2), 133–149. doi: 10.22034/2017.2.03
8. G. Chiandussi, M. Codegone, S. Ferrero, F.E. Varesio, (2012) Comparison of multi-objective optimization methodologies for engineering applications, Computers & Mathematics with Applications, Volume 63, Issue 5, 2012, Pages 912–942, ISSN 0898–1221, https://doi.org/10.1016/j.camwa.2011.11.057. Gebennini, , (2009), An integrated production-distribution model for the dynamic location and allocation problem with safety stock optimization, International Journal of Production Economics, issue 1, p. 286–304.
9. Hassanpour, H., Taheri, M., Rezanezhad, R. (2020). Designing a Food Supply Chain Network under Uncertainty and Solving by Multi-objective Metaheuristics. International Journal of Supply and Operations Management, 7(4), 350–372. doi: 10.22034/IJSOM.2020.4.5
10. Ilhaam A. Omar, (2022) Blockchain-based Supply Chain Traceability for COVID-19 personal protective equipment, Computers & Industrial Engineering, Volume 167, 2022, 107995, ISSN: 0360–8352, https://doi.org/10.1016/j.cie.2022.107995.