



## OPTIMIZATION OF END-TO-END SUPPLY CHAIN COSTS TO MAXIMIZE REVENUE AND PROFITS FROM SUPPLY CHAIN OPERATIONS

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### Abstract

Being aware that the supply chain costs claim a substantial share in the final product cost, organizations, in an effort to improve revenue and increase profitability, should minimize supply chain costs invariably. Besides other costs, supply chain costs vary from time to time depending on the sourcing, transportation, and inventory-related costs. Improving the operational efficiency of the supply chain has become the primary objective for increasing profitability from supply chain operations in present-day context. In reality, supply chain operations are complex with uncertainty predominantly influencing various costs associated with supply chains affecting return on investments and profitability. 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. Optimization of supply chain costs bestows improving operating efficiency that promotes improvements in revenue and increment in profits. The present article aims at considering various supply chains cost parameters such as total operating costs, profit, revenue, logistics costs, and information sharing costs for optimization of supply chain costs using multi-objective optimization. A generic three-stage supply chain model with usual entities like suppliers, manufacturers, and customer zones is assumed in the present article. A trade-off curve among the selected objective function sets and relevant constraints was developed and presented in the article. The trade-off curve provides the basis for decision-makers to better understand the supply chain optimization effect on the selected objective function set elements to make the present and future supply chains promote startling 'profitability' and increase revenue generation in operations.

**Key Words:** Supply Chain Optimization; Multi-objective optimization; Supply Chain Costs; Non-dominated sorting genetic algorithm (NSGA-II); Revenue generation in a Supply Chain.

### 1.0 INTRODUCTION

#### 1.1 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 [11]. 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 [22]. These elements work in synergy in making the product or service from the manufacturer to the final customer with the help of important stakeholders like suppliers, logistics partners, distributors and wholesalers [10].

**1.2 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.

#### 1.3 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 [12].

**1.4 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) [81] which was based exactly on MOGA except for a few changes in fitness assignment leaving the 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 [14]. 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 [18] 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 [9]. 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 [21].

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

1. A parent population called  $P_t$  is randomly generated and an offspring population  $Q_t$  is created from it.
2. Both populations  $P_t$  and  $Q_t$  are combined into population of size  $2N$  where  $N$  is the population size. This new population is called  $R_t$ .
3. The population  $R_t$  undergoes non-dominated sorting where all members are classified and put into fronts.
4. The *best*  $N$  individuals from  $R_t$  are selected using the crowding tournament selection operator and from the parent population of the next generation  $P_{t+1}$ .
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 [2].

### 1.5 Supply Chain Operations – Revenue generation:

Supply chain operations are perceived as revenue generation in business operations [4]. Various objectives like minimization of total operating costs, minimization of information sharing costs, maximization of revenue, etc. form the necessary prerequisites 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 [17]. 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 [15]. 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.

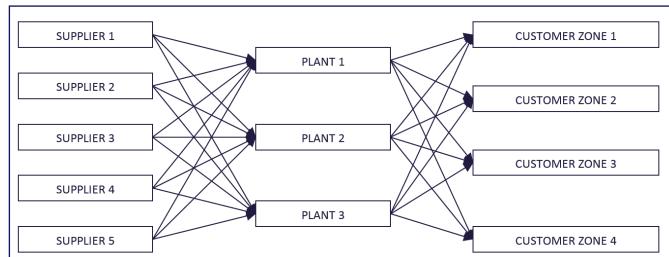
Achieving objective of integration, commitment and coordination of other supply chain partner companies are very important [20]. Therefore, to maximize the profitability of the supply chain it is not to optimize these individual drivers separately, but as a whole. Objective functions catching these drivers will also have to be optimized simultaneously.

## 2.0 SUPPLY CHAIN OPTIMIZATION

### 2.1 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.

**Fig: 6.1 Supply Chain Entities and material Flow**



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' from the supplier 'j' or not and this value is fixed	S(i, j)

## 2.2 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.

**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

## 2.3 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 [6]. 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 [22]. 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 [20]. 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 [1]. 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 [8]. 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 from manufacture to the wholesalers, in turn to the retailers need to be represented in objective function development in end-to-end supply chain optimization [13]. 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 [17]. 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

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

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

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

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)

$$TISC = \sum \sum \sum (ISC_{j,k} + ISCK_{l,1})$$

Then,

$$\text{Total Operating Costs (TOC)} = TC + TMC + SC + TISC$$

$$\text{Profit (TP)} = TR - TOC$$

## 2.4 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 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**

$$\text{Maximize Profit} = T_p$$

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**

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

**Set – 3:****Objective Function 1: Minimize Total Operating Cost**

Minimize  $TOC = TC + TMC + SC + TISC$

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

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

**Set – 4:****Objective Function 1: Maximize Revenue**

Maximize  $T_R$

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

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

Subjected to

**2.5 Constraints****a) Supplier and Plant Capacity constraints;**

$$\sum_l Y_{k,l} \leq U_k \quad \forall k \quad (1)$$

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

**b) Inventory balancing constraints;**

$$\sum_j S_{1,j} X_{1,j,k} = \sum_l Y_{k,l} + I_{1,k} \quad \forall k \quad (3)$$

$$\sum_j S_{2,j} X_{2,j,k} = \sum_l Y_{k,l} + I_{2,k} \quad \forall k \quad (4)$$

$$\sum_j S_{3,j} X_{3,j,k} = \sum_l Y_{k,l} + I_{3,k} \quad \forall k \quad (5)$$

**2.6 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

**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

**2.6.0 NSGA-II OUTPUT**

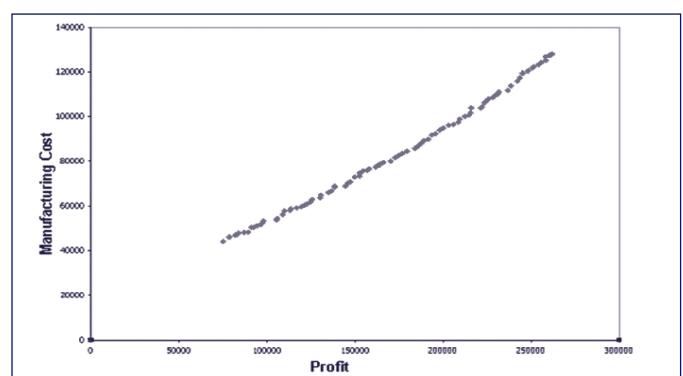
The following sections deal with the obtained results of multi-objective optimization results through NSGA-II for each of the objective set functions. A total number of seeds used for each set is 57. Chromosome representation is one of the important issues when performing optimization [13].

**2.6.1 Objective function SET 1: Manufacturing Costs Vs Profit**

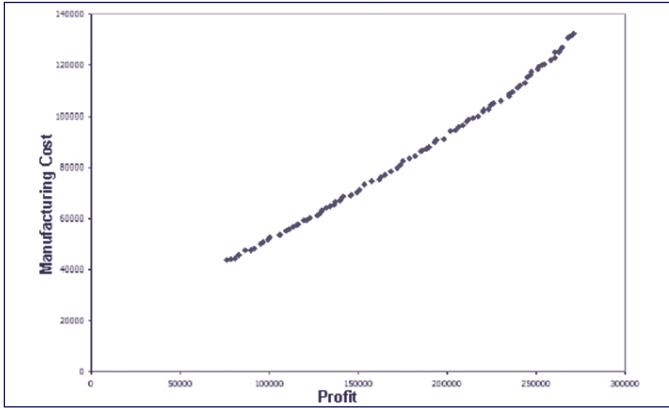
For Objective function set -1, the following table gives random seeds to use as input values in NSGA-II. Random seeds generated for objective functions of manufacturing costs and profit were fed to NSGA-II to obtain the results. Random Seed Analysis is performed for both the objective functions in the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

**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.

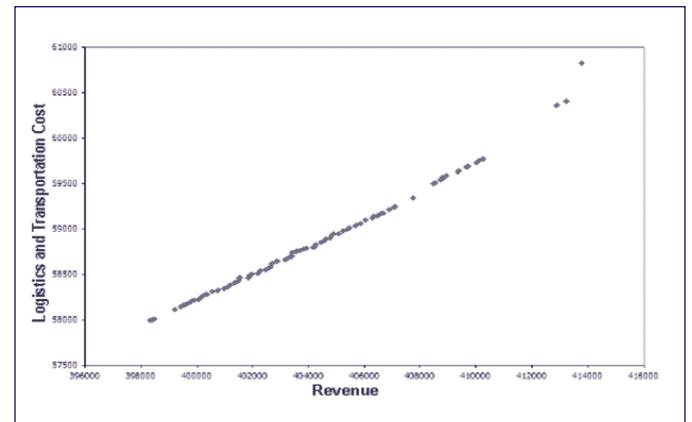
#### 2.6.2 Objective function SET 2: Logistics and Transportation Cost Vs Revenue

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.

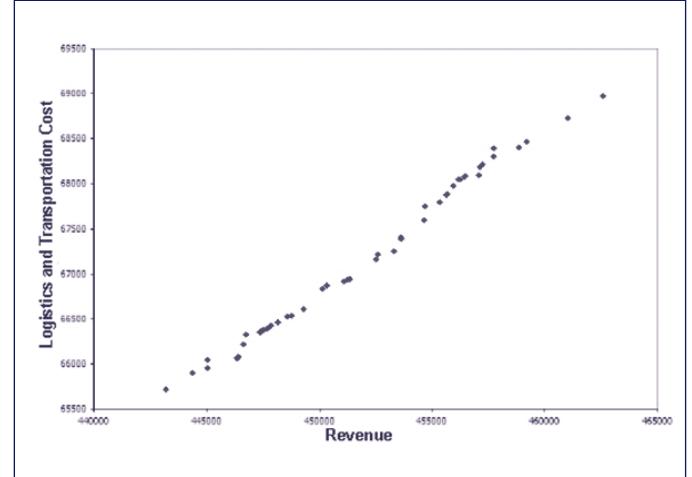
**Table: 6.6. Random Seed analysis for set 2**

	OBJECTIVE FUNCTION	CORRESPONDING VALUE
<b>Statistic</b>	Logistics & Transportation Cost	Revenue
<b>Maximum</b>	60753.9689	413244.6669
<b>Minimum</b>	58008.8504	399045.7778
<b>Mean</b>	59277.9656	
<b>Standard Deviation</b>	879.5506	
<b>Confidence Level (95.0%)</b>	231.2660	
	Revenue	Logistics & Transportation Cost
<b>Maximum</b>	413935.9111	60887.6095
<b>Minimum</b>	399047.6089	58009.2044
<b>Mean</b>	406155.0645	
<b>Standard Deviation</b>	4326.7826	
<b>Confidence Level (95.0%)</b>	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 size 100 & 700 Generations**



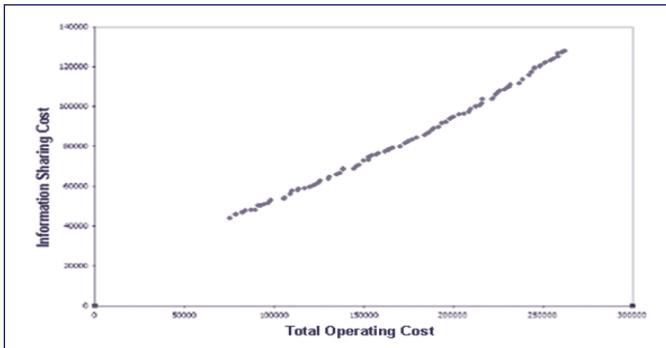
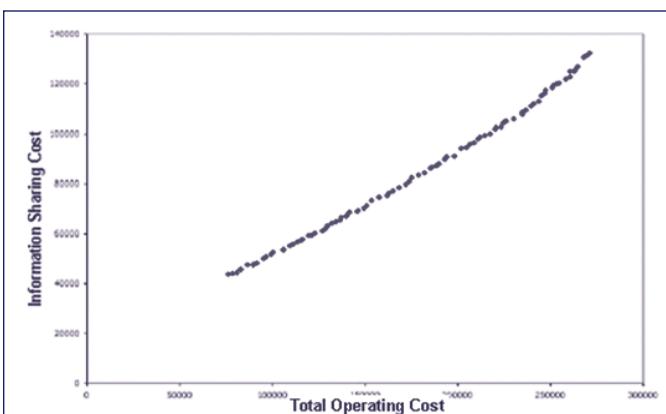
It is evident from the figures that the Pareto front of efficient solution given by NSGA-II output is well-populated for generations 500 and 700. Logistics costs are the costs associated with the scheduling and execution of transportation both in-bound and out-bound logistic activities. There exists 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.

#### 2.6.3 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
<b>Statistic</b>	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
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.**

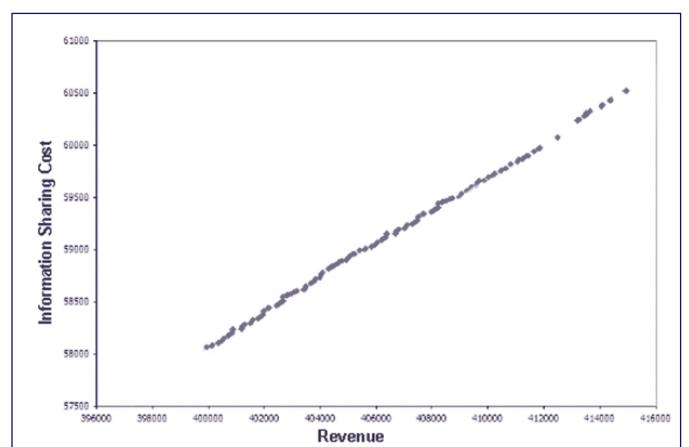
Multi-objective optimization problems arise and the set of optimal compromise solutions (Pareto front) has to be identified by an effective and complete [7]. Search procedure in order to let the designer to carry out the best choice. It is evident from the figures that the Pareto front of efficient solution 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.

#### 2.6.4. Objective function Set 4: Information Sharing Costs and Revenue:

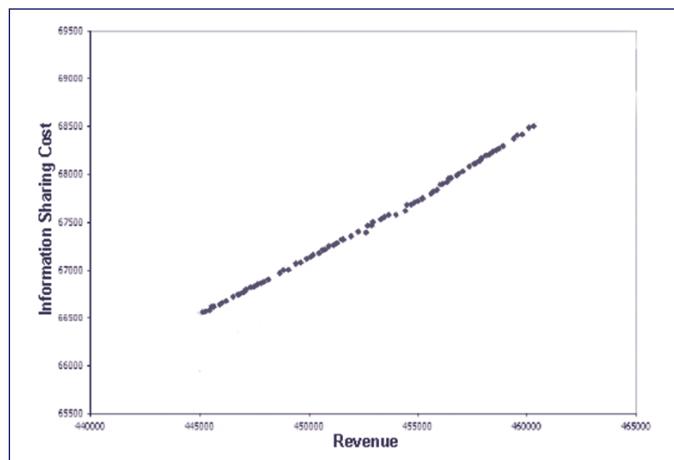
Random seeds generated for objective functions of Information Sharing cost and revenue were fed to NSGA-II to obtain the results. Random Seed Analysis is performed for both the objective functions in the objective function sets. For set 4 table 6.8 gives the Random Seed Analysis.

**Table: 6.8. Random Seed analysis for set 4**

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

**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 [17].

### 3.0 CONCLUSIONS

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.

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