Milk Run System

For

Inbound Logistics

A Major Project thesis

submitted in partial fulfillment

for the requirement of the degree of

Masters of Engineering

in

Production and Industrial Engineering

by

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(021/Pro/2004)

Under the guidance of

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Session 2004-06

Acknowledgement

It is a great pleasure to have the opportunity to extent my heartiest felt gratitude to everybody who helped me throughout the course of this dissertation.

It is distinct pleasure to express my deep sense of gratitude and indebtedness to my guide **Prof**. **S. K. Garg,** Department of Production and Industrial Engineering, Delhi College of Engineering, for his invaluable guidance, encouragement and patience review. His continuous inspiration generated confidence in my inner being and helped my hidden energies to come out in full which made me complete this project.

I am grateful to **Prof. S. Maji**, Head, Department of Mechanical Engineering and **Prof. C. K. Dutta**, Head, Department of Production and Industrial Engineering, Delhi College of Engineering for their expert advice and continuous support throughout the whole project.

I am also thankful to **Mr. Uttam Mishra** (Deputy Manager, Engineering Division, Maruti Udyog Limited) and **Mr. Satyapal Aggarwal** (Deputy Manager, Supply Chain Management, Maruti Udyog Limited) for their vital support in giving valuable information and data.

(Kanchan Vats)

Candidate's Declaration

I hereby certify that the work which is being presented in the dissertation entitled "Milk Run System for Inbound Logistics", in partial fulfillment of the requirements for the award of the degree of Master of Engineering in Production and Industrial Engineering, submitted in the Department of Mechanical Engineering, Delhi College of Engineering, Delhi is an authentic record of my own work carried out for a period of one year under the supervision of Dr. S. K. Garg, Professor of Mechanical Engineering Department, Delhi College of Engineering, Delhi.

I have not submitted the matter embodied in this dissertation for the award of any other degree.

Kanchan Vats

This is to certify that the above statement made by the candidate is true to the best of my knowledge.

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Abstract

The Project entitled “Milk Run System for Inbound Logistics” is concerned with the use of transportation strategies in different supply chains. Transportation which is part of logistics has an important role to reduce the total cost of procuring the raw material and thereby the cost of production. Various cases based on Spoke system (each vendor supplies directly to the buyer) and Rim system (one vehicle collecting material from more than one vendor) have been analyzed in which order size, no. of vendors in a group and their route sequence has been considered. The cost parameters which are affected by these decisions are cost of transportation and cost of carrying inventory.

In this project following two approaches have been worked out to minimize the total cost (total of transportation and cost of carrying inventory)

1. Effect of different ordered quantities on logistics cost (total of transportation and inventory cost) has been analyzed on Rim and Spoke system.

2. Different groups of vendors and their route sequence have been selected for which the transportation cost is minimum. This activity is further carried out in following two ways:

- A computer software has been formulated to workout this activity accurately.
- Two models have been proposed which give approximate optimum results to determine the group size of vendors.

The results comprises of selecting the economical logistic system by deciding the group of vendors covered by a vehicle, optimal transportation vehicle route and full capacity space utilization of the vehicle. The various approaches used in this project show that rim system is more economical than spoke system in meeting the uncertainty in demand and where vendors are nearby.

Contents

List of Figures

List of Tables

List of Symbols and Abbreviations

i	=	(1,2-----13)vendors
j	=	Number of different items supplied by a vendor (j=2----m)
TC	=	Total cost obtain by different systems
C	=	Unit cost of an item
C_i	=	Unit cost of i^{th} item
C_o	=	Ordering + transportation cost (Rs./order) of an item
C_{oi}	=	Ordering + transportation cost (Rs./order) of i^{th} item
C_h	=	Holding cost (Rs. / unit/ yr.) of an item=20% of unit cost
C_{hi}	=	Holding cost (Rs. / unit/ yr.) of i^{th} item
D	=	Annual demand of end product (car)
D_i	=	Annual demand of i^{th} item
Q	=	Maximum quantity of an item loaded in a transport vehicle
Q_i	=	Maximum quantity of i^{th} item loaded in a transport vehicle
U	=	Quantity of an item required per car
U_i	=	Quantity of i^{th} item required per car
V	=	Capacity of truck (cm^3)
P	=	Cubic space occupied by an item
Pi	=	Cubic space occupied by i^{th} item
V_{set}	=	Volume occupied by one set (All the n items in quantities as required for one car)
	=	$\sum_{i=1}^{13} U_i * P_i$
$C_{h,set}$	=	Holding cost of one set
	=	$\sum_{i=1}^{13} U_i * C_{hi}$
D_i	=	$D * U_i$
S	=	Number of kits per trip
N	=	Number of trips
C_t	=	Cost per trip (Rs.)

C_t	=	$K_1 + K_2 * L + K_3 * n$
L	=	Distance covered by a vehicle for a Rim/ Group
K_1	=	Minimum fixed transportation cost for a vehicle (Rs.)
K_2	=	Transportation cost per kilometer (Rs./km)
K_3	=	Loading cost at each vendor plant (Rs./ vendor)
n	=	Number of vendors in a Rim/Group

Chapter 1
INTRODUCTION

1.1 Introduction

In today's world of competition, survival of any enterprise depends upon the customer satisfaction. The customers are satisfied when the supply chain management of an enterprise provides good quality of products and services in a timely, cost effective manner. So, for any supply chain management who succeed inbound logistics plays an important role. It provides continuous stream of raw material, storage of raw material, in-process inventory, finished goods, services, and related information from the point of origin (supplier) to the point of consumption (customer) by proper planning and control.

Logistics involves the operations like transportation, production planning with efficient demand management, distribution network design, location of plants and warehouses, inventory management and movement of material. The challenge is to have an un-interrupted flow of material with minimum logistics cost which includes ordering cost, transportation cost, warehousing cost and inventory carrying cost. Transportation (transport mode choice, routing and scheduling, movement pattern between vendors and buyer, shipment size either consolidated bulk shipment or small lot size) and inventory planning have vital role to minimize the logistics cost.

In JIT purchasing the objective is to procure the material in as small batch order size as possible. But by having a small batch size the transportation and ordering cost increases which may not justify the smaller order size. JIT purchasing emphasizes nearby suppliers to make the smaller order viable. But in existing setup where it is not possible to bring the ancillaries close to manufacturing units Rim system (Milk Run System) can be used, in which each shipment material is collected from a group of vendors. The material may be collected when ordered quantity in number of sets is equal to full truck capacity for all items or EOQ for all items or full truck capacity for a group size of any number of vendors, thereby reduced congestion at the gate, better utilization of truck capacity and small lot size without adversely affecting the transportation cost. In conventional system namely Spoke System, the transport vehicle directly ships the material from each vendor to buyer and hence bulk supply of each item at buyer's end. Again material can be shipped when the ordered quantity is equal to EOQ for each item or EOQ from each vendor or full truck capacity for each item or full truck capacity from each vendor.

About Company

Maruti Udyog Ltd, established with technical collaboration with Suzuki Motor Corporation of Japan, has been the leader of the Indian car market for about two decades. Its manufacturing plant, located in district Gurgaon, has an installed capacity of 3,50,000 units per annum, with a capability to produce about half a million vehicle per annum. It sold 561822 passenger cars in domestic and export market during the year 2005-06, the highest since inception. It is producing 11 models of passenger cars with high volumes of mainly small cars like Maruti800, Omni, Alto and WagonR. It has a widely spread sale network with 375 outlets in 227 cities and 2096 service workshops in 1092 cities. It has approximate 250 vendors supplying car components situated in India and abroad. Out of these approximately 80% are situated nearby to manufacturing plant within a radius of 60km.

1.2 Problem definition

It has been estimated that in recent years, the logistics cost in Indian manufacturing industry has increased to 30% to 40% of the total cost of products. Hence flow of materials from procurement of raw materials to delivery of the finished products has become the most important area for cost control. Inventory and transportation are two critical issues for cost control. A high level of product availability at a reasonable price can be achieved by carrying a low level of inventory at various stages like raw material inventory, in -process and finished goods inventory. Since transportation is required almost at all stages from the supplier to the customer, efficient routing of vehicle and order size (shipment size) allows the company to lower the inventories cost.

Enterprise keeps either 7 days or 15 days inventories to fulfill customer demand by direct shipment of raw material from vendor to buyer i.e. Spoke System. But the

Spoke System causes high inventory, uncoordinated supplies at factory gate, increase manpower to unload and required large space. Whereas when the enterprise procures small lot sizes with Rim System as required in JIT system results in reduced congestion at the gate, better utilization of truck, reduced inventory. But the frequency of deliveries by the vendors is high where a single vehicle collects the material from a group of vendors

Both the systems have their importance. Spoke system is used when the distance between the vendors is large and when the items are not compatible with each other from transportation point of view. The transportation cost will decrease but there will be an increase in inventory cost.

Rim system can be implemented when the vendors are nearby to each other. This results in decrease in inventory cost but there is a little increase in transportation cost. This cost increase is because of increase in distance covered by vehicle.

So, by the discussion of both issues the logistic cost obtains in Rim System is less as compare to Spoke System.

Therefore challenges are to optimize the routes of raw material carrying vehicles from vendors to manufacturing site and shipment size in order to minimize the logistics cost.

1.3 Objectives

To study the issues in inbound logistics.

- To study the existing shipping pattern between vendors and buyer (Rim/Spoke system), order quantity, size of truck, etc.
- To determine the shipment size (ordered quantity) and size & design of group (number of vendors) by considering the total cost of each alternative.

1.4 Scope

Effective supply chain is the continuous movement of products and services from vendors to manufacturer to the customer. Supply chain management involves managing vendors, purchasing the material, scheduling production, packaging and delivery of finished goods to the customer. Transportation and inventory are key areas in supply chain management. Since transportation is more than 30 percent of the logistics costs, efficient use of transportation reduces the logistics cost. In this project emphasize is given on shipment sizes (consolidated bulk shipments versus Lot-for-Lot) and routing of transport mode which are the key in effective management of a firm.

Scope of this project is to study and understand the approaches used to minimize the inbound logistics cost (total of transportation and inventory cost).

1.5 Methodology

As discussed earlier that the transportation cost and inventory cost play a significant role in supply chain management to achieve a high level of product availability at a reasonable price and it is a key factor. If we decrease the transportation cost by decreasing the number of trips, then the inventory cost increases hence the total cost increases. On the contrary if we decrease the inventory cost, the transportation cost increases and so again increases the total cost. To reduce the total cost the transport vehicle can be routed in either SPOKE SYSTEM or RIM SYSTEM. In Spoke system shown in figure 1.1 the individual vehicles deliver the quantity from one vendor to buyer due to which the transportation cost will decrease but there will an increase in inventory cost.

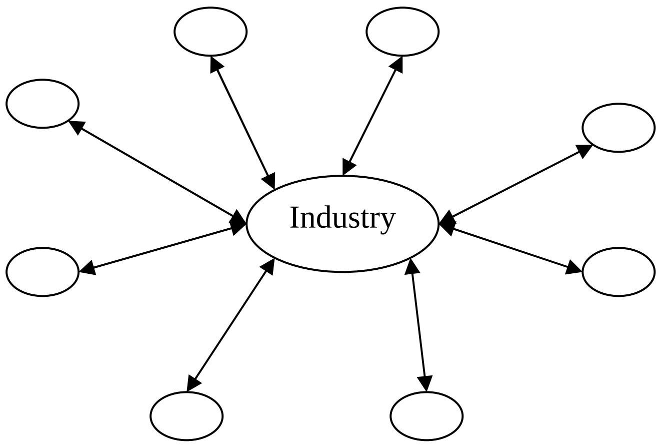

Figure 1.1: Individual vehicles deliver the material of all vendors

On the other side, from the figure 1.2 in Rim system single truck reaches each vendor's location and loads some quantity of each item. Thus in Rim system, instead of all vendors transporting their items using individual vehicle, a single vehicle is used by all the vendors. This results in decrease in inventory cost but there is a little increase in transportation cost.

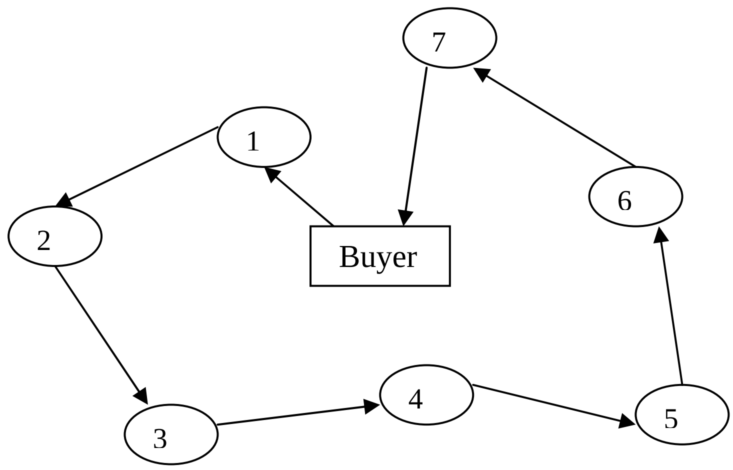

Figure 1.2: A single vehicle delivers the material from a group of vendors

Since the items are received in sets, and in small quantities, they can be unloaded at the point of usage in the factory and thus reduce the material – handling within the factory.

Chapter 2

OVERVIEW OF SUPPLY CHAIN MANAGEMENT

Business Organizations all over the world are striving hard to survive in Global Competitive Environment. Supply Chain Management is one such effective methodology and presents an integrated approach to resolve issues in sourcing, customer service, demand flow and distribution. The results are in the form of reduced operational costs, improved flow of supplies, reduction in delays of distribution and increased customer satisfaction. A typical textbook definition of supply chain management is provided by Nahamias- “It is the logistics of managing the pipeline of goods from contracts with suppliers and receipt of incoming material, control of work- in- process, and finished goods inventories in the plant, to contracting the movement of finished goods to customer through channel of distribution”. Figure 2.1 shows the Typical Supply Chain Management Model which indicates the incoming flow of information and material into the enterprise(where various functions like material flow from planning, purchase and control of inventory, to manufacturing and delivery of finished goods are done) and delivery of finished goods to the distribution channel to meet customer order fulfillment and delivery requirement.

Hence a supply chain is dynamic and involves the constant flow of information, product, and funds between manufacturers, suppliers, transporters, warehouses, retailers and customers themselves in fulfilling a customer request. It exist in both service and manufacturing organizations, although the complexity of the chain may vary greatly from industry to industry and firm to firm. Managing the chain of this process is known as Supply Chain Management.

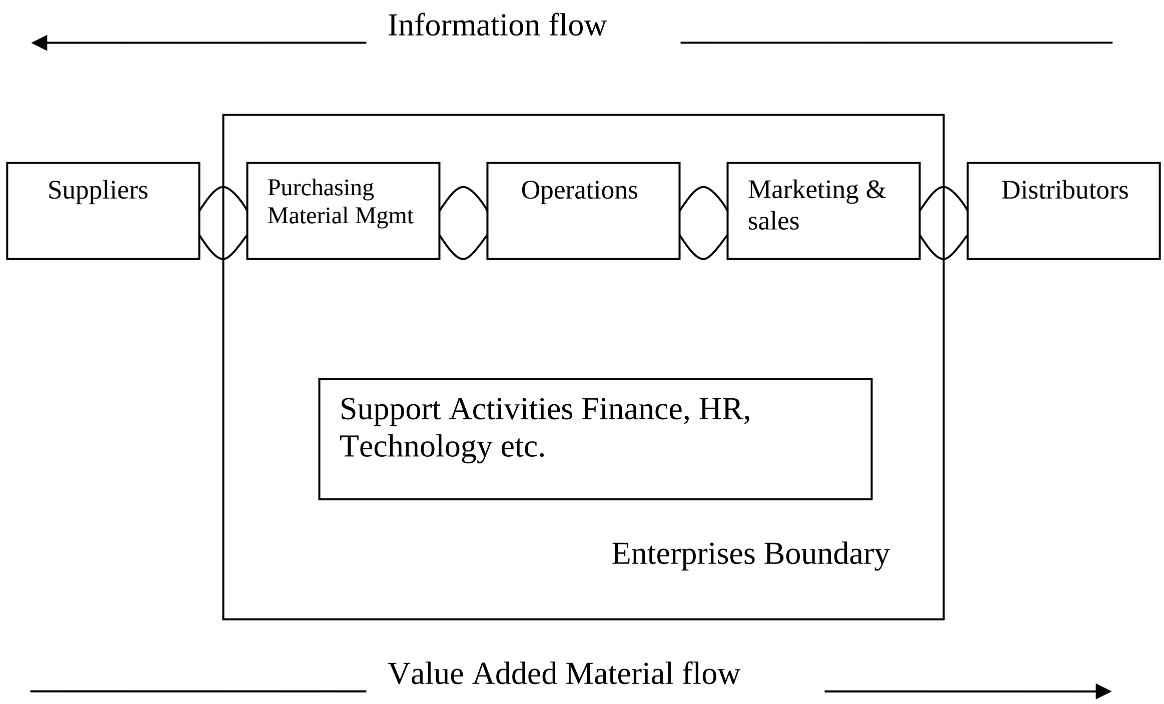

Figure 2.1: Typical Supply Chain Management Model

Global Competitiveness today means that the customer is supreme and he can source his goods and services from anywhere in the world. So, to be successful in this competitive environment the enterprises –

- Are able to provide goods and services to the customer in a timely cost- effective manner and also provide quality which not only satisfies him but delights him
- Will have to mange its time very well so that it can compete on the basis of time.
- Has to manage its operations in such a way that the production costs and delivery costs are kept to the minimum and margins are optimized.
- Has to increase the velocity of transactions within the enterprises and the environment outside by imaginative planning i.e. use of IT. If the information network is extended to cover the supplier also, then it is possible to realize the situation where the supplier is directly in touch with the stock levels and inventory levels in the buyer's enterprise and can plan and supply accordingly.
- Has to build a culture of quality and productivity because without that it is just not possible to survive.
- Has to build a culture of innovation.

In other words if the supply chain is not managed properly, the delivery chain is automatically bound to be affected resulting in customer dissatisfaction, and finally loss of business.

2.1 Supply Chain Decisions

The decisions for supply chain management can be classified into two broad categories -- strategic and operational. As the term implies, strategic decisions are made typically over a longer time horizon. Strategic decisions deal with corporate strategy and guide supply chain policies from a design perspective. On the other hand, operational decisions are short term, and deal with every day activities and problems of an organization. The effort in these types of decisions is to effectively and efficiently manage the product flow in the "strategically" planned supply chain.

Furthermore, market demands, customer service, transport considerations, and pricing constraints all must be understood in order to structure the supply chain effectively. There are all factors, which change constantly and sometimes unexpectedly, and an organization must realize this fact and be prepared to structure the supply chain accordingly.

There are five major decision areas in supply chain:

1) Location
2) Production
3) Inventory
4) Transportation (Distribution), and
5) Information, and

There are both strategic and operational elements in each of these decision areas.

1) Location Decisions

The geographic placement of production facilities, stocking points, and sourcing points is the natural first step in creating a supply chain. The location of facilities involves a commitment of resources to a long-term plan. Once the size, number, and location of these are determined, so are the possible paths by which the product flows through to the final customer. These decisions are of great significance to a firm since they represent the basic strategy for accessing customer markets, and will have a considerable impact on revenue, cost, and level of service. These decisions should be determined by an optimization routine that considers production costs, taxes, duties and duty drawback, tariffs, local content, distribution costs, production limitations, etc. Although location decisions are primarily strategic, they also have implications on an operational level.

2) Production Decisions

The strategic decisions include what products to produce, and which plants to produce them in, allocation of suppliers to plants**.** As before, these decisions have a big impact on the revenues, costs and customer service levels of the firm. These decisions assume the existence of the facilities, but determine the exact path(s) through which a product flows to and from these facilities. Another critical issue is the capacity of the manufacturing facilities. Operational decisions focus on detailed production scheduling. These decisions include the construction of the master production schedules, scheduling production on machines, and equipment maintenance. Other considerations include workload balancing, and quality control measures at a production facility.

3) Inventory Decisions

These refer to means by which inventories are managed. Inventories exist at every stage of the supply chain as either raw material, semi-finished or finished goods. They can also be in-process between locations. Their primary purpose to buffer against any uncertainty that might exist in the supply chain. Since holding of inventories can cost anywhere between 20 to 40 percent of their value, their efficient management is critical in supply chain operations. It is strategic in the sense that top management sets goals. Operational inventory decision includes the determination of the optimal levels of order quantities and reorder points, and setting safety stock levels, at each stocking location. These levels are critical, since they are primary determinants of customer service levels.

4) Transportation Decisions

The transportation decisions are the more strategic ones. These are closely linked to the inventory decisions, since the best choice of mode is often found by the cost of using the particular mode of transport with the indirect cost of inventory associated with that mode. While air shipments may be fast, reliable, and warrant lesser safety stocks, they are expensive. Meanwhile shipping by sea or rail may be much cheaper, but they necessitate holding relatively large amounts of inventory to buffer against the inherent uncertainty associated with them. Therefore customer service levels and geographic location play vital roles in such decisions. Since transportation is more than 30 percent of the logistics costs, operating efficiently makes good economic sense. Shipment sizes (consolidated bulk shipments versus Lot-for-Lot), routing and scheduling of equipment are key in effective management of the firm's transport strategy.

5) Information

Effective supply chain management requires obtaining information from point of end –use, and linking information resources throughout the chain for speed of exchange. Overwhelming paper flow and disparate computer systems are unacceptable in today’s competitive world. Fostering innovation requires good organization of information. Linking computer through networks and internet, and streamlining the information flow, consolidates knowledge and facilities velocity of products. Account management soft wares, product configuration, enterprise resource planning systems, and global communications are key components of effective supply chain management strategy.

2.2 Process view of a Supply Chain

A supply chain is a sequence of processes and flows that take place within and between different stages and combine to fill a customer need for a product. There are two different ways to view the processes performed in a supply chain:

Cycle view:

The processes in a supply chain are divided into a series of cycles, each performed at the interface between two successive stages of a supply chain.

Given the five stages of a supply chain, all supply chain processes can be broken down into the following four-cycle processes.

1) Customer order cycle
2) Replenishment cycle
3) Manufacturing cycle
4) Procurement cycle

Each cycle occurs at the interface between two successive stages of the supply chain. The five stages that result in four supply chain process cycles. Not every supply chain will have all four cycles clearly separated. For example, a grocery supply chain in which a retailer stocks finished goods and places replenishment orders with a distributor is likely to have all four cycles separated. Dell, in contrast, sells directly to customers, thus bypassing the retailer and distributor.

A cycle view of the supply chain is very useful when considering operational decisions because it clearly specifies the roles and responsibilities of each member of the supply chain. The detailed process description of a supply chain in the cycle view forces a supply chain designer to consider the infrastructure required to support these processes. The cycle view is useful, for example, when setting up information systems to support supply chain operations, as process ownership and objectives are clearly defined. We now describe the various supply chain cycles in greater detail.

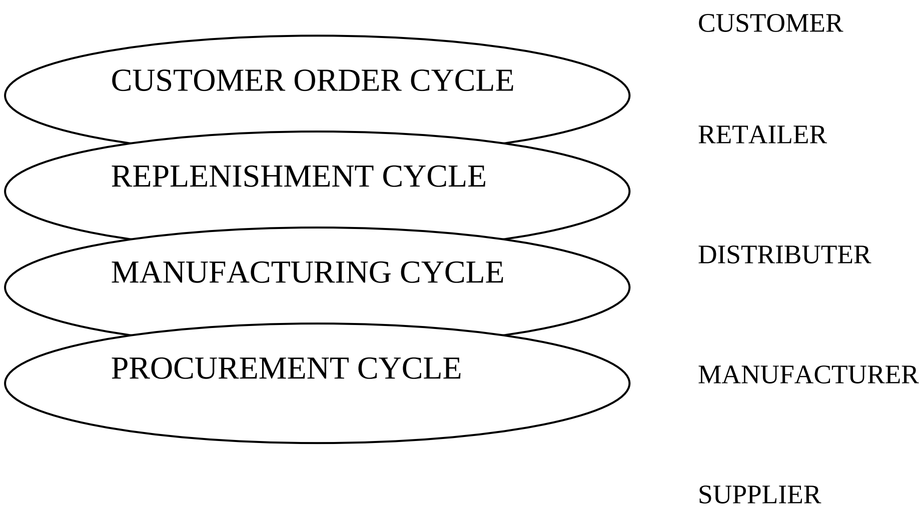

Figure 2.2: Supply Chain Process Cycles

1) Customer Order Cycle

The customer order cycle occurs at the customer/retailer interface and includes all processes directly involved in receiving and filling the customer's orders. Typically, the customer initiates this cycle at a retailer site and the cycle primarily involves filling customer demand. The retailer's interaction with the customer starts when the customer arrives or contact is initiated and ends when customer receives the order. The processes involved in the customer order cycle are:

- Customer arrival
- Customer order entry
- Customer order fulfillment
- Customer order receiving

Customer Arrival

The term customer arrival refers to the customer arrival at the location where he or she has access to his or her choices and makes a decision regarding a purchase. The starting point for any supply chain is the arrival of a customer.

From the supply chain perspective, the key flow in the process is the customer's arrival. The goal is to facilitate the contact between the customer and the appropriate product so that the customer's arrival turns into a customer order. At a supermarket, facilitating a customer order may involve managing customer flows and product displays. It may also mean having system in place so that sales representatives can answer customer queries in a way that turns calls into orders. At a website, a key system may be search capability with tools such as personalization that allow customers to quickly locate and view products that may interest them. The objective of the customer arrival process is to maximize the conversation of customer arrivals to customer orders.

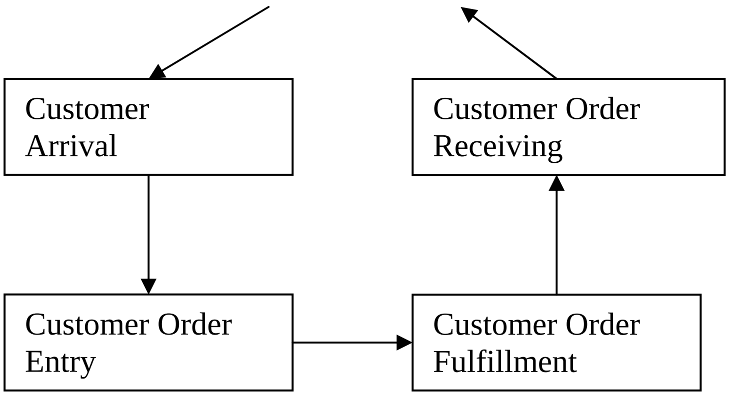

Figure 2.3: Customer Order Cycle

Customer Order Entry

The term customer order entry refers to customers informing the retailer what product they want to purchase and the retailer allocating products to customers. At a supermarket, order entry makes take the form of customers loading all items that they intend to purchase onto their cards. At a mail order firm's telemarketing centre or website order entry may involve customers informing the retailer of the items and quantities they selected. The objective of customer order entry process is to ensure that the order entry is quick, accurate, and communicated to all other supply chain processes.

Customer Order Fulfillment

During this process, the customer's order is filled and sent to the customer. At a supermarket, the customer performs this process. At a mail order firm this process generally includes picking the order from inventory, packaging it, and shipping it to the customer. In general, customer order fulfillment takes place directly from the manufacturer's production line. The objective of the customer order fulfillment is to get the correct orders to customer by the promised due date at the lowest possible cost.

Customer Order Receiving

During this process, the customer receives the order and takes ownership. Records of this receipt may be updated and payment completed. At a supermarket, receiving occurs at the check out counter. For a mail order firm, receiving occurs when the product is delivered to the customer.

2) Replenishment Cycle

The replenishment cycle occurs at the retailer/distributor interface and includes all processes involved in replenishing retailer inventory. It is initiated when a retailer places an order to replenish inventories to meet future demands. A replenishment cycle may be triggered at a supermarket that is running out of stock or at a mail order firm that is low on stock of a particular shirt.

The replenishment cycle is similar to the customer order cycle except that the retailer is now the customer. The objective of the replenishment cycle is to replenish inventories at the retailer at minimum cost while providing high product availability. The processes involved in the replenishment cycle are:

- Retailer order trigger
- Retail order entry
- Retail order fulfillment
- Retail order receiving

Retail Order Trigger

As the retailer fills customer demand, inventory is depleted and must be replenished to meet future demand. A key activity the retailer performs during the replenishment cycle is to devise replenishment or ordering policy that triggers an order from the previous stage. The objective when setting replenishment orders triggers is to maximize profitability by ensuring economies of scale and balancing product availability and the cost of holding inventory.

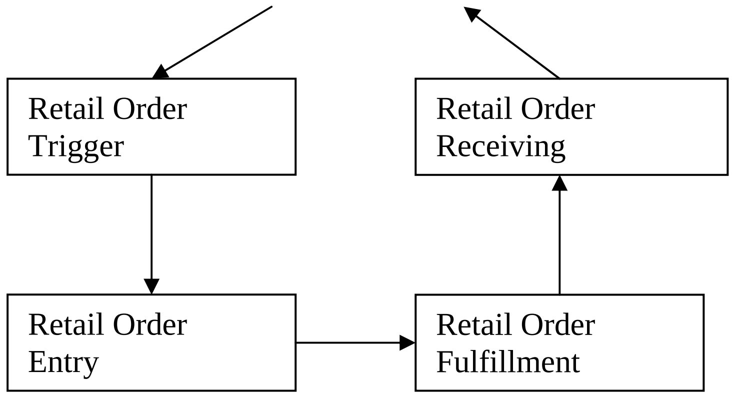

Figure 2.4: Replenishment Cycle

Retail Order Entry

This process is similar to customer order entry at the retailer. The only difference is that the retailer is now the customer placing the order that is conveyed to the distributor. This may be done electronically or by some other medium. Inventory or production is then allocated to the retail order. The objective of the retail order entry process is that an order be entered accurately and conveyed quickly to all supply chain processes affected by the order.

Retail Order Fulfillment

This process is very similar to customer order fulfillment except that it takes place at the distributor. A key difference is the size of each order as customer orders tend to be much smaller than replenishment orders. The objective of the retail order fulfillment is to get the replenishment order to the retailer on time while minimizing costs.

Retail Order Receiving

Once the replenishment order arrives at a retailer, the retailer must receive it physically and update all inventory records. This process involves product flow from the distributor to the retailer as well as information updates at the retailer and the flow of funds from the retailer to the distributor. The objective of the retail order receiving process is to update inventories and displays quickly and accurately at the lowest possible cost.

3) Manufacturing Cycle

The *manufacturing cycle* typically occurs at the distributor/manufacturer (or retailer/manufacturer) interface and includes all processes involved in replenishing distributor (or retailer) inventory. The manufacturing cycle is triggered by customer orders, replenishment orders from a retailer or distributor (Wal-Mart ordering from P&G), or by the forecast of customer demand and current product availability in the manufacturer's finished-goods warehouse.

One extreme in a manufacturing cycle is an integrated steel mill that collects orders that are similar enough to enable the manufacturer to produce in large quantities. In this case, the manufacturing cycle is reacting to customer demand. Another extreme is a consumer products firm that must produce in anticipation of demand. In this case the manufacturing cycle is anticipating customer demand. The processes involved in the manufacturing cycle are:

- Order arrival from the finished goods warehouse, distributor, retailer, or customer
- Production scheduling
- Manufacturing and shipping
- Receiving at the distributor, retailer, or customer

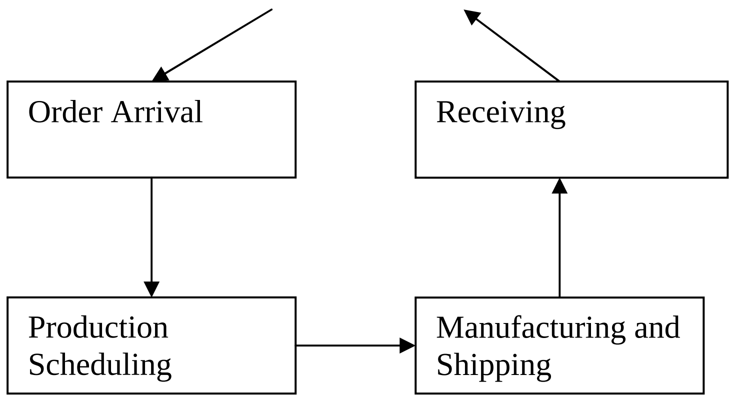

Figure 2.5: Manufacturing cycle

Order Arrival

During this process, a finished-goods warehouse or distributor sets a replenishment order trigger based on the forecast of future demand and current product inventories. The resulting order is then conveyed to the manufacturer. In some cases, the customer or retailer may be ordering directly from the manufacturer. In other cases a manufacturer may be producing to stock a finished products warehouse. In the latter situation, the order is triggered based on product availability and a forecast of future demand. This process is similar to the retail order trigger process in the replenishment cycle.

Production Scheduling

This process is similar to the order entry process in the replenishment cycle where inventory is allocated to an order. During the production scheduling process, orders (or forecasted orders) are allocated to a production plan. Given the desired production quantities for each product, the manufacturer must decide on the precise production sequence. If there are multiple lines, the manufacturer must also decide which products to allocate to each line. The objective of the production scheduling process is to maximize the production of orders filled on time while keeping costs down.

Manufacturing and Shipping

This process is equivalent to the order fulfillment process described in the replenishment cycle. During the manufacturing phase of the process, the manufacturer produces to the production schedule. During the shipping phase of this process, the product is shipped to the customer, retailer, distributor, or finished-product warehouse. The objective of the manufacturing and shipping process is to create and ship the product by the promised due date while meeting quality requirements and keeping costs down.

Receiving

In this process, the product is received at the distributor, finished-goods warehouse, retailer, or customer and inventory records are updated. Other processes related to storage and fund transfers also take place.

4) Procurement Cycle

The *procurement cycle* occurs at the manufacturer/supplier interface and includes all processes necessary to ensure that materials are available for manufacturing to occur according to schedule. During the procurement cycle, the manufacturer orders components from suppliers that replenish the component inventories. The relationship is quite similar to that between a distributor and manufacturer with one significant different. Whereas retailer/distributor orders are triggered by uncertain customer demand, component orders can be determined precisely once the manufacturer has decided what the production schedule will be. Component orders depend on the production schedule. Thus it is important that suppliers be linked to the manufacturer's production schedule. Of course, if a supplier's lead times are long, the supplier has to produce to forecast because the manufacturer's production schedule may not be fixed that far in advance.

In practice, there may be several tiers of suppliers, each producing a component for the next tier. A similar cycle would then flow back from one stage to the next.

A cycle view of the supply chain clearly defines the processes involved and the owners of each process. This view is very useful when considering operational decisions because it specifies the roles and responsibilities of each member of the supply chain and the desired outcomes for each process.

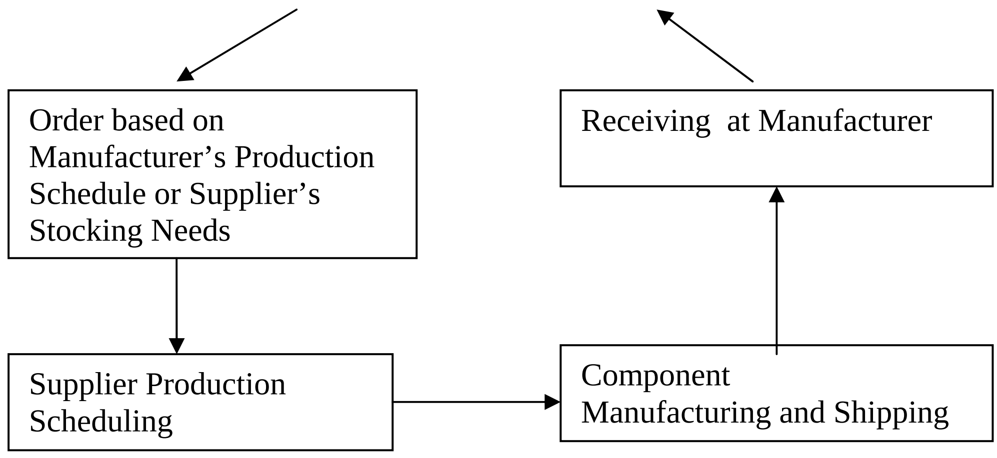

Figure 2.6: Procurement Cycle

Push/Pull View of Supply Chain

All processes in a supply chain fall into one of two categories depending on the timing of their execution relative to end customer demand. With pull processes, execution is initiated in response to a customer order. With push processes, execution is initiated in anticipation of customer orders. Therefore, at the time of execution of a pull process, customer demand is known with certainty whereas at the time of execution of a push process, demand is not known and must be forecast. Pull processes may also be referred to as reactive processes because they react to customer demand. Push processes may also be referred to as speculative processes because they respond to speculated (or forecasted) rather than actual demand. The push/pull boundary in a supply chain separates push processes from pull processes. At Dell, for example, the beginning of PC assembly represents the push/pull boundary. All processes before SPC assembly are push process and all processes after and including assembly are initiated in response to a customer order and are thus pull processes.

A push/pull view of the supply chain is very useful when considering strategic decisions related to supply chain design. This view forces a more global consideration of supply chain processes as they relate to a customer order. Such a view may, for instance, result in responsibility for certain processes being passed on to a different stage of the supply chain if making this transfer allows a push process to become a pull process.

Chapter 3

LOGISTICS MANAGEMENT IN SCM

The importance of logistics management as a means for maintaining and improving corporate profitability has never been grater then it is today. Logistics play a major role in identifying vendors, routing raw materials through warehouses in an optimal manner to different plants, deciding in- plant movement of materials, and even stocking finished goods and then delivering them to customers. Logistics involving material procurement is called inbound logistics; and that involving supply finished products to the customers is called outbound logistics.

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The definition formulated by the Council of Logistics Management defined logistics as: “the process of planning, implementing and controlling the efficient, cost – effective flow and storage of raw material, in- process inventory, finished goods and related information from the point of origin to the point of consumption (including inbound, outbound, internal and external movement) for the purpose of conforming to customer requirements.

Perhaps the best way to understand logistics is to divide into separate functions illustrated in Figure 3.1 the first function is termed as **material management** and is identified with the incoming flow of information and material into the enterprise. Material management can be defined as collection of business function supporting the cycle of material flow from planning, purchase and control of inventory, to manufacturing and delivery of finished goods to the distribution channel system. The second function is termed as **physical distribution**. This function is associated with warehousing and movement of finished goods and service parts through the distribution channel to meet customer order fulfillment and delivery requirements. Peter Drucker one of the gurus of management, writing in Fortune magazine as early as 1962 had observed: ‘Physical distribution is today’s frontier in business. It is one area where managerial results of great magnitude can be achieved. And is still largely unexpected territory.

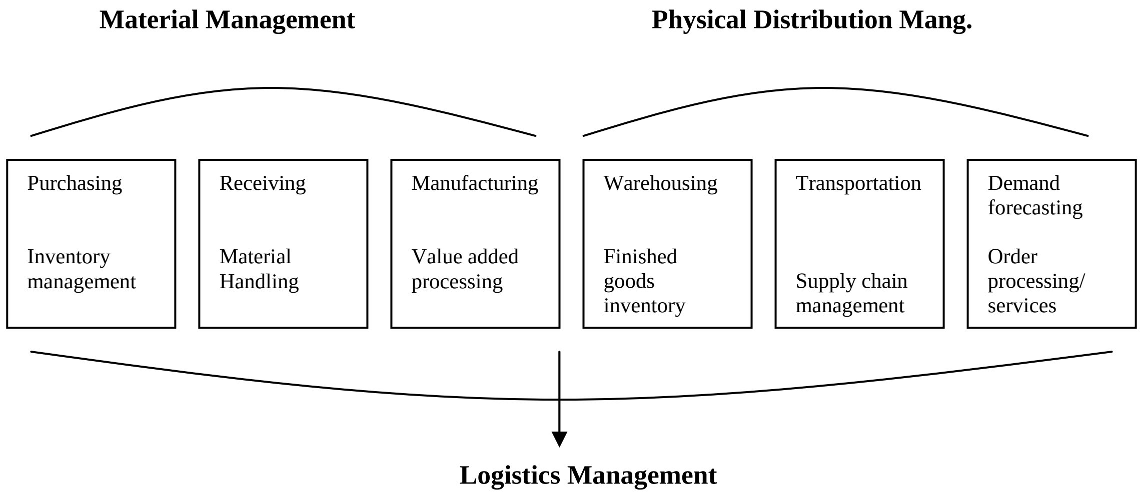


Figure 3.1: Structure of Logistics Management

The raw material cost forms a significant portion, nearly 40% of the total cost. Hence, the raw material must be procured and provided for processing in an optimal manner. The decisions like economic orders size, reorder level, etc. are generally considered to minimize the cost of holding inventory. Special emphasis for the cost of transportation of raw materials which in turn depends upon the location of vendors, and intermediate warehouses. Again within the plant the logistics play a major role to minimize the in- plant movements which will help in minimizing throughout time and cost of transportation. Sometimes even the quality of the products improves because of reduced movement.

3.1 Need for Integrated Logistics System

In total logistics system, the movement of materials/products will be in between five stages as listed:

- Vendors (V)
- Raw Materials Warehouses (RMW)
- Plants (P)
- Finished Goods Warehouses (FGW)
- Markets (M)

The complete cycle from sourcing of raw materials to the dispatch of finished goods to the market point is diagrammatically shown in Figure 3.2. This is a more generalized representation incorporating all possible options of logistics system components. In an ideal situation, the business logistics. It consists of the following parameters:

- Total number of vendors identified for supplying raw materials
- Total number of raw material warehouses proposes
- Total number of plants proposed
- Total number of finished goods warehouses proposed
- Total number of markets identified

In an existing organization, where the locations of members of each stage are known, then the objective(s) in an ideal situation is to consider all the five stages together for planning the movement pattern of the raw material from vendors to Raw Material Warehouses and then from Raw Material Warehouses to Plants, products from Plants to Finished Goods Warehouses and then from Finished Goods Warehouses to Markets. Sometimes, there may be movements of materials/products between the members at a given stage, for example, between Raw Material Warehouses or between Plants.

This type of decision on the movement pattern of the raw materials/products will provide integration among various stages which will lead to more overall productivity of the organization.

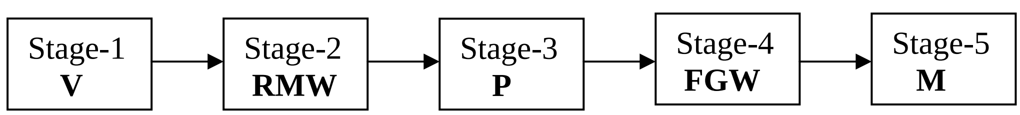


Figure 3.2: Integrated Business Logistics System

3.2 Criticalities of Integrated Business Logistics System

In the design of a new business logistics system, at the first phase, it is essential to determine the following:

- Potential Vendors and their locations.

- Potential Sites for Raw Material Warehouses.
- Potential Sites for Locating Plants.
- Potential Sites for Locating Finished Goods Warehouses.
- Potential Market Points.

While proposing potential sites for each of the above items, relevant requirements are to be matched with the features of each item.

In the second phase, an integrated logistic or subsystem study must be conducted to optimize the total cost of operating the business logistics system.

There are several cases in the Integrated Business Logistics System which are to be considered. They are as listed below:

Case 1:

Consider from Stage 1 (V) to Stage 2 (RMW) of the Figure3.2. Here, the objective is to determine the optimal shipping pattern between them such that the total cost of transportation is minimized.

Case 2:

Consider from Stage 2 (RMW) to Stage 3(P) of the Figure3.2. Here, the objectives are as follows:

a) Find the optimal movement pattern such that the cost of transportation is minimized by assuming fixed sites at both stages.
b) Identify the optimal number of warehouses, such that the total cost of operation of the warehouses is minimized by assuming unfixed sites at the Stage 2 and fixed sites at Stage

Case 3:

Consider from Stage 1(V) to Stage 3 (P).

a) If all the first three stages are with fixed sites, then the objective is to find the optimal movement plan for this segment of the logistics system such that the total cost of transportation is minimized.

b) If only the vendor sites and plant locations are fixed, then the objective may be to determine the optimal number of raw material warehouses such that the total cost of operation of the V-RMW-P logistics subsystems is minimized.

Case 4:

Consider the Stage 3 (P) of the Figure 3.2. Within the stage 3 (Plants), one may be interested in optimizing the inter-plant movement or intra-plant movement of materials/semi-finished items/finished items.

Case 5:

Consider from Stage 3 (P) to Stage 4 (FGW) of the Figure 3.2. In this form of logistics subsystem, the objective is to find the optimal distribution plan such that the total cost of transporting finished goods from the plants to the finished goods warehouses is minimized.

Case 6:

Consider from Stage 4 (FGW) to Stage 5 (M) of the Figure 3.2. Some time there may be items in the finished goods warehouses based on regular time production and subcontracting. Under such situation, one may consider only the Finished Goods Warehouses and market points as a logistics subsystem for analysis. Here, the objective may be just to determine the movement pattern from the Finished Goods Warehouses to the market points.

Case 7:

Consider from Stage 1 (V) to Stage 5 (M) of the Figure 3.2. By incorporating all the stages together, one will be interested to determine the optimal movement pattern from the first stage (vendor) to the last stage (market points). This is the fully integrated Logistics Systems.

These cases clearly show the links of the logistics system with the entire supply chain management.

The selection of particular case from the above cases depends on the reality. For example, if the vendors are closely located, the intermediate raw material warehouses can be eliminated. Similarly, if the market points are very closer to the plants, then the intermediate finished goods warehouses can be avoided.

3.3 Techniques/Approaches to Manage Criticalities

The various techniques/approaches for different cases that are proposed in this project are presented in this section.

Case 1: Stage 1 (V)-Stage 2(RMW)

In this case, the objective is to determine the optimal movement pattern between the vendors and raw material warehouses such that the total cost of transportation is minimized.

The conventional transportation method can be used to determine the optimal movement pattern between the vendors and the Raw Materials Warehouses. Here, the vendors and the Raw Materials Warehouses will be assumed as sources and destinations, respectively.

Case 2: Stage 2 (RMW) – Stage 3 (P)

Let the number of fixed/proposed sites for locating raw material warehouses be b and c be the number of plants.

Here, the following sub problems can be generated.

a) Number of Raw Material Warehouses is known for a known number of plants.
b) Number of Raw Material Warehouses is unknown for a known number of plants.

Number of Raw Material Warehouses known for a known number of plants

Here again, one can use the conventional transportation method to find the optimal movement plan such that the total cost of transportation for this segment of the logistics system is minimized. In this problem, the Raw Material Warehouses and the plants will act as sources and destinations, respectively.

Case 3: Stage 1 (V) - Stage 2 (RMW)- Stage 3 (P)

a) Assume that the sites for all the first three stages are fixed. Then, the objective is to find the optimal distribution plan such that the total cost of transportation is minimized. The trans-shipment method can be used to find the solution for this problem.

b) Assume that the sites in the Stage 1 (V) and Stage 3 (P) are fixed. The sites for the Stage 2 (RMW) are not fixed.

Here, the objective is to determine the optimal number of Raw Material Warehouses such that the total cost of operation of the V-RMW-P logistics subsystem is optimized.

For this situation, an attempt may be made to develop a mathematical model to determine the optimal number of Raw Material Warehouses such that the sum of the cost of operations of Raw Material Warehouses and the movement cost from Stage 1 to Stage 3 is minimized.

Case 4: Within Stage 3 (P)

In each plant, there is a lot of scope for productivity improvement through better logistics planning. Some of the important problems are as listed below:

a) Process layout design
b) Product layout design
c) Group Technology Layout design
d) Introduction of a new facility into the existing layout
e) Introduction of a set of new facilities into the existing layout
f) Raw materials stores layout design
g) Finished goods stores layout design

a) **Process Layout Design**

Here, the objective is to relocate the departments of an existing layout or determine the locations of the departments of a new layout such that the total material handling cost is minimized.

There are many techniques available to solve these problems which are listed below:

- Mathematical Model [Frances and White 1974]
- CRAFT [Panneerselvam 1998]
- ALDEP [Panneerselvam 1998]
- CORELAP [Panneerselvam 1998]
- Steepest Descent Pair wise interchange technique for a special problem in which the departments have equal area [Francis and White, 1974].

b) **Product Layout Design**

In this type of layout, the design of layout is trivial, but balancing the stations of the product line is a challenging task. The heuristics like Rank positional weight method, COMSOAL etc. (Panneerselvam 1998) can be used to design the assembly line which will maximize the balancing efficiently.

c) **Group Technology Layout Design**

This type of layout tries to combine the advantages of the process layout and the product layout.

d) **Introducing a new facility into an existing layout**

In literature, this type of problem is called as the single facility location problem. The objective of this problem is to find the best location for the new single facility such that the cost of transportation from the new facility to a set of existing facilities is minimized. Some examples are introducing CNC Machine/Machine Centre in a machine ship.

The Median Location Technique (P Anneerselvam 1998) can be used to solve this problem.

e) **Introduction of a Set of New Facilities into an Existing Layout**

In literature, this type of problem is called as multifacility location problem. A linear programming modeling approach (P Anneerselvam, 1998) can be used to solve this type of problem.

(f and g) **Raw Materials Stores Layout and Finished Goods Stores Layout Design**

Here, the objective is to allocate different items to different racks of the stores and fetch them on need such that the total time taken to draw raw materials from the stores is minimized.

Coding and Classification technique may be used to group different items in the stores such that the overall movements and time for storing and fetching are minimized.

Case 5: Stage 3 (P) to Stage 4 (FGW)

In a make to stock situation, the organization will be interested in optimizing the logistics between Plants and Finished Goods Warehouses. This problem may be treated as the conventional transportation problem by assuming the plants as the sources and the finished goods warehouses as the destinations. The objective is to find the optimal distribution plan such that the total cost of transportation in this segment of the total logistics system is minimized.

Case 6: Stage 4 (FGW) to Sage 5 (M)

This problem may also be viewed as in Case 5 by assuming the Finished Goods Warehouses as the sources and the market Points as the destinations.

Case 7: Stage 1 (V)-Stage 2(RMW)-Stage 3(P)-Stage 4 (FGW)-Stage 5 (M)

In this case, all the stages of the logistics system are considered simultaneously to design the distribution system starting from the vendor stage to the market stage in an integrated manner. A mathematical model may be tried for each of the following situations.

a) All the stages are with fixed sites.

b) Stage 1, Stage 3 and Stage 5 are with fixed sites and Stage 2 and Stage 4 are with unfixed sites.

3.4 Role of transportation in Logistics

It is virtually inconceivable in today's economy for a firm to function without the aid of transportation. Transportation in simple language can be defined as a means through which goods are transformed from one place to another. Given the facility and information capabilities, transportation is the operational area of logistics that geographically positions inventory. It is fundamentally important function and has most visible cost, hence there is a lot of importance given to the transportation in logistics process and hence demand due attention and time of manager responsible for transportation. In fact, the backbone of the entire supply chain is the transportation management that makes it possible to achieve the well- known seven R's- the right product in the right quantity and the right condition, at the right place, at the right time, for the right customer at the right cost.

3.5 Functions of Transportation

Figure 3.3 illustrates the functions of transportation to understand where it occurs in the entire supply chain. As it can be seen, transportation occurs between almost all the steps up and down the value chain. However, the internal transportation can and should be avoided as far as possible by getting the manufacturing process physically occurs. The major challenge lies in handling the external transportation.

Functionality

Hence, transportation provides two basic function:-

1) Product movement
2) Product storage

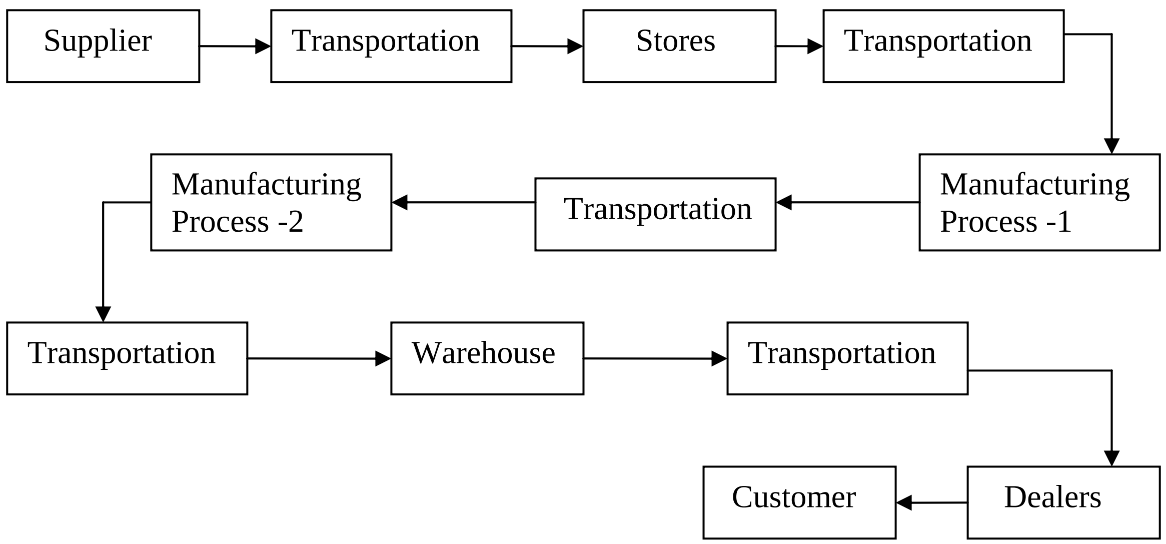


Figure 3.3: Functions of Transportation in SCM

1) Product movement

It is a primary transportation function. It moves the product up and down in the supply chain. Whether the product is in the form of materials, components, assemblies, work in process or finished goods, transportation is necessary to move it to the next stage of manufacturing process or physically closer to the ultimate customer.

However, during transportation of the product, there could be some loss on account of damage or product loss. Also the product is in accessible for use when it is in transit. There could also be environmental hazards due to use of polluting fuel. Hence, for a transportation decision- financial and environmental resources have to be considered.

2) Product storage

This is a less common function of transportation. This is because vehicles make rather expensive storage facilities. However, it makes sense to use it as a storage facilities in the following few instances.

- When the in- transit product requires to be moved shortly and the cost of unloading and reloading the goods will be more than the charges of storage in the vehicle.
- When the origin and destination warehouses space is limited. In such circumstances, when warehouse space is limited a circuited route is taken to increase the transit time that is greater than it would be in case of direct route.

Cost of storage < cost of unloading + cost of reloading + cost of warehouse
In vehicle

3.6 Key Factors in Decision Making

3.6.1 Factors Affecting Transportation Decision

There are two key players in any transportation that takes place within a supply chain. The shipper is the party that requires the movement between two points in the supply chain. The carrier is the party that moves or transports the product.

When making transportation related decisions, factors to be considered vary depending upon whether one takes the perspective of a carrier or shipper. A carrier makes investment decisions regarding the transportation infrastructure (rails, locomotives, trucks, airplanes, etc) and then makes operating decisions to try to maximize the return from these assets. A shipper, in contrast, uses transportation to minimize the total cost (inventory, transportation and facility) whiling providing an appropriate level of responsiveness to the customer.

3.6.2 Factors Affecting Carrier Decisions

A carrier's goal is to make investment decisions and set operating policies that maximize the return on its asset. A carrier such as an airline, railroad or trucking company must account for the following costs when investing in assets or setting pricing and operating policies.

a) *Vehicle related cost:* This is the cost a carrier incurs for the purchase or lease of the vehicle used to transport goods. The vehicle related cost is incurred whether the vehicle is operating or not and is considered fixed for short term operational decisions by the carrier. When making long term strategic decisions or medium term planning decisions, these costs are variable and the number of vehicles purchased or leased is one of the choices that a carrier makes. The vehicle cost is proportional to the number of vehicles leased or purchased.
b) *Fixed operating Cost:* This includes any cost associated with terminals, airport gates and labor that are incurred whether vehicles are in operation or not. Examples include the fixed cost of a trucking terminal facility or airport hub that is incurred independent of the number of trucks visiting the terminal or flights landing at the hub. If drivers were paid independent of the travel schedule, these costs are fixed. For planning and strategic decisions concerning the location and size of facilities, these costs are variable. The fixed operating cost is generally proportional to the size of operating facilities.
c) *Trip related cost:* This cost includes the price of labor and the fuel incurred for each trip independent of the quantity transported. The trip related cost depends on the length and duration of the trip but is independent of the quantity shipped. This cost is considered variable when strategic or planning decisions. The cost is also considered variable when making operational decisions that impact the length and duration of a trip.
d) *Quantity related cost:* This category includes loading/unloading costs and a portion of the fuel cost that varies with the quantity being transported. These costs are generally variable in all transportation decisions unless labor used for loading and unloading is fixed.
e) *Overhead cost:* This category includes the cost of planning and scheduling a transportation network as well as any investment in information technology.

When a trucking company invests in routing software that allows a manager to devise good delivery routes, the investment in the software and its operation is included in overhead. Airlines include the cost of groups that schedule and route planes and crew in overhead.

For strategic and planning decisions a carrier should consider all the costs mentioned above to be variable. For operational decisions, most of the aforementioned costs become fixed.

A carrier’s decision is also affected by the responsiveness it seeks to provide in target segment and the prices that the market will bear. An example can be the hub and spoke system designed by Fedex for transporting packages to provide fast, reliable delivery times. UPS is contrast used a combination of airline and trucks to provide cheaper transportation with somewhat longer delivery times.

3.6.3 Factors Affecting Shippers Decisions

Shipper’s decisions include the design of the transportation network, choice of means of transport and the assignment of each customer shipment to a particular means of transport. A shipper’s goal is to minimize the total cost of fulfilling a customer order while achieving the responsiveness promised. A shipper must account for the following cost when making the transportation decisions.

1. *Transportation cost:* This the total amount paid to various carriers for transporting products to customers. It depends on the prices offered by different carriers and the extent to which the shipper uses inexpensive and slow or expensive and fast means of transportation. Transportation costs are considered variable for all shipper decisions as long as the shipper does not own the carrier.
2. *Inventory cost:* This is the cost of holding inventory incurred by the shipper’s supply chain network. Inventory costs are considered fixed for short-term transportation decisions that assign each customer shipment to a carrier. Inventory costs are considered variable when a shipper is designing the transportation network or planning operating policies.
3. *Facility cost:* This is the cost of various facilities in the shipper’s supply chain network. Facility costs are considered as variable costs when supply chain

managers make strategic design decisions but are considered as fixed for all other transportation decisions.

4. *Service level cost:* This is the cost of not being able to meet the delivery commitments. In some cases it may clearly be specified as a part of a contract while in other cases it may be reflected in customer's satisfaction. This cost should be considered in strategic, planning and operational decisions.
5. *Processing cost:* This is the cost of loading/unloading orders as well as other processing costs associated with transportation. These are considered variable for all transportation decisions.

3.7 Modes of Transportation and Their Performance Characteristics

Supply chains use a combination of the following modes of transportation:

- Air
- Package carriers
- Truck
- Rail
- Water
- Pipeline
- Intermodal

Air

Major airlines in the United States that carry both passenger and cargo includes Delta Airlines and American Airlines. Airlines have a high fixed costing infrastructure and equipment. Labor and fuel costs are largely trip related and independent of the number of passengers or the amount of cargo carried on a flight. An airline's goal is to maximize the daily flying time of a plane and the revenue generated per trip. Given the large fixed costs and relatively low variable costs, revenue management in which airlines vary seat prices and allocate seats to different prices classes, is a significant factor in the success of a passenger airline. At present, airline practice venue management for passengers but not for cargo.

Air carriers offer a very fast and fairly expensive mode of transportation. Small high value items or time sensitive emergency shipments that have to travel long distances are best suited for air transport. Normally air carriers move shipments under 500 pounds, including high value but lightweight high tech products.

Key issues air carriers face include identifying the locating and number of hubs, assigning planes to routes, setting up maintenance schedules for planes, scheduling crews, managing prices and availability at different prices.

Package Carriers

Package carriers are transportation companies like FedEx, UPS etc. that carry small packages ranging from letters to shipments weighing about 150 pounds. Package carriers use air, truck and rail to transport time critical smaller packages. Package carriers are expensive and cannot compete with LTL carriers on price for large shipments. The major service they offer the shipper is rapid and reliable delivery. Thus, shippers use package carriers for small and time sensitive shipments. Package carriers also provide other value added services that shipper's to speed inventory flow and track order system. By tracking order status, shippers can proactively inform customers about their packages. Package carriers also pick up the package from the source and delivery it to the destination site. With an increase in JIT deliveries and focus on inventory reduction, demand for package carriers has grown.

Package carriers are the preferred mode of transport for e-business likes amazon.com and companies like Dell and McMaster Carr that send small packages to customers. With the growth in e-business the use of package carriers has increased significantly over the last few years. Package carriers like FedEx that use primarily airplanes are similar to air cargo carriers except that they seek out smaller and more time sensitive shipments where tracking and other value added services are more important. FedEx uses trucks to pickup packages at the source and deliver them to the final destination. Air Cargo carriers do not provide this combined service. Companies use air cargo carriers for larger shipments and package carriers for smaller shipments.

Given the small size of the packages and several delivery points, consolidation of shipments is a key factor in increasing utilization and decreasing costs for package carriers. Package carriers have trucks that make local deliveries and pick up packages. Packages are then taken to a sort center closest to the delivery point. From the delivery point sort center, the package is sent to the customers on small trucks using milk runs. Key issues in the industry include the location and capacity of transfer points as well as information capability to facilitate and track package flow. For the final delivery to the customer, an importation consideration is the scheduling and routing of the delivery trucks.

Truck

Truck is the dominant mode of freight transportation in the United States and accounts for over 75 percent of the nation’s freight bill. The trucking industry consists of two major segments –TL and LTL; TL operations charge for the full truck independent of the quantity shipped. Rates vary with the distance traveled. The LTL rates exhibit economies of scale. Trucking is more expensive than rail but offers the advantage of door-to-door shipment and a shorter delivery time. It also has an advantage of requiring no transfer between pickup and delivery. Major TL carriers include Schneider National, JB Hunt, Ryder Integrated, Werner and Swift Transportation

TL operations have relatively low fixed costs and owning a few trucks is often sufficient to enter the business. As a result there are many TL carriers in the industry Schneider National the larges TL carriers had only 17 percent of the market share among the top 40 firms in the United States in 1996. The idle time and travel distance between successive loads add to cost in the TL industry. Carriers thus try to schedule shipments to meet service requirements while minimizing both their trucks idle and empty travel time.

TL pricing displays economies of scale with respect to the distance traveled. Given trailers of different size pricing also displays economies of scale with respect to the size of the trailer used. TL shipping is suited for transportation between manufacturing facilities and warehouses or between suppliers and manufactures.

LTL operations are priced to encourage shipments in small lots usually less than half a TL tends to be cheaper for larger shipments prices display some economies of scale with the quantity shipped as well as the distance traveled. LTL shipments take longer than TL shipments because of other loads that need to be picked up and dropped off. LTL shipping is suited for shipments that are too large to be mailed as small packages but constitutes less than half a TL.

Key issues of LTL industry include location of consolidation centers assigning of loads to trucks and scheduling and routing of pickup and delivery. The goal is to minimize costs through consolidation without hurting delivery time and reliability.

Rail

Rail carriers incur a high fixed cost in terms of rail, locomotives, cars and yards. There is also a significant trip related labor and fuel cost that is independent of the number of cars (fuel costs do vary somewhat with number of cars) but does vary with the distance traveled and the time taken. Any idle time once the train is powered, is very expensive because labor and fuel costs are incurred even through the trains are not moving. Idle time occurs when trains exchange cars for different destinations. It also occurs because of track congestion. Labor and fuel together account for over 60 percent of railroad expense. From an operational perspective, it is thus important for railroads to keep locomotives and crew well utilized.

Rail is priced to encourage large shipments over a long distance. Price displays economies of scale in the quantity shipped as well as the distance traveled. The price structure and the heavy load capability makes rail an ideal mode for carrying large, heavy or high density products over long distances. Transportation time by rail however can be higher. Rail resulting transportation cost tends to be low. Coal for example, is a major part of each railroad shipments. Small, time sensitive, short distance or short lead-time shipments rarely use rail.

A major goal in railroads is to keep locomotives and crew well utilized. Major operational issues at railroads include vehicle and staff scheduling, track and terminal delays, and poor on time performance. The travel time is usually a small fraction of the amount of the time taken at each transition. The travel time is usually a small fraction of the total time for a rail shipment. Delays get exaggerated because trains today are typically not scheduled but built. In other words, a train leaves once there are enough cars to constitute the train. Cars wait for the train to build, adding to the uncertainty of the delivery time for a shipper. A railroad can improve on time performance by scheduling some of the trains instead of building all of them. In such a setting a more sophisticated pricing strategy that includes revenue management will need to be instituted for scheduled trains.

Water

Major ocean carriers include Maersk Sealand, Evergreen group, American president Lines, and Hanjin shipping Co. Water transport by its nature is limited to a certain areas. Water transport is ideally suited for carrying very large loads at low cost. This mode of transport is used primarily for movement of large bulk commodity shipments and is the cheapest mode for carrying such shipments. It is, however the slowest of all modes and significant delays occur at the terminals and ports. This makes water transport difficult to operate for short haul trips through it is used effectively in Japan and part of Europe for daily short haul trips of a few miles.

In global trade, water transport is a dominant mode for shipping all kinds of products. Cars, grain, apparel and other product are shipped by sea. For the quantities shipped and the distance involved, water transport is by far the cheapest mode of transport for global shipping. Delays at ports, customs and the management of containers used are major issues in global shipping.

Pipeline

Pipeline is used primarily for the transport of crude petroleum, refined petroleum products and natural gas. A significant initial cost fixed cost is incurred in setting up the pipeline and related infrastructure that does not vary significantly with the diameter of the pipeline. Pipeline operations are typically optimized at about 80 to 90 percent of the pipeline capacity. Given the nature of the costs, pipelines are best suited when relatively stable and large flows are required. Pipeline may be an effective way of getting crude oil to a port or refinery. Sending Gasoline to a gas station does not justify investment in a pipeline and is done better with a truck. Pipeline pricing usually consists of two components a fixed component related to the shipper’s peak usage and a second charge relating to the actual quantity transported. The pricing structure encourages the shipper to use the pipeline for the predictable component of demand with other modes often being used to cover fluctuation.

Intermodal

Intermodal transportation is the use of more than one mode of transport to move a shipment to its destination. A variety of intermodal combinations are possible with the most common being truck/rail. Major intermodal providers with rail include CSX Intermodal, Pacer Stack strain and Triple Crown. Intermodal traffic has grown considerably with the increased use of containers for shipping and the rise of global trade. Containers are easy to transfer from one mode to another and their use facilitates intermodal transportation. Containerized freight often uses truck/rail/water combinations, particularly for global freight. For global trade intermodal is often the only option because factories and markets may not be next to the ports. As the quantity shipped using containers has grown the truck/rail/water intermodal combination has also grown. On land rail/truck intermodal system offers the benefit of lower cost than TL and delivery times that are better than rail, thereby bringing together different modes of transportation to create a price effective offering that cannot be matched by a single mode. It also creates convenience for shippers who now deal with only one entity representing all carriers who together provide the intermodal service.

Key issues in the intermodal industry involve the exchange of information to facilitate shipment transfers between different modes because these transfers often involve considerable delays, hurting delivery time performance.

3.8 Design Options for a Transportation Network

The design of a transportation network impacts the performance of a supply chain by establishing the infrastructure within which operational transportation decisions regarding scheduling and routing are made. A well-designed transportation network allows a supply chain to achieve the desired degree of responsiveness at a low cost. Discussed below are a variety of design options for transportation network along with their strength and weaknesses.

3.8.1 Direct Shipping Network

With this option, the retail chain structures its transportation network to have all shipments comes directly from the suppliers to the retail stores as shown in the figure3.4 With a direct shipment network the routing of each shipment is specified and the supply chain manager only needs to decide on the quantity to ship and the mode of transportation and the inventory costs.

The major advantage of a direct transportation network is the elimination of the intermediate warehouses and its simplicity of operation and coordination. The shipment decision is completely local and the decision made for one shipment does not influence others.

A direct shipment network is justified if retail store are large enough such that optimal replenishment lot sizes are close to a TL from each supplier to each retailer. With small retail stores however a direct shipment network tends to have higher costs. If a TL carrier is used for transportation, the high fixed cost of each truck results in large lots moving from suppliers to each retail store, resulting in high supply chain inventory rise. If an LTL carrier is used the transportation cost and the delivery time increase through inventories are lower. If package carriers are used, transportation cost will be very high. With direct deliveries from each supplier, receiving costs will be high because each supplier must make a separate delivery.

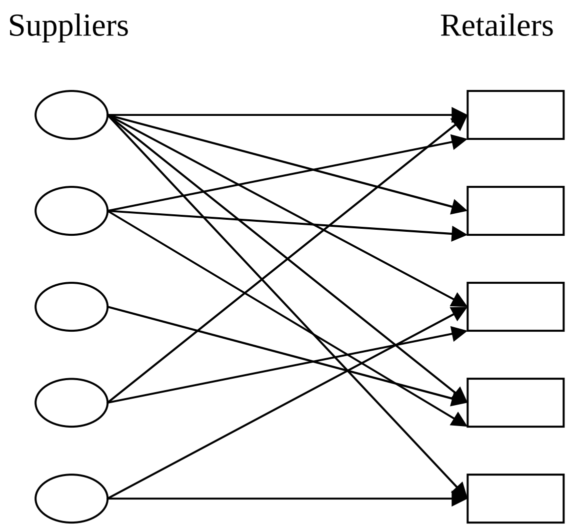


Figure 3.4: Direct Shipping Network

3.8.2 Direct Shipping with Milk Runs

A milk run is a route, which a truck either delivers products from a single supplier to multiple retailers or goes from multiple suppliers to a single retailer as shown below. In direct shipping with milk runs a supplier delivers directly to multiple retailers on a truck or a truck picks up deliveries from many suppliers destined for the same retail store. When using this option, a supply chain manager has to decide on the routing of each milk run.

Direct shipping provides the benefit of eliminating intermediate warehouse, whereas milk runs lower transportation cost by consolidating shipments to multiple stores on a single truck. For example the replenishment lot size of each retail stores may be small and require LTL shipping if sent directly. The use of milk runs allows deliveries to multiple stores to be consolidated on a single truck, resulting in better utilization of truck and somewhat lower costs. Companies like Frito Lay that make direct store deliveries using milk runs to lower transportation costs. If very frequent small deliveries are needed on a regular basis and either a set of suppliers or a set of retailers are in close vicinity, the use of milk runs can significantly reduce transportation costs. For example, Toyota has JIT manufacturing plants located close together and thus uses milk runs from a single supplier to many plants.

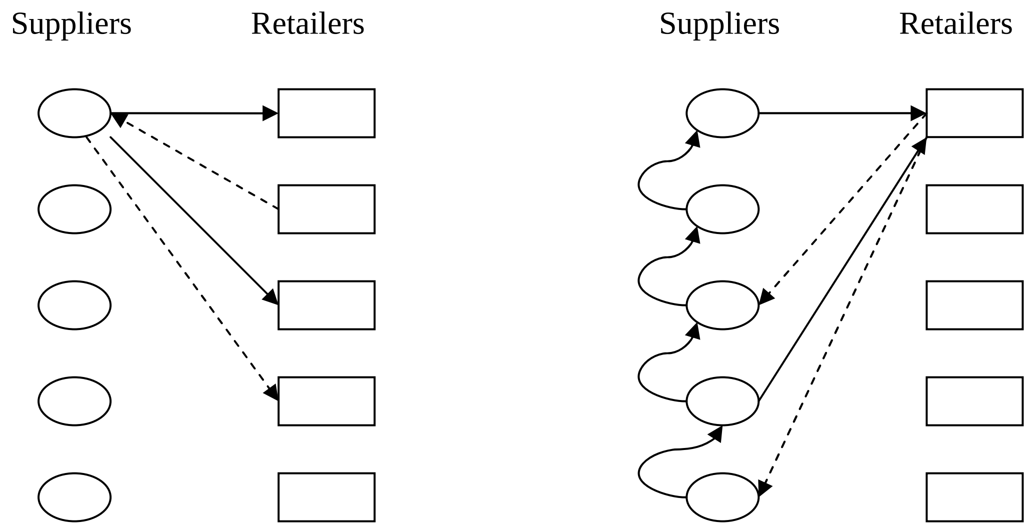


Figure 3.5: Milk Run from Multiple Suppliers or to Multiple Retailers

3.8.3 All Shipments via Central Warehouse

With this option, suppliers do not send shipments directly to the retail stores. The retail chain divides stores by geographical region and a warehouse DC is built for each region. Suppliers send their shipment to the DC and the DC then forwards appropriate shipments to each retail store as shown in the figure.

The DC is an extra layer between suppliers and retailers and can play two different roles. One is to store inventory and the other is to serve as a transfer location. In either case the presence of DC's can help reduce supply chain costs when suppliers are located far from retail stores and transportation costs are high. The presence of a DC allows a supply chain to achieve economies of scale for inbound transportation to a point close to the final destination because each supplier sends a large shipment to the DC containing product for all stores the DC serves. Because DC's serve stores located nearby, the outbound transportation cost is not very large.

If transportation economies require very large shipments on the inbound side, DC's hold inventory and send product to retail stores in smaller replenishments lots. If replenishments lots for the stores served by the DC are large enough to achieve economies of scale on inbound transportation, the DC does not hold inventory. In this case the DC can cross-dock product arriving from many suppliers on inbound trucks by breaking each inbound shipment into smaller shipments that are then loaded onto trucks going to each retail store

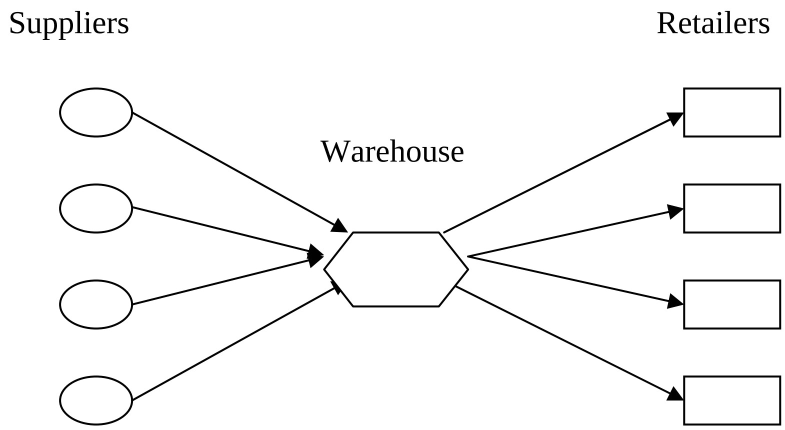


Figure 3.6: All Shipments via Warehouse

3.8.4 Shipping via Warehouse Using Milk Runs

As shown in the Fig. 3.7 milk runs can be used from a DC if lot sizes to be delivered to each retail store are small. Milk runs reduce outbound transportation costs by consolidating small shipments. For example, 7-Eleven Japan cross-docks deliveries from its fresh food suppliers at its DC's and sends out milk runs to the retail outlets because the total shipment to a store from all suppliers does not fill a truck.

The use of cross docking and milk runs allows 7-Eleven to lower its transportation costs while sending small replenishment lots to each store. The use of cross docking with milk runs requires a significant degree of coordination and suitable routing and scheduling of milk runs. The online grocer Peapod use milk runs from DC's when making customer deliveries to help reduce transportation costs for small shipments to be delivered to homes.

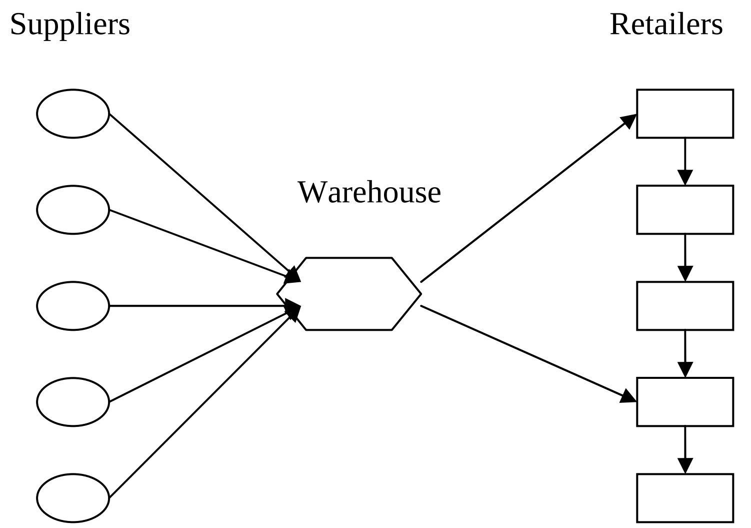


Figure 3.7: Milk Runs from Warehouses

3.9 The Milk Run Systems

3.9.1 Introduction to the Milk Run System

The origin of the Milk Run system can be traced to the dairy industry. It was originally used and is still being used to supply milk to the milk booths spread out over a town or a city. In the morning, the truck carrying the milk packets in crates is loaded at the main dairy, it then travels to the booths in a particular sequence, such that all the booths to be supplied are covered one after the other. The route is planned such that it is the shortest and any crossing of the route itself is avoided. Once the truck arrives at the booth it is unloaded and then it moves to the next booth, until all the crates have been unloaded. In the afternoon, the truck follows the same route in the reverse order, picking up the empty crates from the booth. Once all the crates have been picked up, the truck travels to the main dairy and deposits the crates there. Each trip of the truck is known as a run and hence the name ‘Milk Run’.

Earlier Practices in the Automobile Industry

Earlier, an inventory system was used to maintain continuity in the production process. This was done to ensure that the production line was never stopped due to shortfall in the supply of a particular component. Under this system, the component vendor would supply components in bulk and these were stored in the warehouse of the automobile company. These components were acquired from the warehouse by the production department as and when necessary, depending upon the line requirements. The inventory system meant that the company was able to negotiate lower prices for the component, as it was buying the components in bulk. Also, a stock was always maintained for the components and as a result the company would be insulated from fluctuations in the price of the component, as well as their temporary unavailability.

3.9.2 Disadvantages of the Inventory System

1. The company needed to buy the components in bulk and so a large amount of money was required at one point in time and so interest on the amount was lost for the period until the product would finally be sold.
2. A separate warehouse was required to store the components. The costs associated with acquiring land and building the warehouse, maintaining it was found to be very high.
3. Development and maintenance of an inventory system entailed high costs.
4. The procedure of procuring components from the warehouse caused delays and decreased the overall productivity of the company.

3.9.3 Replacement for the Inventory System

To overcome the disadvantages associated with the inventory system, a Delivery Instructions or a DI system can be used. In such a system, a delivery schedule is prepared for a fixed time period based on the likely production line requirements. The schedule contains the daily requirement of the components. This schedule is then supplied to the component vendor. The vendor is expected to supply components as per the delivery schedules. In MUL, the schedule is for fifteen days. The DI system makes unnecessary the need for a large warehouse and whatever stock needs to be maintained can be done at the production line itself. Thus the DI system is a Demand Pull rather than a Supply Push system. This means that under the DI system the company sources components based on the forecasted demand, rather than according to the volume produced by the vendor.

3.9.4 Deficiencies in the Delivery Instructions System

Although the DI system helps a company to reduce the stock it holds it has a few inherent disadvantages as well. These are:

1. There is a risk of stock run out. In case the component vendor does not deliver as per the DI schedule, the stock present on the production line may get depleted leading toe stoppage of the line.
2. The component has to deliver the day's requirement on the same day. For this purpose, the vendor has to dispatch at least one vehicle per day. The volume of the components may not be enough to fully utilize the space available in the vehicle. Thus a portion of the vehicle remains unutilized and this causes the transportation cost to increase.
3. The DI system is based on accurate forecasting. If the forecasting is unable to predict the actual demand then there will be chances of stock overruns or stock run outs.
4. An increase in demand may cause the daily production target to be revised. However, since the DI schedule is prepared beforehand, the supplies components may fall short.
5. The DI system can only be used effectively for vendors that are located close to the main assembly factory. For vendors located at a large distance from the company, a hidden cost is involved. For supplying components everyday, on time these vendors will have to maintain some inventory warehouses located close to the company. Thus the cost of inventory is merely shifted from the company to its vendor. This extra cost to the vendor is reflected in the overall cost of the component.

3.9.5 Relevance of the Milk Run System

The Milk Run system can be used to over some the deficiencies of the DI system. A group of vendors whose plants are located in close proximity is formed and the milk run is implemented for those vendors. A third party (Logistic Company) is hired to provide the transport and it send its vehicle to each vendor to collect the quantity asked for the company.

The shortest possible route encompassing all the plants is selected. It is ensured that the route at no point crosses itself. The transport vehicle is sent to the first vendor where it is loaded with the components. It then moves on to the second vendor, is loaded there and so on until all the vendors in the group have loaded their components into the vehicle. The vehicle then moves to the automobile factory. After the components have been unloaded at the designated locations in the factory, the truck collects the empty bins of each of the vendors. These are then transported back to their plants.

Thus in the milk run system, instead of five different vendors transporting their components using five different vehicles, a single vehicle is used for all the vendors. This leads to a significant reduction in the transportation cost.

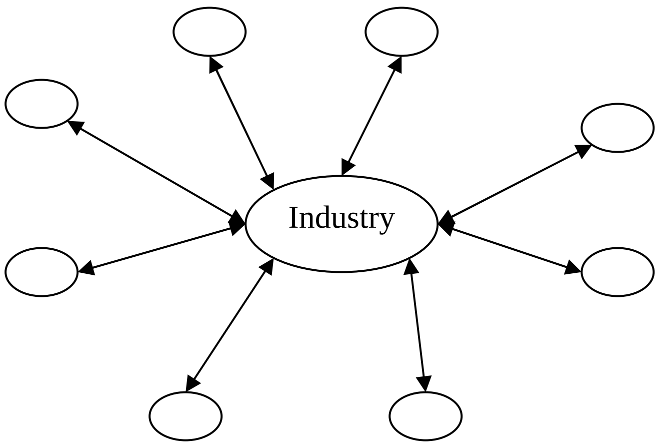


Figure 3.8: Spoke System

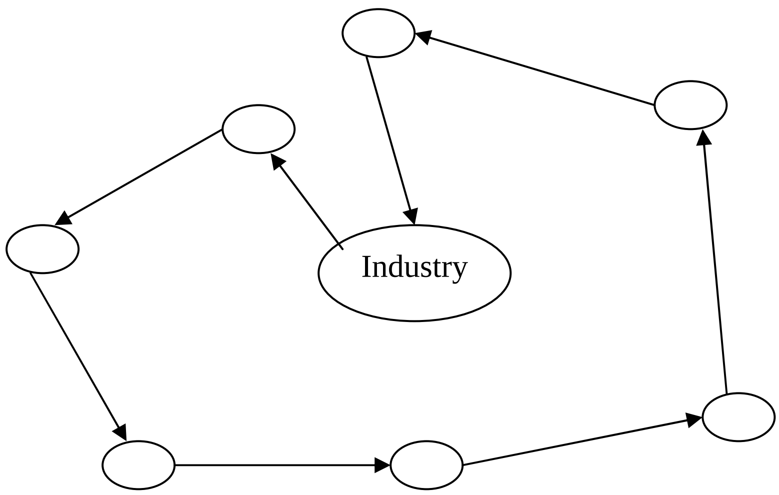


Figure 3.9: Conventional Milk Run System

3.9.6 Problems in the Milk Run System

1. **Delay in Loading:** The major problem that can arise in the milk run system is when one or more vendors are not able to supply the components due to various reasons. This means that the truck has to wait until all the components can be loaded. This in turn causes the entire truckload to be delayed. This means that the supplies of all the vendors are delayed due to one or two vendors. This can lead to stoppage of the production line.

   Suggestion – To ensure that the entire load from all the vendors is not delayed, time slots should be allocated to the different vendors that are part of the milk **run** system. These time slots can be decided based on the average loading time at each vendor, and the time between these slots can be based on the time taken to travel from one vendor to the next one. A small time delay of say ten minutes should be incorporated into the time slot to allow for any small problems. Once the truck arrives at the vendor, it would stay at the vendor's plan for the period of the time slot. It would leave when the time slot has expired, even if loading is not complete. It then becomes the responsibility of the vendor to deliver the components on time using its own transportation arrangements. This would act as a deterrent to the vendors as they would have to pay an extra amount for the transport. In addition to this, a penalty can be levied on the vendor for not supplying the material on time, when there is a failure to supply on a greater number of days than a present limit.

2. **Breakdown of Transport Vehicle:** If the transport vehicle breaks down due to some reason, the components of all the vendors are delayed, and this also is responsible for causing production line stoppages. This happens as under normal circumstances, when a truck breaks down the consignment of only a single vendor is delayed and alternative arrangements are not always possible.

   Suggestion- To prevent delays on account on breakdown, the logistics provider should be briefed that they will be required to make alternative arrangements in case their transport vehicle breaks down. Normally the logistics companies have vehicles on standby to substitute for a broken down vehicle. This requirement can be made clear in the contract with the logistics firm.

3. **Lack of Availability of Transport Cost:** Due to the fact that the cost of the component is landed cost at most companies and not the ex-factory cost at the vendor's factory, it is not possible to accurately state the transportation cost for each component, or for each vendor. Thus, it becomes difficult to calculate the exact amount of money that would be saved by employing the milk run system. In addition to this problem, once the milk run system is in place, it will be difficult to determine how much savings must be passed on to the company by the vendor.

   Suggestion- In order to be able to accurately state the transportation cost, for a particular component, the transportation cost should be provided separately from the cost of the component, that is, the cost of the component should be on ex factory basis instead of landed basis. This would also allow the company to evaluate whether or not the use of a third party logistics company to run the milk runs is beneficial and is so, to what extent.

3. **Excessive Unloading Time-** As a large variety of components has to be unloaded at

   multiple locations in a factory; it would require a larger time period to unload a milk run truck than it would for a truck from a single vendor. Presently, it can take as long as four hours for the complete unloading procedure. This time will be further lengthened if the milk run system is employed. Thus although the milk run itself leads to a cost saving there is an additional cost that is due to the increased unloading period which must be considered.

   Suggestion- Though the time required for the unloading of the milk run truck will be longer than that for a truck from a single vendor, it will still be les than the cumulative time required to unload the trucks from individual vendors. To further improve the unloading time the milk run trucks can be unload on a priority basis. There can be a single unloading point at the factory for the milk run trucks, from where the components can be taken to the required plant, as soon as they are unloaded.

3.10 Routing and Scheduling In Transportation

The most important operational decision related to transportation in a supply chain is routing and scheduling of the deliveries. Managers must decide on the customers to be visited by a particular vehicle and the sequence in which they will be visited. For example, an online grocer like peapod is built on delivering customer orders to their homes. The success of its operations turns on its ability to decrease transportation and delivery costs while providing the promised level of responsiveness to the customer. Given a set of customer orders, the goal is to route and schedule delivery vehicles such that the costs incurred to meet delivery promises are as low as possible.

Typical objectives when routing and scheduling vehicles are a combination of minimizing cost by decreasing the number of vehicles needed, the total distance traveled by vehicles, as well as eliminating service failures such as a delay in shipments.

Let the routing and scheduling problem be discussed in context of a manager of a company. After the customers place orders for the products, the staff at the company has to pick up the items needed and load them on trucks for delivery. The manager must decided which trucks will deliver to which customer and the route that each truck will take when making the deliveries. The manager must also ensure that no truck is overloaded and that promised delivery times are met.

The manager's first task is to assign the customers to be served by each vehicle and then decide on each vehicles route. After initial assignment, route sequencing and route improvement procedures are used to decide on the route for each vehicle. The manager decides to use the following computational procedures to support his decision: -

- The Saving Matrix Method
- The Generalized Assignment Method
- Transportation Problem
- Vehicle Routing Problem (By Vogel's Approximation Method)
- Traveling Salesman Problem
- Capacitated Transshipment Problem
- Shortest Path Problem

Chapter 4

ANALYSIS OF SPOKE AND MILK RUN (RIM) SYSTEMS

The transportation cost plays a significant role in supply chain management to achieve a high level of product availability at a reasonable price and it is a key factor. As the distance between the vendors, and between the vendor and the buyer increases the transportation cost and so the overall total cost increases. If we decrease the transportation cost by decreasing the number of trips, then the inventory cost increases hence the total cost again increases. To avoid this transport vehicles are routed in a sequence such that the total distance covered is minimized hence the total cost is also reduced. The transport vehicle can be routed in either SPOKE SYSTEM or RIM SYSTEM. In Spoke system the individual vehicles delivers the quantity from vendor to buyer due to which the transportation cost will decrease but there will an increase in inventory cost. This system is used when the distance between the vendors is large and when the items are not compatible with each other from transportation point of view. On the other side, in Rim system single truck reaches each vendor's location and loads some quantity of each item. Thus in Rim system, instead of all vendors transporting their items using individual vehicle, a single vehicle is used by all the vendors. This results in decrease in inventory cost but there is a little increase in transportation cost. This cost increase is because of increase in distance covered by vehicle. The major problem that arises in this system is that for a particular vendor the truck has to wait until the quantity of an item is loaded, thus the entire supply of all the vendors are delayed and this leads to stoppage of the production line. Secondly, break down of transport vehicle due to some reason causes the same stoppage of production line. Third problem is that as a variety of components are unloaded at multiple locations in a factory, it would require a large time period to unload a truck, loaded through Rim than it would for a truck from a single vendor i.e. spoke system. But all these problems are compensated by decrease in the inventory cost.

Research Plan

In this study analytical and integrated approach is used to decide:

a) Transport system: Rim System or Spoke system

b) No. of vendors in a group in rim system. The options are all the vendors in one group, two groups each with equal no. of vendors, three groups etc., uneven no. of vendors in each group depends upon their geographical proximity.

c) Route of the vehicle in rim system

d) No. of units per lot. The options are EOQ, Full truck load

The following cases are analyzed and discussed

Spoke System

Case 1: Ordered quantity is equal to EOQ for each item

Case 2: Ordered quantity is equal to EOQ from each vendor

Case 3: Ordered quantity is equal to full truck capacity for each item

Case 4: Ordered quantity is equal to full truck capacity from each vendor

Rim System

A: All the vendors forming one group

Case 5: Ordered quantity (in number of sets) is equal to full truck capacity (sets).

Case 6: Ordered quantity (in number of sets) is equal to EOQ (sets).

B: Two groups/ three groups/ four group with equal number of vendors

Case 7: Ordered quantity (in number of sets) is equal to full truck capacity (sets).

Case 8: Ordered quantity (in number of sets) is equal to EOQ (sets)

C: Optimized Model having Groups with unequal number of vendors

Case 9: Ordered quantity (in number of sets) is equal to full truck capacity (Sets)

Case 10: Ordered quantity (in number of sets) is equal to EOQ (Sets)

To understand the effect of transportation cost in supply chain management an analysis of various system are given in the following pages.

Notation Used

i	=	(1,2-----13)vendors
j	=	Number of different items supplied by a vendor (j=2----m)
TC	=	Total cost obtain by different systems
C	=	Unit cost of an item
C_i	=	Unit cost of i^{th} item
C_o	=	Ordering + transportation cost (Rs./order) of an item
C_{oi}	=	Ordering + transportation cost (Rs./order) of i^{th} item
C_h	=	Holding cost (Rs. / unit/ yr.) of an item=20% of unit cost
C_{hi}	=	Holding cost (Rs. / unit/ yr.) of i^{th} item
D	=	Annual demand of end product (car)
D_i	=	Annual demand of i^{th} item
Q	=	Maximum quantity of an item loaded in a transport vehicle
Q_i	=	Maximum quantity of i^{th} item loaded in a transport vehicle
U	=	Quantity of an item required per car
U_i	=	Quantity of i^{th} item required per car
V	=	Capacity of truck (cm^3)
P	=	Cubic space occupied by an item
Pi	=	Cubic space occupied by i^{th} item
V_{set}	=	Volume occupied by one set (All the n items in quantities as required for one car)
	=	$\sum_{i=1}^{13} U_i * P_i$
$C_{h,set}$	=	Holding cost of one set
	=	$\sum_{i=1}^{13} U_i * C_{hi}$
D_i	=	$D * U_i$
S	=	Number of kits per trip
N	=	Number of trips

C_t	=	Cost per trip (Rs.)
L	=	Distance covered by a vehicle for a group
K_1	=	Minimum fixed transportation cost for a vehicle (Rs.)
K_2	=	Transportation cost per kilometer (Rs./km)
K_3	=	Loading cost at each vendor (Rs./ vendor)
n	=	Number of vendors in a group

4.3 Assumptions

1. Demand is deterministic**.**
2. Only one type of truck (TATA-407)is considered as mode of transport.
3. Vendors far away from MUL have their warehouses in Gurgaon. So calculations are based on warehouses for same vendors.
4. Only one vendor for an item is considered.
5. Holding cost is equal to 20% of unit price (assumed).
6. Ordering cost includes transportation cost, rather transportation cost is the major component/part of ordering cost.
7. Transportation cost (TC) is given by the relationship given in Equation 1.

   $$TC = K_1 + K_2 * (\text{Distance traveled}) + K_3 * (\text{No. of vendors in a Rim}) \qquad (1)$$

   Where K_1, K_2 and K_3 are the constants.
8. Loading and unloading time and cost is not considered and assumed to be constant for all the cases.
9. Items are compatible and can be transported together.

4.4 Data for Spoke and Rim System

To study the spoke and rim system, 13 vendors of MUL are selected. Table 4.1 provides the data of these 13 vendors (component name, components used per car, volume occupied etc.). Table 4.2 gives data about distance between vendors.

Table 4.1: Data for Alto and Maruti-800

DATA FOR ALTO AND MARUTI- 800								
S. No.	Vendor's Name	Name of Component	Components Used per car	Annual Demand	Volume occupied by each component	Transportation & ordering cost	Unit cost	Holding cost/unit/ year (20%of unit cost)
			(U_i)	(Di)	(P_i)($cm^{3)}$	(C_{oi})Rs.	(C_i) Rs.	(C_{hi})Rs.
1	Side Mirror	Side Mirror	1	165000	2287	750	192	38.40
2	Ceekay	a)Clutch Plate	1	165000	1264	750	328	65.60
		b)Pressure Plate	1	165000	1936	750	280	56.00
3	Delphi	Rear Shocker	2	330000	1150	750	700	140.00
4	SPR	Piston	3	495000	448	750	90	18.00
5	Wipe	Wiper Blade	2	330000	282	300	45	9.00
6	Brakes India	Brakes Shoe	4	660000	424	200	150	30.00
7	Purelator	a) Oil Filter	1	165000	4200	200	25	5.00
		b) Air Filter	1	165000	1776	200	30	6.00
8	Munjal	Strut	2	330000	5544	150	125	25.00
9	Amtec	Connecting Rod	3	495000	225	300	120	24.00
10	Padmni	Horn	1	165000	1267	300	50	10.00
11	Denso	ECM	1	165000	6720	300	4710	942.00
12	Lumax	Tail Light	2	330000	9030	300	195	39.00
13	Talbrose	Suspension Arm	2	330000	1960	700	98	19.60

Demand of cars= 1,65,000 per year

Transportation mode-By road

Vehicle=TATA-407

Capacity of truck (V)=6669000cm^3

Table 4.2: Distances between Vendors (km)

Distances between Vendors (km)															
Vendor's Name	**V**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**Maruti 14 (Buyer)**
Side Mirror	**1**	0	30	10	5	76	74	70	77	60	50	55	53	25	77
Ceekay	**2**	30	0	25	40	71	66	65	70	75	74	75	72	40	70
Delphi	**3**	10	25	0	15	62	67	62	69	55	72	75	73	15	70
SPR	**4**	5	40	15	0	72	71	68	74	60	55	57	53	30	74
Wipe	**5**	76	71	62	72	0	5	10	3	21	22	22	20	58	3
Brakes India	**6**	74	66	67	71	5	0	3	4	24	20	20	17	57	5
Purelator	**7**	70	65	62	68	10	3	0	5	28	18	19	21	52	9
Munjal	**8**	77	70	69	74	3	4	5	0	19	20	18	19	60	1
Amtec	**9**	60	75	55	60	21	24	28	19	0	15	17	1	50	20
Padmini	**10**	50	74	72	55	22	20	18	20	15	0	2	6	38	24
Denso	**11**	55	75	75	57	22	20	19	18	17	2	0	13	40	25
Lumax	**12**	53	72	73	53	20	17	21	19	1	6	13	0	41	20
Talbrose	**13**	25	40	15	30	58	57	52	60	50	38	40	41	0	60
Maruti (Buyer)	**14**	77	70	70	74	3	5	9	1	20	24	25	20	60	0

4.5 Spoke System

4.5.1 Case1: Spoke System when order quantity is EOQ for each item

a) Individual shipment for each item.

b) Order quantity is equal to economic order quantity**.**

- Individual trucks deliver the EOQ from the vendors to Buyer (MUL).
- Vendors deliver the economic order quantity as per the demand of an item.

- If EOQ is higher than full truck capacity, then order quantity is equal to full truck capacity.

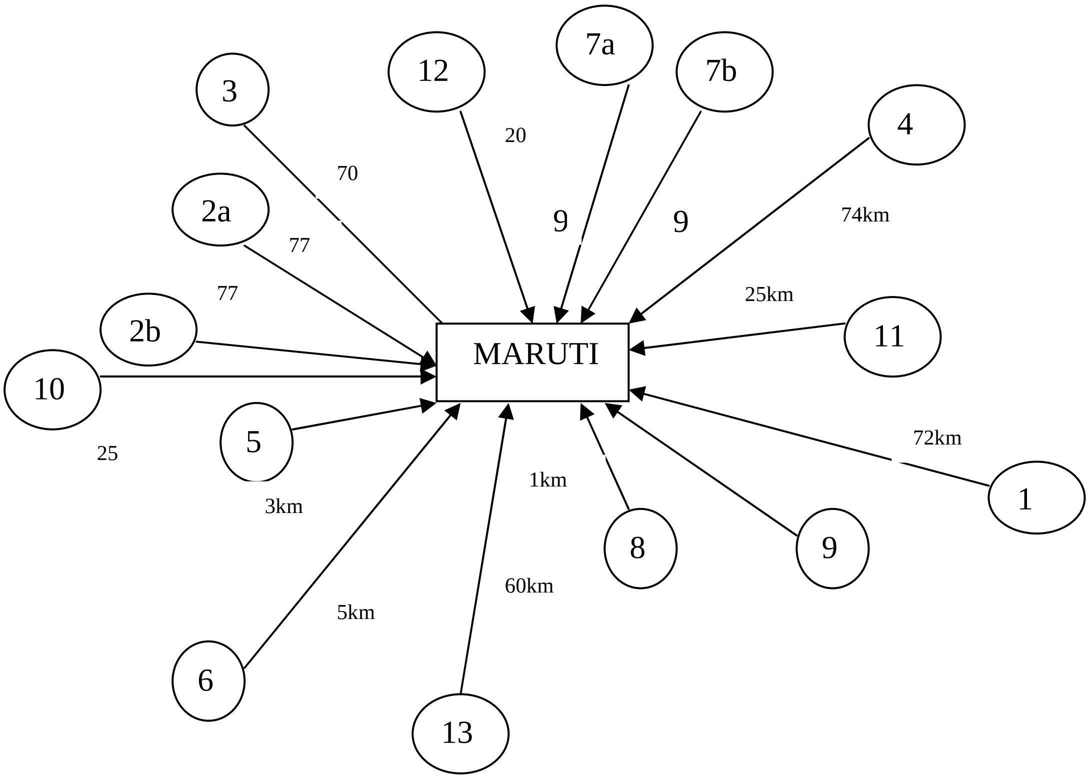


Figure 4.1: Spoke System

We can understand the Spoke System by the Figure 4.1

1. The circle (1 to 13) signifies the vendors
2. The rectangle signifies the MUL.
3. The arrows show the direction of transportation.
4. Wilson's EOQ Model is used for determining the EOQ for a single source and single vendors system
5. Since we have considered 15 items, Wilson's EOQ Model is applied individually to each item to calculate EOQ.

$$\mathrm{EOQ}_i = \sqrt{\frac{2 * C_{oi} * D_i}{C_{hi}}}$$

If, $\mathrm{EOQ}_i > Q_i$ (full truck capacity)

Then ordered quantity is Q_i (full truck capacity)

BY WILSON EOQ MODEL-

Total variable cost:-

$$\mathbf{TC_i =} \sqrt{2C_{oi} * C_{hi} * D_i}$$

The results of the analysis for the case data are given in Table 4.3. The Total Cost per year is Rs. 19,23,053

4.5.2 Case2: Spoke System when order quantity is EOQ from each vendor

a) Individual shipment from each vendor.

b) Order quantity is equal to economic order quantity

In previous case items were shipped individually even if vendor manufactured different items, but here different items of a vendor are transported in a single transport vehicle.

For example vendor '7' (Purelator) and vendor'2' (Cekay) are manufacturer of two items which have different uses in car. Individual truck (from Purelator) delivers economic order quantity of two items (Oil Filter and Air Filter)

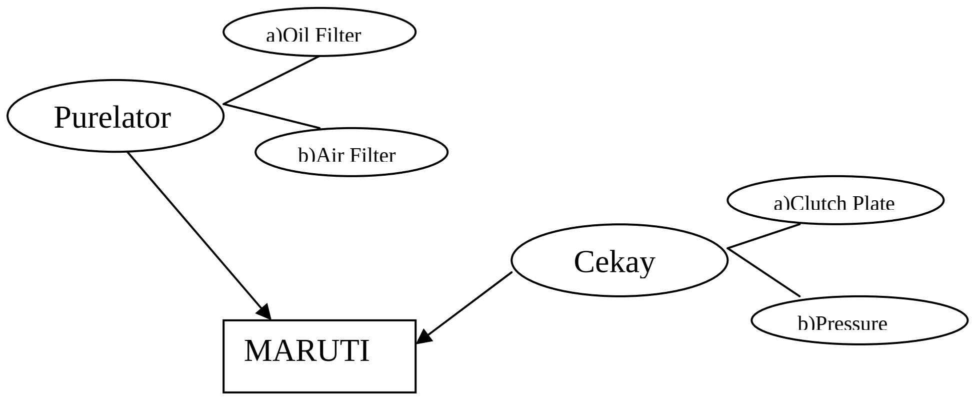


Figure 4.2: Individual shipment from each vendor.

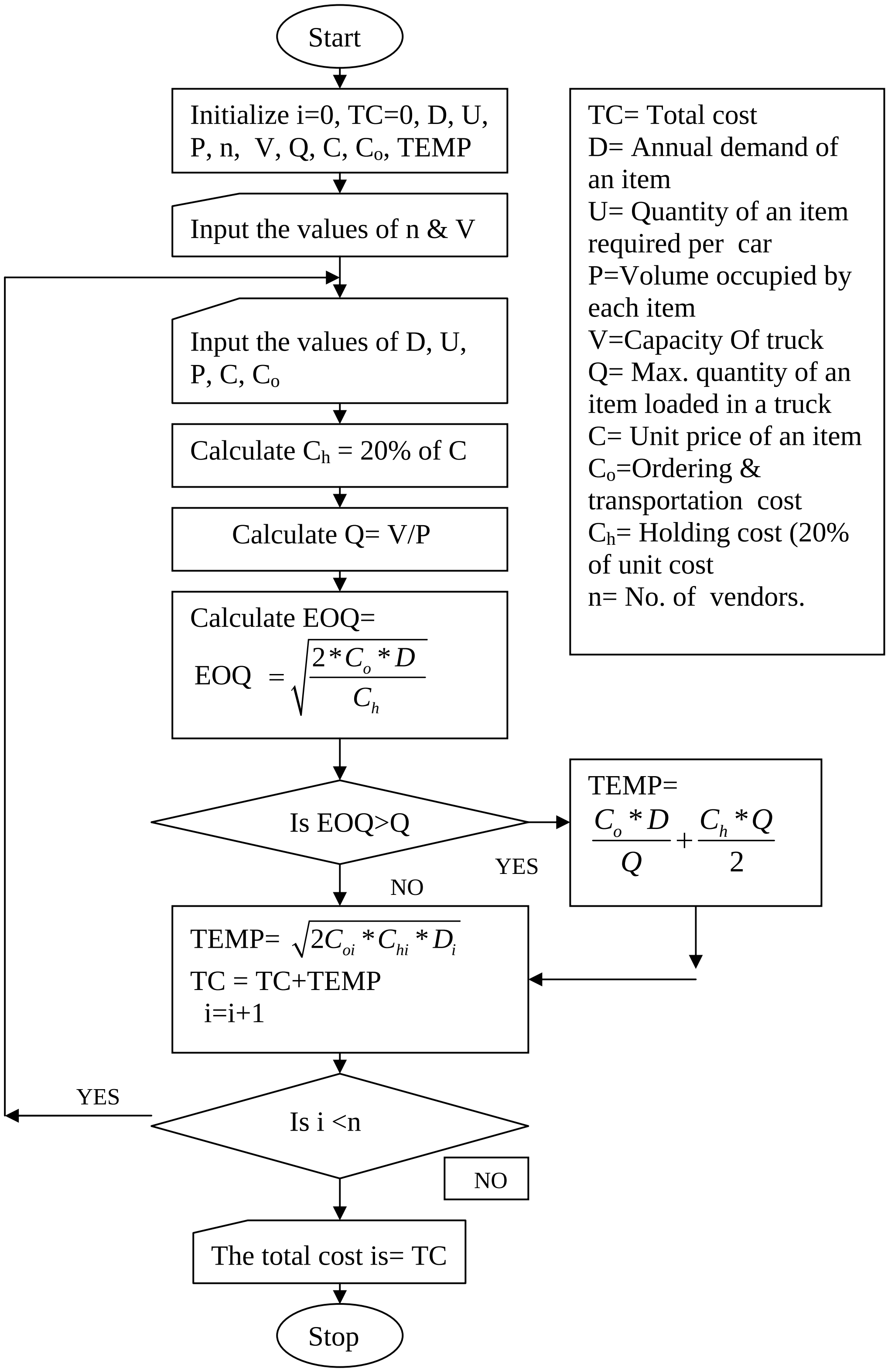
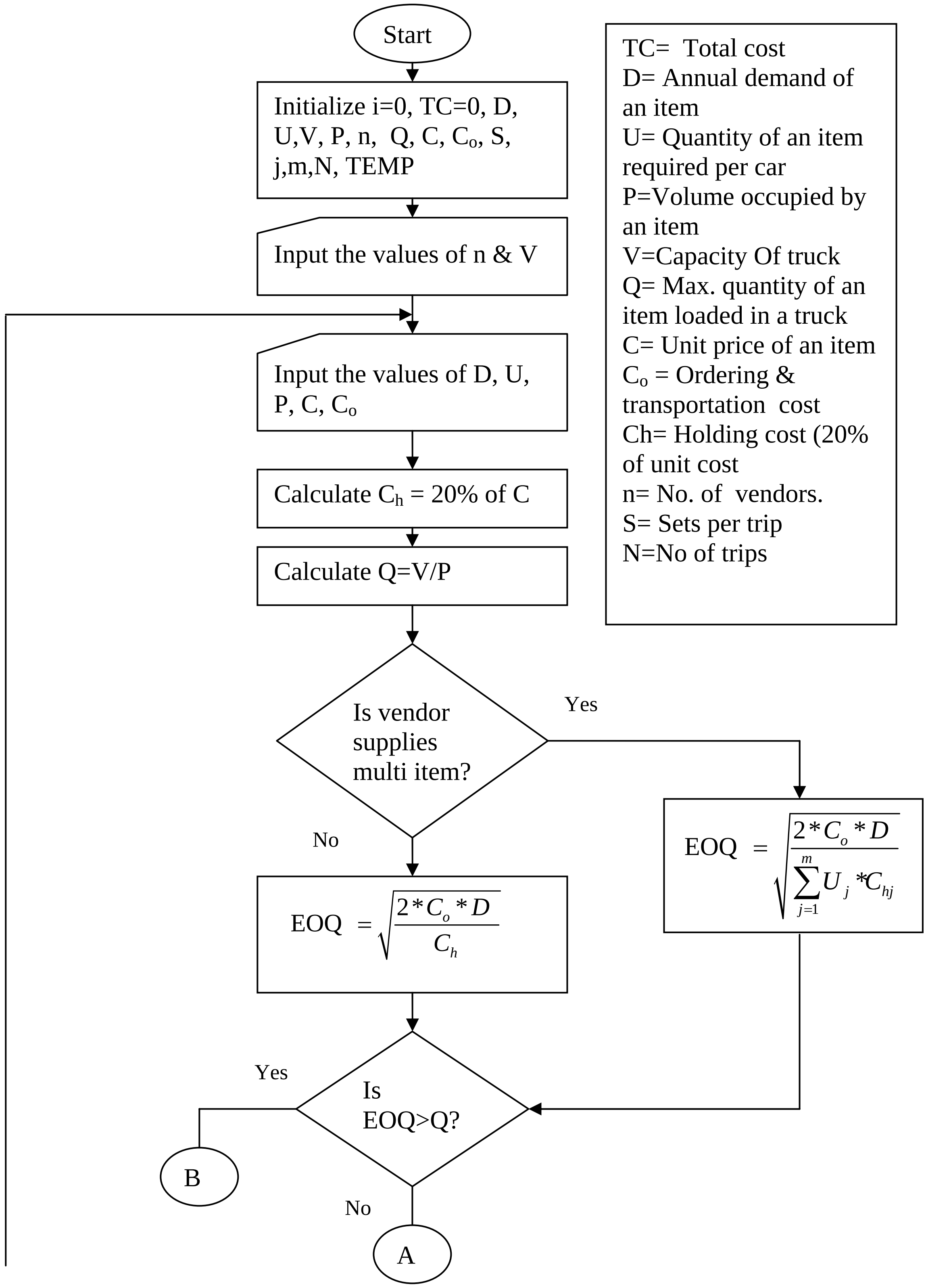


Figure 4.3: Flow Chart for Spoke System when order quantity is EOQ for each item


Start
Initialize i=0, TC=0, D, U,V, P, n, Q, C, C_o, S, j,m,N, TEMP
Input the values of n & V
Input the values of D, U, P, C, C_o
Calculate C_h = 20% of C
Calculate Q=V/P
Is vendor supplies multi item?
Yes
No
EOQ $= \sqrt{\frac{2 * C_o * D}{C_h}}$
EOQ $= \sqrt{\frac{2 * C_o * D}{\sum_{j=1}^{m} U_j * C_{hj}}}$
Is EOQ>Q?
Yes
No
B
A
TC= Total cost
D= Annual demand of an item
U= Quantity of an item required per car
P=Volume occupied by an item
V=Capacity Of truck
Q= Max. quantity of an item loaded in a truck
C= Unit price of an item
C_o = Ordering & transportation cost
Ch= Holding cost (20% of unit cost
n= No. of vendors.
S= Sets per trip
N=No of trips

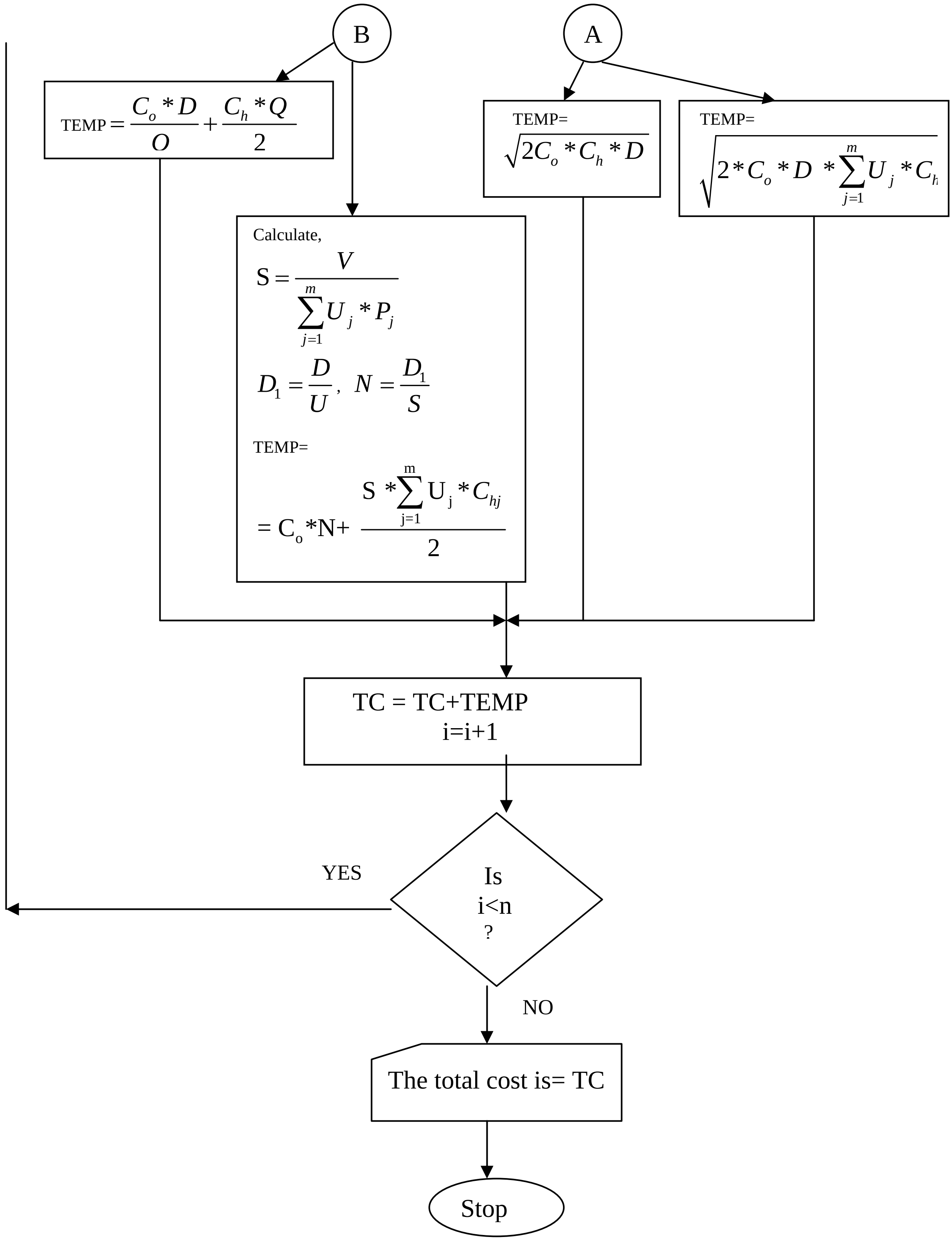


Figure 4.4: Flow Chart for Spoke System when order quantity is EOQ from each vendor (continued)

Formula used :-

$$\mathrm{EOQ_i} = \sqrt{\frac{2*C_{oi}*D_i}{\sum_{j=1}^{m_i} U_{ij} * C_{hij}}}$$

m_i= No. of different items supplied by vendor 'i '

$$\mathrm{TC_i} = \sqrt{2*C_{oi}*D_i*\sum_{j=1}^{m_i} U_{ij}*C_{hij}}$$

The results of this case are presented in Table 4.4. The Total Cost is Rs. 18, 34,627

4.5.3 Case3: Spoke System when order quantity is full truck capacity for each item

a) Individual shipment for each item.

b) Order quantity is equal to full truck capacity

To utilize the full space of the truck left in previous case, maximum quantity of an item as per the truck capacity is loaded.

Here, Q_i is the ordered quantity equal to full truck capacity.

$$\mathrm{Q_i} = \frac{V}{P_i}$$

$$TC_i = \frac{C_{oi}*D_i}{Q_i} + \frac{C_{hi}*Q_i}{2}$$

The results of this case are presented in Table 4.5. The Total Cost per year is Rs.28, 38,859

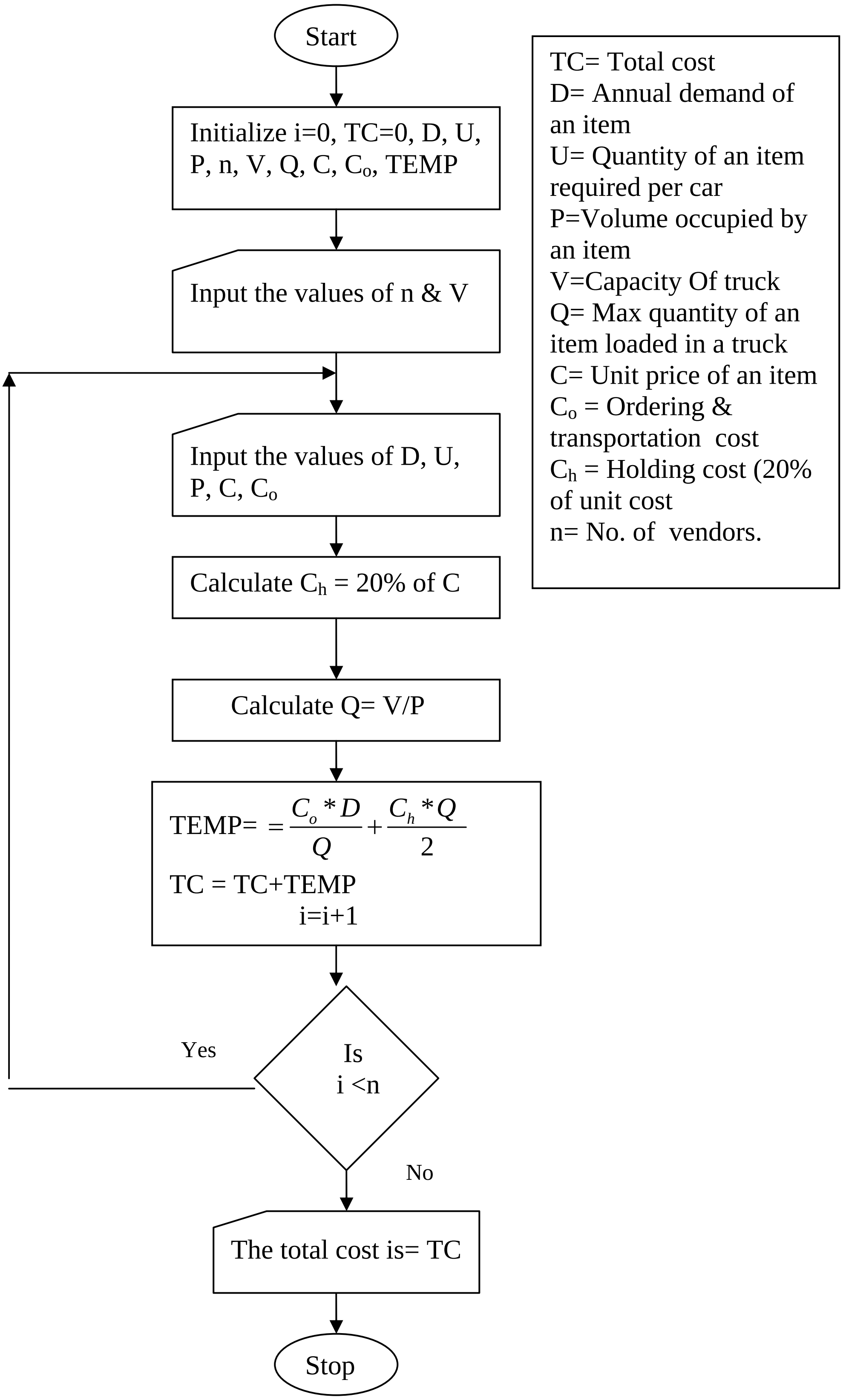


Figure 4.5: Flow Chart for Spoke System when order quantity is full Truck capacity for each item

4.5.4 Case4: Spoke System when order quantity is full truck capacity from each vendor

a) Individual shipment from each vendor.

b) Order quantity is equal to full truck capacity

The number of units in a truck loads (S_i) where a vendor is supplying more than one item is calculated as

$$S_i = \frac{V}{\sum_{j=1}^{m} U_{ij} * P_{ij}}$$

The number of truck loads per year (N_i) is given by

$$N_i = \frac{D_{1i}}{S_i}$$

Total cost per year TC_i is given as

$$TC_i = C_{oi} * N_i + \frac{S_i * \sum_{j=1}^{m} U_{ij} * C_{hij}}{2}$$

The results of this case are presented in Table 4.6. The Total Cost per Year is Rs. 26, 86,847

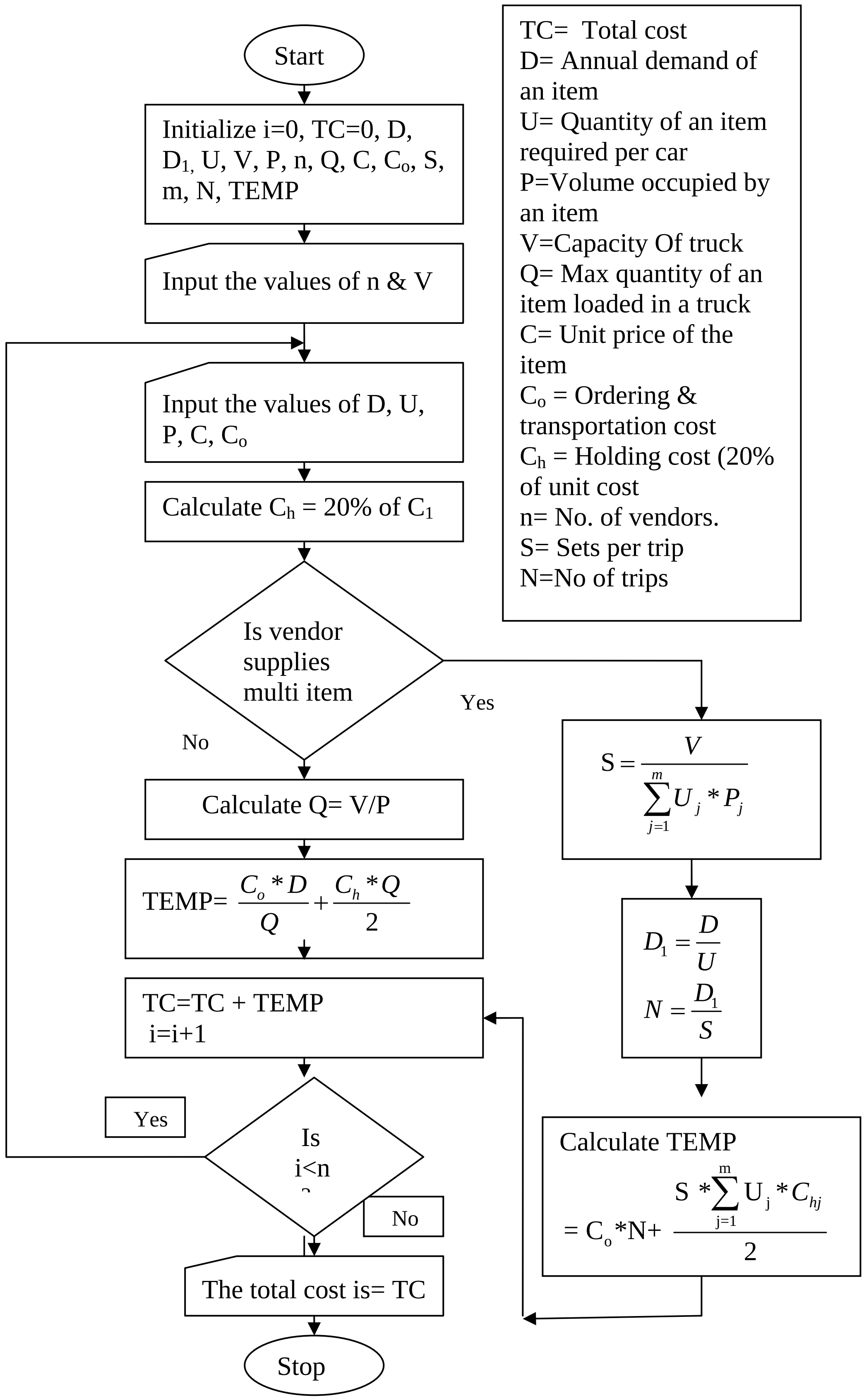


Figure 4.6: Flow Chart for Spoke System when order quantity is full truck capacity from each vendor

4.6 Rim System

4.6.1 Case5: Rim System when order quantity is equal number of sets of all items

a) One vehicle ships for all vendors

b) Order quantity is equal number of sets of all items.

In this case Rim system of supply is considered where a Rim of all 13 vendors is prepared. The transport vehicle starts from factory and travel vendor to vendor in a particular route, such that the distance is shortest. Traveling Salesman Algorithm is applied to determine the optimal route.

An optimal solution is shown in Table 4.7 by traveling salesman problem (Hungarian method). But this solution breaks the sequence of visit to all vendors, therefore next best solution has been obtained by bringing the next (non -zero) minimum element into the solution in Table 4.7

Table 4.7: Optimal Solution

Vendor's Name	S. No.	M	1	2	3	4	5	6	7	8	9	10	11	12	13
Maruti	M	∞	81	54	81	73	$\boxed{0}$	4	8	$\boxed{0}$	19	23	24	19	54
Side Mirror	1	72	∞	10	15	$\boxed{0}$	69	69	65	72	55	45	50	48	5
Cekay	2	35	$\boxed{0}$	∞	$\boxed{0}$	5	44	31	30	35	40	39	40	37	$\boxed{0}$
Delphi	3	60	5	$\boxed{0}$	∞	5	50	57	62	59	39	52	65	63	$\boxed{0}$
SPR	4	64	$\boxed{0}$	15	15	∞	60	61	58	64	50	45	47	43	15
Wipe	5	$\boxed{0}$	78	53	69	69	∞	2	60	$\boxed{0}$	18	79	19	17	50
Brakes India	6	2	76	48	74	78	$\boxed{0}$	∞	$\boxed{0}$	1	20	16	16	14	49
Purelator	7	6	72	47	68	65	5	$\boxed{0}$	∞	2	25	15	16	18	54
Munjal	8	$\boxed{0}$	81	54	78	73	$\boxed{0}$	3	4	∞	18	19	17	18	54
Amtec	9	19	64	59	64	59	18	23	17	18	∞	14	16	$\boxed{0}$	45
Padmni	10	20	53	57	78	53	18	18	16	18	13	∞	$\boxed{0}$	4	31
Denso	11	23	58	58	83	55	18	18	27	16	15	$\boxed{0}$	∞	11	33
Lumax	12	19	57	55	82	52	17	17	20	18	$\boxed{0}$	5	12	∞	36
Talbrose	13	35	5	$\boxed{0}$	$\boxed{0}$	5	31	32	27	35	25	13	15	16	∞

Table 4.8: Next best solution

Vendor's Name	S. No.	M	1	2	3	4	5	6	7	8	9	10	11	12	13
Maruti	M	∞	81	54	81	73	0	4	8	$\boxed{0}$	19	23	24	19	54
Side Mirror	1	72	∞	$\boxed{10}$	15	0	69	69	65	72	55	45	50	48	5
eekay	2	$\boxed{35}$	0	∞	0	5	44	31	30	35	40	39	40	37	0
Delphi	3	60	5	0	∞	$\boxed{5}$	50	57	62	59	39	52	65	63	0
SPR	4	64	$\boxed{0}$	15	15	∞	60	61	58	64	50	45	47	43	15
Wipe	5	0	78	53	69	69	∞	$\boxed{2}$	60	0	18	79	19	17	50
Brakes India	6	2	76	48	74	78	0	∞	$\boxed{0}$	1	20	16	16	14	49
Purelator	7	6	72	47	68	65	5	0	∞	2	25	$\boxed{15}$	16	18	54
Munjal	8	0	81	54	78	73	$\boxed{0}$	3	4	∞	18	19	17	18	54
Amtec	9	19	64	59	64	59	18	23	17	18	∞	14	16	0	$\boxed{45}$
Padmni	10	20	53	57	78	53	18	18	16	18	13	∞	$\boxed{0}$	4	31
Denso	11	23	58	58	83	55	18	18	27	16	15	0	∞	$\boxed{0}$	33
Lumax	12	19	57	55	82	52	17	17	20	18	$\boxed{0}$	5	12	∞	36
Talbrose	13	35	5	0	$\boxed{0}$	5	31	32	27	35	25	13	15	16	∞

The new best solution (optimal route) given in Table 4.8 gives the following sequence -

Maruti $\xrightarrow{\text{1km}}$ Munjal Showa $\xrightarrow{\text{3km}}$ Wipe $\xrightarrow{\text{5km}}$ Brakes India $\xrightarrow{\text{3km}}$ Purelator $\xrightarrow{\text{18km}}$

$\longrightarrow$ Padmini $\xrightarrow{\text{2km}}$ Denso $\xrightarrow{\text{13km}}$ Lumax $\xrightarrow{\text{1km}}$ Amtec $\xrightarrow{\text{50km}}$ Talbrose $\xrightarrow{\text{15km}}$

$\longrightarrow$ Delphi $\xrightarrow{\text{15km}}$ SPR $\xrightarrow{\text{5km}}$ Side Mirror $\xrightarrow{\text{30km}}$ Cekay $\xrightarrow{\text{70km}}$ Maruti

The total distance for this optimal route is 231 Km.

The number of sets (kits) to be loaded in each truck is calculated based on the capacity (volume in cubic cm) of the truck and the capacity required (cubic cm) by one set of all the units for manufacturing one car. In this system, the truck starts from Maruti and reaches at first vendor on the route. The number of unit, calculated earlier, are loaded in the truck. In this way the truck moves from vendor to vendor, load the calculated number of units and then returned back to the Maruti with specified number of kits.

The arrow in figure 4.3 shows the path of truck. Thus in Milk Run (Rim) System where instead of vendors transporting their items individually, a single vehicle transports the items from more than one vendor.

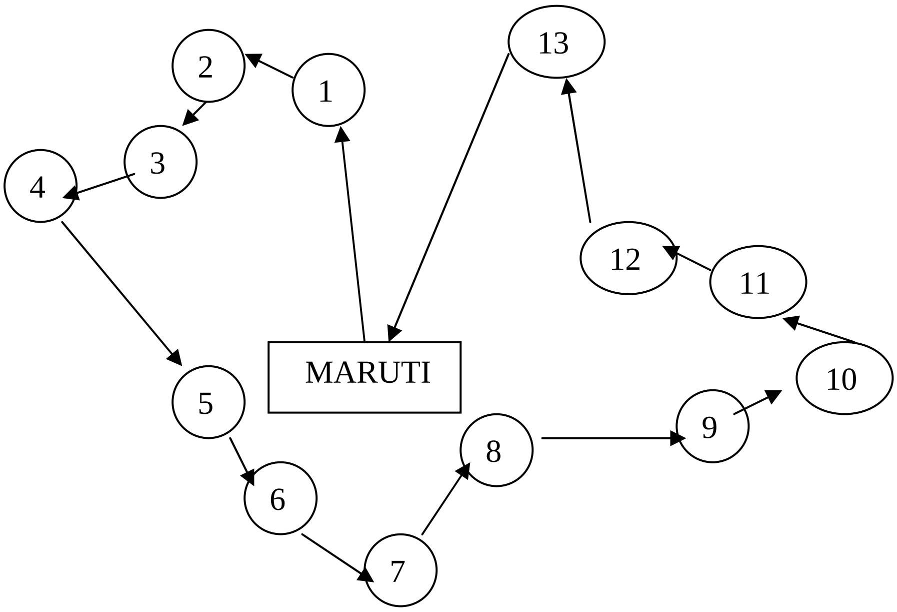


Figure 4.7: Rim System

The results of this case are presented in Table 4.9. One truck can load 113 sets. The total cost of this case is Rs. 24, 61,532

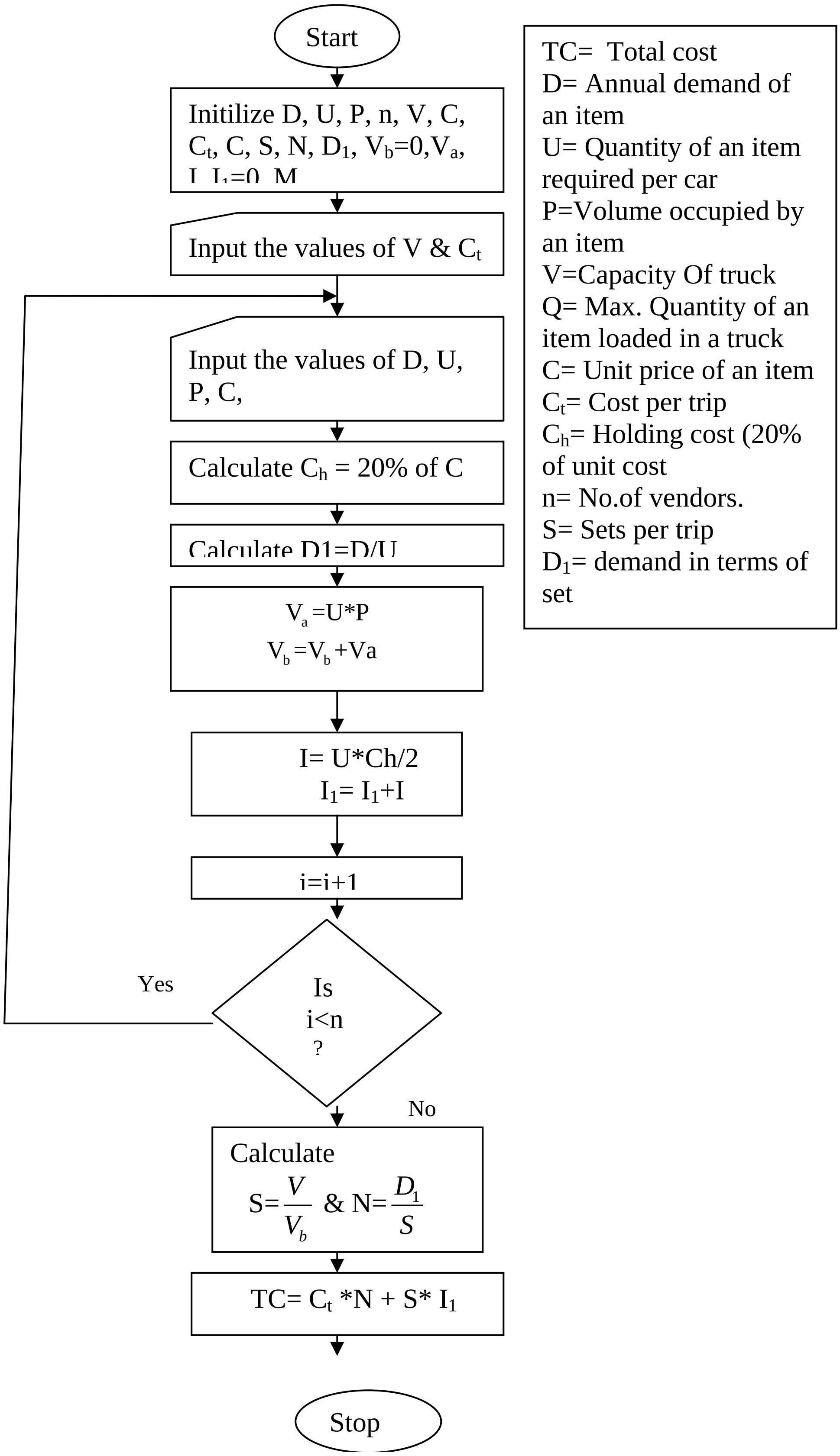


Figure 4.8: Flow Chart for One Rim of all vendors

Table 4.3

CASE-1: ECONOMIC ORDER QUANTITY(individual shipment for each item)

S. No.	Vendor's Name	Name of Component	Annual Demand	Items used per car	Volume occupied by each item	Distance travelled by truck	Transportation & ordering cost	Unit cost	Holding cost/unit/ year (20%of unit cost)	EOQ
			(Di)	**(Ui)**	**(Pi) (cm^3)**	**(km)**	**(Coi)Rs.**	**(Ci) Rs.**	**(Chi)**	
1	Side Mirror	Side Mirror	165000	1	2287.00	154.00	990	192.00	38.40	**2917**
2	Ceekay	Clutch Plate	165000	1	1264.00	140.00	920	328.00	65.60	2151
		Pressure Plate	165000	1	1936.00	140.00	920	280.00	56.00	2328
3	Delphi	Rear Shosker	330000	2	1150.00	140.00	920	700.00	140.00	2083
4	SPR	Piston	495000	3	448.00	148.00	960	90.00	18.00	7266
5	Wipe	Wiper Blade	330000	2	282.00	6.00	250	45.00	9.00	4282
6	Brakes India	Brakes India	660000	4	424.00	10.00	270	150.00	30.00	3447
7	Purelator	Oil	165000	1	4200.00	18.00	310	25.00	5.00	**4523**
		Air Filter	165000	1	1776.00	18.00	310	30.00	6.00	**4129**
8	Munjal	Strut	330000	2	5544.00	2.00	230	125.00	25.00	**2464**
9	Amtec	Connecting Rod	495000	3	225.00	40.00	420	120.00	24.00	4162
10	Padmni	Horn	165000	1	1267.00	48.00	460	50.00	10.00	3896
11	Denso	ECM	165000	1	6720.00	50.00	470	4710.00	942.00	406
12	Lumax	Tail Light	330000	2	9030.00	40.00	420	195.00	39.00	**2666**
13	Talbrose	Suspension Arm	330000	2	1960.00	120.00	820	98.00	19.60	**5255**

Maximum Quantity per full truck load	Quantity to be order	Total transportation cost(Rs.)	Total inventory cost (Rs.)	Total cost (Rs.)
(Qi)	**Q_{2i}**	**$A=Coi*Di/Q_{2i}$**	**$B=(Chi*Q_{2i})/2$**	**TCi=A+B**
2916	2916	56018.52	55987.20	112005.72
5276	2151	70571.83	70552.80	141124.63
3445	2328	65206.19	65184.00	130390.19
5799	2083	145751.32	145810.00	291561.32
14886	7266	65400.50	65394.00	130794.50
23649	4282	19266.70	19269.00	38535.70
15729	3447	51697.13	51705.00	103402.13
1588	1588	32213.23	3969.64	36182.87
3755	3755	13621.84	11265.00	24886.84
1203	1203	63096.36	15036.53	78132.88
29640	4162	49951.95	49944.00	99895.95
5264	3896	19481.52	19480.00	38961.52

992	406	191009.85	191226.00	382235.85
739	739	187668.02	14401.50	202069.51
3403	3403	79528.57	33345.00	112873.57
				1923053

Transportation mode-By road
Vehicle=TATA-407
Volume Capacity=6669000cm^3
Transportation cost = Rs. 200 + Rs.5 per km * distance travelled + Rs. 20 *no. of vendors

Table 4.4
CASE-2: ECONOMIC ORDER QUANTITY(individual shipment from each vendor)

S. No.	Vendor's Name	Name of component	Annual Demand	Items used per car	Volume occupied by each item	Distance travelled by truck	Transportation & ordering cost	Unit cost
			(Di)	(Ui)	(Pi) (cm^3)	(km)	(Coi)Rs.	(Ci) Rs.
1	Side Mirror	Side Mirror	165000	1	2287.00	154.00	990	192.00
2*	**Ceekay**	**Clutch Plate**	**165000**	**1**	**1264.00**	140.00	**920**	**328.00**
		Pressure Plate	**165000**	**1**	**1936.00**	140.00	**920**	**280.00**
3	Delphi	Rear Shosker	330000	2	1150.00	140.00	920	700.00
4	Shriram	Piston	495000	3	448.00	148.00	960	90.00
5	Wipe	Wiper Blade	330000	2	282.00	6.00	250	45.00
6	Brakes India	Brakes India	660000	4	424.00	10.00	270	150.00
7**	**Purelator**	**Oil Filter**	**165000**	**1**	**4200.00**	18.00	**310**	**25.00**
		air filter	**165000**	**1**	**1776.00**	18.00	**310**	**30.00**
8	Munjal	Strut	330000	2	5544.00	2.00	230	125.00
9	Amtec	Connecting Rod	495000	3	225.00	40.00	420	120.00
10	Padmni	Horn	165000	1	1267.00	48.00	460	50.00
11	Denso	ECM	165000	1	6720.00	50.00	470	4710.00
12	Lumax	Tail Light	330000	2	9030.00	40.00	420	195.00
13	Talbrose	Suspension Arm	330000	2	1960.00	120.00	820	98.00

Holding cost/unit/ year (20%of unit cost)	EOQ	Maximum Quantity of an item loaded per truck	Quantity to be order	Transportation cost per year(Rs.)	Inventory cost per year (Rs.)	Total cost per year(Rs.)
(Chi)		(Qi)	Q_{2i}	$A=Coi*Di/Q_{2i}$	$B=(Chi*Q_{2i})/2$	TCi=A+B
38.40	2917	2916	2916	56018.52	55987.20	112005.72

65.60 **56.00**	**1580 sets**	**2084**	**1580**	**192139.94**		**192139.94**
140.00	2083	5799	2083	145751.32	145810.00	291561.32
18.00	7266	14886	7266	65400.50	65394.00	130794.50
9.00	4282	23649	4282	19266.70	19269.00	38535.70
30.00	3447	15729	3447	51697.13	51705.00	103402.13
5.00 **6.00**	**3049**	**1116**	**1116**	**52018.00**		**52018.00**
25.00	**2464**	**1203**	1203	63096.36	15036.53	78132.88
24.00	4162	29640	4162	49951.95	49944.00	99895.95
10.00	3896	5264	3896	19481.52	19480.00	38961.52
942.00	406	992	406	191009.85	191226.00	382235.85
39.00	**2666**	**739**	739	187668.02	14401.50	202069.51
19.60	**5255**	**3403**	3403	79528.57	33345.00	112873.57
						1834627

Ceekay
EOQ=
Sqrt(2*165000**920)/(1*65.6+1*56)=1580
TC=Sqrt(2*920*165000*(65.6+56)= 192139.94

Purelator
EOQ= Sqrt(2*165000**310)/(5+6)=3049
Total volume 3049 * (4200 +1776)>6669000 cubic cm
18220824>6669000
Since volume occupied by EOQ is greater than truck capacity
Therefore, order quantity is the quantity equal to full truck capacity

Table 4.5

CASE-3: FULL CAPACITY OF TRUCK (individual shipment for each item)

S. No.	Vendor's Name	Name of Component	Annual Demand	Components used per car	Volume occupied by each item	Distance travelled by truck	Transportation & ordering cost	Unit cost
			(Di)	(Ui)	(Pi)(cm^3)	(km)	(C_{oi})(Rs.)	(C_i) Rs.
1	Side Mirror	Side Mirror	165000	1	2287	154.00	990	192
2	Cekay	Clutch Plate	165000	1	1264	140.00	920	328
		Pressure Plate	165000	1	1936	140.00	920	280
3	Delphi	Rear Shosker	330000	2	1150	140.00	920	700
4	Shriram	Piston	495000	3	448	148.00	960	90
5	Wipe	Wiper Blade	330000	2	282	6.00	250	45
6	Brakes India	Brakes India	660000	4	424	10.00	270	150
7	Purelator	Oil	165000	1	4200	18.00	310	25
		Air Filter	165000	1	1776	18.00	310	30
8	Munjal	Strut	330000	2	5544	2.00	230	125
9	Amtec	Connecting Rod	495000	3	225	40.00	420	120
10	Padmni	Horn	165000	1	1267	48.00	460	50
11	Denso	ECM	165000	1	6720	50.00	470	4710
12	Lumax	Tail Light	330000	2	9030	40.00	420	195
13	Talbrose	Suspension Arm	330000	2	1960	120.00	820	98

Holding cost/unit/ year (20%of unit cost)	Maximum quantity of an item loaded per truck	COST (Rs.)		
(Chi)	(Qi)	A(trans+order cost)	B(inventory cost)	Total cost =A+B
38.40	2916	56017.61	55988.11	112005.72
65.60	5276	28771.21	173056.33	201827.54
56.00	3445	44067.30	96452.48	140519.78
140.00	5799	52352.68	405939.13	458291.81
18.00	14886	31922.27	133975.45	165897.71
9.00	23649	3488.53	106420.21	109908.74
30.00	15729	11329.55	235931.60	247261.16
5.00	1588	32213.23	3970.00	36183.23
6.00	3755	13621.59	11265.20	24886.80
25.00	1203	63096.36	15036.53	78132.88
24.00	29640	7014.17	355680.00	362694.17
10.00	5264	14419.75	26318.07	40737.82
942.00	992	78143.05	467425.45	545568.50
39.00	739	187668.02	14401.50	202069.51
19.60	3403	79528.57	33345.00	112873.57
				2838859

Table 4.6

CASE-4: FULL CAPACITY OF TRUCK (individual shipment from each vendor)

S. No.	Vendor's Name	Name of Component	Annual Demand	Components used per car	Volume occupied by each item	Distance travelled by truck	transportation & ordering cost	Unit cost
			(Di)	(Ui)	(Pi)(cm^3)	(km)	(Coi)(Rs.)	(Ci) Rs.
1	Side Mirror	Side Mirror	165000	1	2287	154.00	990	192
2*	Cekay	Clutch Plate	**165000**	**1**	**1264**	140.00	**920**	**328**
		Pressure Plate	**165000**	**1**	**1936**	140.00	**920**	**280**
3	Delphi	Rear Shosker	330000	2	1150	140.00	920	700
4	Shriram	Piston	495000	3	448	148.00	960	90
5	Wipe	Wiper Blade	330000	2	282	6.00	250	45
6	Brakes India	Brakes India	660000	4	424	10.00	270	150
7**	Purelator	Oil	**165000**	**1**	**4200**	18.00	**310**	**25**
		Air Filter	**165000**	**1**	**1776**	18.00	**310**	**30**
8	Munjal	Strut	330000	2	5544	2.00	230	125
9	Amtec	Connecting Rod	495000	3	225	40.00	420	120
10	Padmni	Horn	165000	1	1267	48.00	460	50
11	Denso	ECM	165000	1	6720	50.00	470	4710
12	Lumax	Tail Light	330000	2	9030	40.00	420	195
13	Talbrose	Suspension Arm	330000	2	1960	120.00	820	98

Holding cost/unit/ year (20%of unit cost)	No. of items loaded per truck	COST (Rs.)		
(Chi)	(Q1i)	A(trans+order cost)	B(inventory cost)	Total cost =A+B
38.40	2916	56017.61	55988.11	112005.72
65.60	**2084**	**199387.20**		**199387.20**
56.00				
140.00	5799	52352.68	405939.13	458291.81
18.00	14886	31922.27	133975.45	165897.71
9.00	23649	3488.53	106420.21	109908.74
30.00	15729	11329.55	235931.60	247261.16
5.00	**1116**	**52018.00**		**52018.00**
6.00				
25.00	1203	63096.36	15036.53	78132.88

24.00	29640	7014.17	355680.00	362694.17
10.00	5264	14419.75	26318.07	40737.82
942.00	992	78143.05	467425.45	545568.50
39.00	739	187668.02	14401.50	202069.51
19.60	3403	79528.57	33345.00	112873.57
				2686847

Purelator
sets per trip=6669000/(1*4200+1*1776)=1116, N. of trips=165000/1116=148
cost per trip=Rs. 310
total cost= 310*148 + 1116*(1*5 + 1*6)/2=Rs. 52018

Table 4.9

CASE-5: RIM SYSTEM (Order Quantity in no. of sets =Full Truck Capacity)

S. No.	Vendor's Name	Name of Component	Annual Demand	Quantity of item used per car	Annual demand in terms of set	Volume occupied by each item	Unit cost
			(Di)	Ui	D_{1i}	Pi (cm^3)	(C_i) Rs.
1	Side Mirror	Side Mirror	165000	1	165000	2287	192
2	Cekay	Clutch Plate	165000	1	165000	1264	328
		Pressure Plate	165000	1	165000	1936	280
3	Delphi	Rear Shosker	330000	2	165000	1150	700
4	Shriram	Piston	495000	3	165000	448	90
5	Wipe	Wiper Blade	330000	2	165000	282	45
6	Brakes India	Brakes India	660000	4	165000	424	150
7	Purelator	Oil	165000	1	165000	4200	25
		Air Filter	165000	1	165000	1776	30
8	Munjal	Strut	330000	2	165000	5544	125
9	Amtec	Connecting Rod	495000	3	165000	225	120
10	Padmni	Horn	165000	1	165000	1267	50
11	Denso	ECM	165000	1	165000	6720	4710
12	Lumax	Tail Light	330000	2	165000	9030	195
13	Talbrose	Suspension Arm	330000	2	165000	1960	98

Volume occupied by the items for a car (volume per set)	Holding cost/unit/ year	Holding cost per kit	Inventory cost
	Chi=20%Ci	**A=Ui *Chi**	**113*A/2**
2287	38.40	38.40	2169.60
1264	65.60	65.60	3706.40
1936	56.00	56.00	3164.00
2300	140.00	280.00	15820.00
1344	18.00	54.00	3051.00
564	9.00	18.00	1017.00
1696	30.00	120.00	6780.00
4200	5.00	5.00	282.50
1776	6.00	6.00	339.00
11088	25.00	50.00	2825.00
675	24.00	72.00	4068.00
1267	10.00	10.00	565.00
6720	942.00	942.00	53223.00
18060	39.00	78.00	4407.00
3920	19.60	39.20	2214.80
59097		1834.20	103632.3

Volume occupied by one set of a car = 59097cm^3
Sets per trip=6669000/59097 = 112.848 (113 approx))
No. of trips=165000/113=1460
ByTravelling Salesman Algorithm the optimum route and distance is 231 km
Cost per trip=Rs. 1615 (cost/ trip 200+ 5*231 +20*13 =Rs.
1615)

TC=1615*1460 + 103632=Rs. 2461532

Table 4.10

CASE-6: RIM SYSTEM (with Economic Order Quantity)

S. No.	Vendor's Name	Name of Component	Annual Demand	Components used per car	Annual demand in terms of set	Volume occupied by each item	Unit cost	Volume occupied by the items for a car (volume per set)	Holding cost/unit/year	Holding cost per set
			(Di)	Ui	D	Pi (cm^3)	(Ci) Rs		Chi=20%Ci	A=Ui *Chi
1	Side Mirror	Side Mirror	165000	1	165000	2287	192	2287	38.40	38.40
2	Cekay	Clutch Plate	165000	1	165000	1264	328	1264	65.60	65.60
		Pressure Plate	165000	1	165000	1936	280	1936	56.00	56.00
3	Delphi	Rear Shosker	330000	2	165000	1150	700	2300	140.00	280.00
4	Shriram	Piston	495000	3	165000	448	90	1344	18.00	54.00
5	Wipe	Wiper Blade	330000	2	165000	282	45	564	9.00	18.00
6	Brakes India	Brakes India	660000	4	165000	424	150	1696	30.00	120.00
7	Purelator	Oil	165000	1	165000	4200	25	4200	5.00	5.00
		Air Filter	165000	1	165000	1776	30	1776	6.00	6.00
8	Munjal	Strut	330000	2	165000	5544	125	11088	25.00	50.00
9	Amtec	Connecting Rod	495000	3	165000	225	120	675	24.00	72.00
10	Padmni	Horn	165000	1	165000	1267	50	1267	10.00	10.00
11	Denso	ECM	165000	1	165000	6720	4710	6720	942.00	942.00
12	Lumax	Tail Light	330000	2	165000	9030	195	18060	39.00	78.00
13	Talbrose	Suspension Arm	330000	2	165000	1960	98	3920	19.60	39.20
								59097		1834.20

EOQ=√2 *Co * D/ A
EOQ=√2 *165000 *1000/1834.20= 424.16 (424approx)

$\text{Volume}_{(EOQ)} > \text{Volume}_{(\text{Full Truck Capacity})}$

Order Quantity = Quantity of Full Truck Capacity
Total Cost = Rs. 2461532 as in case5 (Full Truck Capacity)

4.6.2 Case 6: Rim System when order quantity in number of sets is equal to EOQ

a) One Rim for all the 15 items (13 vendors).

b) Order quantity, in number of sets is equal to EOQ.

It has been known that if ordered quantity is equal to the economic order quantity, then the total cost is minimum. In this case, EOQ is calculated in terms of Kits i.e. a set of items to manufacture one car. To calculate EOQ, the unit cost and inventory carrying cost of one kit is calculated. Wilson formula is applied to calculate the EOQ. The ordering cost (transportation cost) is calculated for 231 Km and 13 vendors by using the Equation 4.1. In this case the transport vehicle loads the number of units equal to the EOQ (sets) from each vendor, so the total cost of Rim System decreases.

It is kept in mind that whatever quantity is to be loaded, the total volume occupied by the items must not exceed the truck capacity. In this case EOQ turns out to be 424 sets as calculated in Table 4.10 which is more than the capacity of the truck (113 sets). Therefore the results of this case are same as for case 5 (Table 4.9).

With all the 15 items from 13 vendors, it was observed that EOQ is 3.7 times the truck capacity. Generally EOQ gives the lowest cost, it was decided to examine the following two cases:

1) Three rims of 4 to 5 vendors each
2) Four rims of 3 to 4 vendors each

These cases are analyzed and discussed in Chapter 5.

4.7 Conclusion

In this chapter we compare the Rim System with Spoke System under three cases namely:-

a) Individual shipment for each item
b) Individual shipment from each vendor
c) one rim for all vendors

Table 4.11: Comparison of Spoke system and Rim system

Transportation Mode	**Systems**	**Total cost (Rs.)**	
		Order Quantity= full truck capacity	**Order Quantity= Economic order quantity**
Individual shipment for each item	Spoke system	28,38,859	19,23,053
Individual shipment from each vendor		26, 86, 847	18,34,627
One rim for all vendors	Rim system	24,61,532	24,61,532

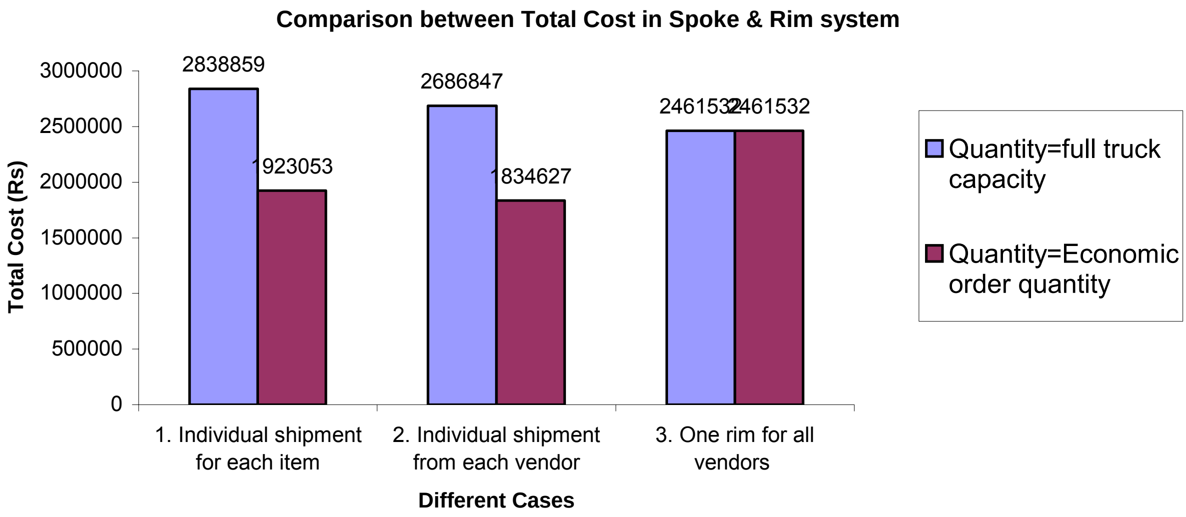


Figure 4.9: Graph between Total cost in Spoke and Rim System

The comparison shows that rim system is more economical than spoke system. However there is a need to further examine the design of rim system to see whether one rim of all the items are optimal or multi rims consisting of different group size is optimal. This analysis is given in Chapter 5.

Chapter 5

Design of Optimal Rim System

In the last chapter comparison between rim and spoke system has been carried out and it was found that the rim system is better than the spoke system when order quantity is equal to full truck capacity. However in case of order quantity equal to EOQ, the optimal results were not achieved as EOQ is much higher than the truck capacity. This can be due to the size of the rim. A rim of all the 13 vendors was considered. To achieve the optimal rim system, multiple rims having different group sizes (number of vendors) are being formulated by using two different Algorithm. Both the algorithm results in forming rims with different number of vendors like 2, 3, 4 and so on.

In the Algorithm A, first a decision was made regarding the number of rims to be designed. Based on this, the average number of vendors in each rim is calculated. In this case three rims with number of vendors 4, 4, 5 are considered. After deciding the number of rims and the no of vendors in each rim, the optimal route of each Rim is calculated.

In Algorithm B, The number of rims and the number of vendors are not predefined. Decision regarding adding a vendor to the current rim is made after reaching at a vendor by comparison of cost. Let in a given rim already n vendors are selected, now whether to add n+1 or not will depend upon the cost of rim with n vendors and n+1 vendors.

These two alternate Algorithms are explained in sections 5.1 and 5.2 to find the group of vendors and optimal route. Only Algorithm B is applied to the data of this case study and the analysis is given in section 5.3.

5.1 Algorithm A

Step 1: First prepare the distance matrix (as in Table 4.2) which shows the distance between the buyer and supplier and between the suppliers. If n is the number of vendors, then first n column shows the distance between the vendors and n+1th column shows the distance of each vendor from the buyer (factory). In the matrix r_{pq} is the distance between p^{th} and q^{th} vendor. e.g. r_{34} = the distance between 3^{rd} vendor and 4^{th} vendor.

Table 5.1: Distance Matrix between Vendors

Distance Matrix											
vendor	**1**	**2**	**3**	**4**	**5**	**6**				**n**	**M**
1	0	r_{12}	r_{13}	r_{14}	r_{15}	r_{16}	_	_	_	r_{1n}	r_{1m}
2	r_{21}	0	r_{23}	r_{24}	r_{25}	r_{26}				r_{2n}	r_{2m}
3	r_{31}	r_{32}	0	r_{34}	r_{35}	r_{36}				r_{3n}	r_{3m}
4	r_{41}	r_{42}	r_{43}	0	r_{45}	r_{46}				r_{4n}	r_{4m}
5	r_{51}	r_{52}	r_{53}	r_{54}	0	r_{56}				r_{5n}	r_{5m}
6	r_{61}	r_{62}	r_{63}	r_{64}	r_{65}	0				r_{6n}	r_{6m}
							0				
								0			
									0		
n	r_{n1}	r_{n2}	r_{n3}	r_{n4}	r_{n5}	r_{n6}				0	r_{nm}

Step 2: Decide the group size of the rim. Let it is 3 (i.e. three vendors in each rim).

Step 3: The truck will start from factory and will identify the first vendor, nearest and not yet assigned to previous rims (Let the vendor 1). Refer Table 5.2a.

Table 5.2a: Modified distance matrix

Distance Matrix											
vendor	**1**	**2**	**3**	**4**	**5**	**6**				**n**	**m**
1	NA	r_{12}	r_{13}	r_{14}	r_{15}	r16	_	_	_	r_{1n}	R_1 m
2	NA	0	r_{23}	r_{24}	r_{25}	NA				r_{2n}	NA
3	NA	r_{32}	0	r_{34}	r_{35}	NA				r_{3n}	NA
4	NA	r_{42}	r_{43}	0	r_{45}	NA				r_{4n}	NA
5	NA	r_{52}	r_{53}	r_{54}	0	NA				r_{5n}	NA
6	NA	r_{62}	r_{63}	r_{64}	r_{65}	NA				r_{6n}	NA
							0				
								0			
									0		
n	NA	r_{n2}	r_{n3}	r_{n4}	r_{n5}	NA				0	NA
Total distance covered = r_{m1} + r_{16}											

Step 4: Now identify the vendor, nearest and not yet assigned, to the vendor identified in step 3. Let it is the 6th vendor (Table 5.2a). Go to 6th row (i.e. 6th vendor). Neglect the distance r_{61}, r_{66} and r_{6m}. These are considered to be NA because repetition of vendor for loading their items is not allowed. Again select the minimum distance in the 6th row. Say it is r_{69}. Refer Table 5.2b.

Table 5.2b:

Distance Matrix											
vendor	**1**	**2**	**3**	**4**	**5**	**6**			**9**	**N**	**m**
1	NA	r_{12}	r_{13}	r_{14}	r_{15}	r_{16}	_	_	NA	r_{1n}	NA
2	NA	0	r_{23}	r_{24}	r_{25}	NA			NA	r_{2n}	NA
3	NA	r_{32}	0	r_{34}	r_{35}	NA			NA	r_{3n}	NA
4	NA	r_{42}	r_{43}	0	r_{45}	NA			NA	r_{4n}	NA
5	NA	r_{52}	r_{53}	r_{54}	0	NA			NA	r_{5n}	NA
6	NA	r_{62}	r_{63}	r_{64}	r_{65}	NA			r_{69}	r_{6n}	NA
							0				
								0			
									0		
n	NA	r_{n2}	r_{n3}	r_{n4}	r_{n5}	NA			NA	0	NA
The total distance covered is $r_{m1} + r_{16} + r_{69}$											

Step 5: Continue step 3 till the required size of the rim is prepared. Calculate the distance of the rim. Calculate the transportation cost, EOQ (sets) and the total cost for the rim.

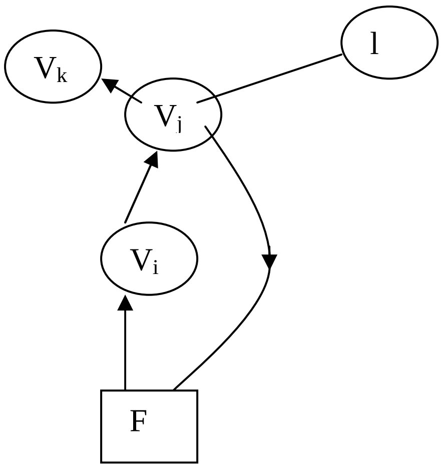
Step 6: Now start with new rim. Repeat steps 2 to 5.

Step 7: Repeat step 6 till all the rims are prepared and all the vendors are assigned.

5.2 Algorithm B

The steps to be followed are given below:

Step 1: The truck starts from the factory and can go to the vendor, nearest to the factory and not yet assigned. Let the truck finds the nearest supplier V_i from the factory F which is not yet covered.



Step 2: After reaching at supplier V_i, the truck finds its nearest supplier $V_{j.}$.

Step 3: Calculate the total cost of the Rim system of two suppliers and total cost of two suppliers by the Spoke system (when quantity order is EOQ).

Step 4: Check for the condition :

If $(\text{Total cost})_{Rim} < (\text{Total cost})_{Spoke}$ go for rim of atleast two vendors otherwise use spoke system.

Step 5: If condition in step 4 is true, then check whether any more vendor can be added to the rim. Find the vendor which is nearest to the vendor $V_{j.}$ Calculate the total cost of a Rim of three vendors and total cost of these three vendors by Rim of 2 as in step 3 and Spoke system with EOQ of third vendor.

This is explained with the help of Table 5.3

Table 5.3: Decision Logic for Algorithm B

Rim Size	Total Cost of the Rim System	Total Cost of the Spoke System	Decision
1	R_1	S_1	$R_1 = S_1$, Both are same.
2	R_2	$S_{12} = S_1 + S_2$	If $R_2 < S_2$, Opt for Rim system otherwise spoke system.
3	R_3	$S_{123} = R_2 + S_3$	If $R_3 < S_{123}$, Opt for Rim system otherwise spoke system. Stop further analysis of this Rim. Start new Rim.
4	R_4	$S_{1234} = R_3 + S_4$	If $R_4 < S_{1234}$, Opt for Rim system otherwise spoke system. Stop further analysis of this Rim. Start new Rim.

1.a) In case of Rim System

Total cost of a rim of two vendors when order quantity is equal number of sets of all items

For Munjal and Wipe

Distance covered = Factory+ Munjal + Wipe +Factory

$$= 1 + 3 + 3$$
$$= 7\,km$$

Sets per trip:-

$$= \frac{6669000\,cubic - cm}{2 * 5544 + 2 * 282\,cubic - cm}$$
$$= \frac{6669000}{11652}$$
$$= 572.3 \approx 573$$

No. of trips:-

$$= \frac{165000}{573}$$
$$= 287.95 \approx 288$$

Cost per trip:-

$$= K_1 + K_2 * (\text{distance covered}) + K_3 * (\text{No. of vendors})$$

$$= 200 + 5*7 + 20*2$$

$$= Rs.275$$

Total cost of Rim System (a group of 2 vendors):-

$$= 275*288 + \frac{573}{2}(2*25 + 2*9)$$

$$= 79200 + 19482$$

$$= Rs.98,682$$

1.b) In Case of Spoke System

Total cost of spoke system of two vendors when order quantity is EOQ.

From the Table 4.4

Total cost of Spoke system (for 2 vendors):-

$$= (TC_{munjal}) + (TC_{wipe})$$

$$= 78132 + 38535$$

$$= Rs.1,16,667$$

Rim Size	Total Cost of the Rim System	Total Cost of the Spoke System	Decision
2 **F- Munjal – Wipe-F**	98,682	78, 132 + 38, 535 = 1, 16, 667	$R_2 < S_{12}$, Opt Rim system
3 **F- Munjal – Wipe- Brakes India- F**	1, 55, 900	98, 682 + 1, 03, 402 = 2, 02, 084	$R_3 < S_{123}$, Opt Rim and continue the rim for 4th vendor
4 **F- Munjal – Wipe- Brakes India- Purelator-F**	2, 18,743	1, 55, 900 + 52, 018 = 2, 07, 918	$R_4 > S_{1234}$, addition of 4th vendor in a Rim of three vendors is not economical. Break the rim

First Rim

Rim Size	Sequence of vendors in a rim	Total cost of a rim (Rs.)
Rim of three vendors	F- Munjal – Wipe-Brakes India- F	1, 55, 900

Step 6: Find the next nearest vendor to Factory i. e. Purelator.

Rim Size	Total Cost of the Rim System	Total Cost of the Spoke System	Decision
2 **F- Purelator-Padmini-F**	98,760	52, 018 + 38, 961 = 90, 979	$R_2 > S_{12}$, a rim of 2 vendors is not economical. Brake the rim

Step 7: Find the second nearest vendor to Factory after Purelator i. e. Padmini.

Rim Size	Total Cost of the Rim System	Total Cost of the Spoke System	Decision
2 **F-Padmini- Denso-F**	4, 95, 470	4, 21, 196	$R_2 > S_{12}$, a rim of 2 vendors is not economical. Brake the rim

Step8: Find the third nearest vendor to Factory after Purelator and Padmini.

Rim Size	Total Cost of the Rim System	Total Cost of the Spoke System	Decision
2 **F- Denso- Lumax- F**	4, 62, 610	5, 84,304	$R_2 < S_{12}$, Opt Rim system. Continue the rim for 3rd vendor
3 **F- Denso- Lumax-Amtec-F**	4, 92, 702	4, 62, 610 + 99, 895= 5, 62, 505	$R_3 < S_{123}$, Opt Rim and continue the rim for 4th vendor
4 **F- Denso- Lumax-**	5, 79, 950	4, 92, 702 + 38, 961=	$R_4 > S_{1234}$, addition of 4th vendor in a Rim of three

Amtec- Padmini- F		5, 31, 663	vendors is not economical. Break the rim

Second Rim

Rim Size	Sequence of vendors in a rim	Total cost of a rim (Rs.)
Rim of three vendors	F-Denso- Lumax- Amtec- F	4, 92, 702

Step 9: Find the next nearest vendor to Factory i. e. Delphi.

Rim Size	Total Cost of the Rim System	Total Cost of the Spoke System	Decision
2 **F- Delphi- Side Mirror- F**	3, 48, 326	4, 03, 566	$R_2 < S_{12}$, Opt Rim system. Continue the rim for 3rd vendor
3 **F- Delphi- Side Mirror- SPR - F**	3, 64, 149	3, 48, 326 + 1, 30, 794= 4, 79, 120	$R_3 < S_{123}$, Opt Rim and continue the rim for 4th vendor
4 **F- Delphi- Side Mirror- SPR - Cekay- F**	4, 64, 040	3, 64, 149 + 1, 92, 139= 5, 26, 288	$R_4 < S_{1234}$, Opt Rim and continue the rim for 5th vendor
5 **F- Delphi- Side Mirror- SPR - Cekay—Talbrose-F**	5, 96, 379	4, 64, 040 + 1, 12, 873	$R_5 > S_{12345}$, addition of 5th vendor in a Rim of four vendors is not economical. Break the rim

Third Rim

Rim Size	Sequence of vendors in a rim	Total cost of a rim (Rs.)
Rim of four vendors	F- Delphi- Side Mirror- SPR - Cekay-F	4, 64, 040

Step 10: Find the next nearest vendor to Factory i. e. Talbrose.

Rim Size	Total Cost of the Rim System	Total Cost of the Spoke System	Decision
2 **F- Talbrose- Padmini-F**	1, 40, 435	1, 51, 834	$R_2 < S_{12}$, Opt Rim system. Continue the rim for 3rd vendor
3 **F- Talbrose- Padmini—Purelator-F**	2, 62, 259	1, 40, 435 + 52, 018 = 1, 92, 453	$R_3 > S_{123}$, addition of 3rd vendor in a Rim of two vendors is not economical. Break the rim

Fourth Rim

Rim Size	Sequence of vendors in a rim	Total cost of a rim (Rs.)
Rim of two vendors	F- Talbrose- Padmini-F	1, 40, 435

Fifth Rim

Rim Size	Sequence of vendors in a rim	Total cost of a rim (Rs.)
Rim of one vendor	F- Purelator -F	52, 018

5.3 Optimum Rim Simulation

To further check out the optimum no. of vendors in a rim, a computer program is designed and coded in java. This program forms the rims of different number of vendors and calculates the total cost for each possible rim. Thereafter it gives the output, a rim with minimum total cost. The basic logic of the program is explained below for a rim of 3 vendors each.

Individual truck ships the sets of three vendors of a rim for which the total cost is minimum. Transportation cost will depend on the total distance covered. The task is to divide total vendors into rims of three each so that total distance in covering all the vendors can be optimized. Suppose there are total six vendors- 1, 2, 3, 4, 5 & 6 located at different locations. Now there will be total ${}^6C_3$ =20 rims of three vendors each, however total possible routes for these vendors will be ${}^6P_3$ =120. Corresponding to each route total cost is calculated. Now grand total for each possible combination of two routes out of these 120 routes, covering all the vendors without repetition, will be calculated. Finally the combination with minimum grand total will be selected. A similar approach can be extended for any number of vendors to optimize the total of transportation and inventory cost.

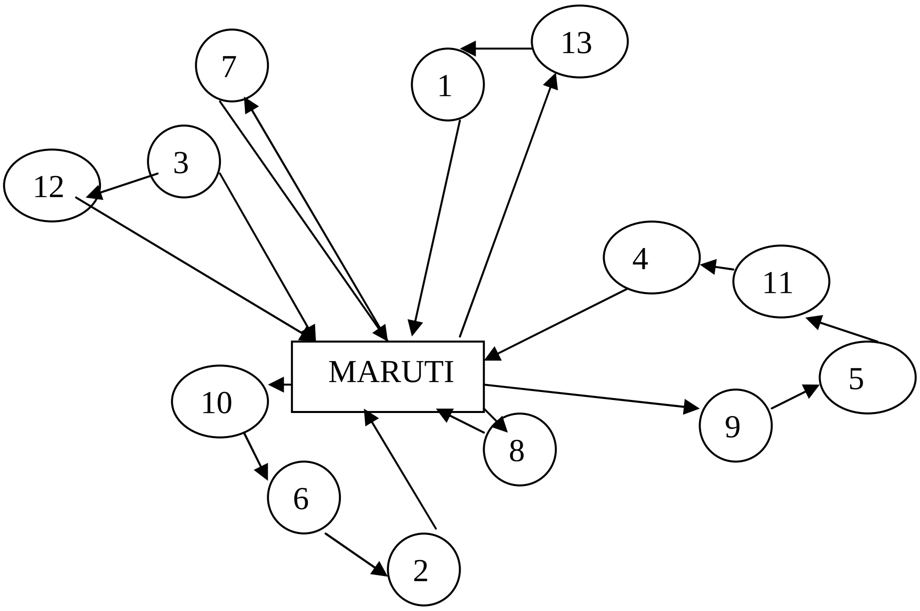


Figure 5.1: Rims of Different group size

Calculations:-

For a group of three vendors-

L= Distance covered by a vehicle for a group.

$$C = K_1 + K_2 * L + K_3 * n$$

$$S = \frac{V}{\sum_{i=1}^{n} U_i * P_i} \quad (\text{for } n = 1 \text{ to } 3)$$

$$N = \frac{D}{S}$$

$$TC = C * N + \frac{S * \sum_{i=1}^{n} U_i * C_{hi}}{2}$$

The rims formed by this are presented in Table 5.5

5.4 Conclusion

The results of total cost calculated earlier by different cases and multi rims consisting of different group sizes and routes are tabulated below:

Table 5.4: Total cost of various types of Rims

Transportation Mode	Systems	Total cost (Rs.)	
		Order Quantity= full truck capacity	**Order Quantity= Economic order quantity**
Individual shipment for each item	Spoke system	28,38,859	19,23,053
Individual shipment from each vendor		26, 86, 847	18,34,627
One rim for all vendors	Rim system	24,61,532	24,61,532

Rim Size	Sequence of vendors in a rim	Total cost of a rim (Rs.)	Grand Total Cost for 13 Vendors
3	F- Side Mirror-Padmini-Wipe- F	1, 57, 791	**14, 08, 182**
3	F- Cekay- Delphi- SPR- F	4, 22, 477	
3	F- Brakes India- Purelator-Munjal Showa- F	1, 85, 578	
3	F- Amtec- Denso- Lumax- F	5, 28, 636	
1	F- Talbrose- F	1, 13, 700	

Rim Size	Sequence of vendors in a rim	Total cost of a rim (Rs.)	Grand Total Cost for 13 Vendors
3	F- Munjal – Wipe-Brakes India- F	1, 55, 900	**13, 05, 095**

3	F-Denso- Lumax- Amtec-F	4, 92, 702	
4	F- Delphi- Side Mirror- SPR -Cekay-F	4, 64, 040	
2	F- Talbrose- Padmini-F	1, 40, 435	
1	F- Purelator -F	52, 018	

It shows that if the items are delivered in rims of two, three and four vendors covering all the 13 vendors as compared to spoke system, then the total cost can be minimized.

From the whole discussion, it has been concluded that Rim system gives better results in terms of low transportation and inventory cost

- where either all the vendors are closer to each other or a no. of vendors is nearby to each other.
- when small batch size as required in JIT is needed.
- where the company manufactures a variety of components in small quantities.
- when chances of abrupt change in demand are more.

Chapter 6

Conclusions

In this project, the issue of inbound logistics was analyzed to compare the two systems of transporting materials from vendors to buyer. This is an important decision as it will influence the cost of carrying inventory and transportation cost along with other factors like companies production policy, quality, flexibility to change etc. In the Spoke system, each vendor is transporting the items individually to the buyer, whereas, in Rim system, material is collected from a group of vendors.

Firstly the four cases of spoke system are studied and it was found that the system where order quantity is equal to EOQ and all the items of a vendor are transported together is the optimal. Then the spoke system is compared with the Rim system where a single rim is designed of all the 13 vendors. The cost of Rim system was higher, because the EOQ of 13 vendor Rim system is 3.7 times the capacity of the truck. So EOQ can be used as the order quantity and a sub optimal solution of full truck capacity was compared.

At the third stage an attempt was made to make multiple rims of group of vendors so that the order quantity is close to EOQ. Two different algorithms were explained.
The results show that the multiple rims with different number of vendors in each rim is the optimal solution. This shows that an analysis is needed before deciding between Spoke and Rim systems. Further an optimal design is required for the spoke system.

From the data and the analysis of results it appears that if the vendors are close to each other, Rim system is favorable, whereas if the vendors are geographically not close to each other then the increase in transportation cost outweigh the advantage of savings in inventory cost.

Scope for Further Study

1. In this project only one example is taken. It is required to apply the study to more such cases and validate the results with the actual practice and costs.
2. The transportation cost is considered as consist of three components. A parametric study can be conducted to check the sensitivity of the parameters and to examine the optimality of different strategies under different values and ratios of the cost parameters.

Refrences

1. Sahay B. S.,(1999), *Supply Chain Management for Global Competitiveness*.,Macmillan India Limited
2. Mohanty R. P. and Deshmukh S. G., *Supply Chain Management, Theories & Practices* : Biztantra, Indian Text Edition.
3. Chopra Sunil & Meindle Peter. *Transportation in Supply Chain.* II Edition.
4. Jain Karuna. *Cost Minimization Through Consolidation of Logistics: A Case.*
5. Burns L. D., Hall R. W., Blumenfeld D. E., and Daganzo C.F. (1985)., "*Distribution strategies that minimizes transportation and inventory costs.*" Operation research, Vol. 33(3),pp.469.
6. Sharma J. K. *Operations Research Theory & Applications.* Macmillan India Ltd.
7. Hamdy A. Taha. *Opearations Research.* Pearson Education.
8. Jones, T. C. & Riley, D. W. *Using Inventory for Competitive Advantage Through Supply Chain Management.* International Journal Of Physical Distribution & Material Management.
9. Ukovich, B and Speranza, M.,(1997)., "*Minimization of logistics cost with given frequencies*",. Transportation Research, Vol. 31 B(4), pp.327.
10. Bellmore,M., and Nemhauser, G.L.,. *The Traveling- Salesman Problem*: *A survey*
11. Little, J., Murty,K., Sweeney,D., and Karel,C., (1963), "*An Algorithem for Travelling- Salesman Problem*", Operation Resarch. , Vol.11
12. Karg,R.L., and Thompson, G.L., (1965)., "*A heuristic Approach to Solving the Travelling- Salesman Problem*", Management Science, Vol.10,pp.225
13. Viswanathan, S and Mathur, K .,(1997), "*Integrating routing and inventory decisions in one- warehouse mluti- retailer multi- product distribution system*"', Management Science, Vol.31, B(4), pp.327 .
14. Ellarm, L. M, & Cooper C. M., (1990), "*Supply Chain Management, Partnerships, and the Shipper- Third Party Relationship*", International Journal of Logistics Management,Vol.11,pp.54
15. Fisher, M. L, Greenfield,A.J., Jaikumar,R., & Lester. III .J.T., (1982), "*A Computerized Vehicle Routing Application*", Interfaces (Aug).

B

16. Dantzig, G.B., Fulkerson,R., and Johnson, S.M., (1954), “*Solution of a Large-Scale Traveling Salesman Problem”*, Operations Research , Vol.2 , pp.393-410
17. Arora, S., (1998), “*Polymonial Time Approximation Schemes for Euclidean Travelling Salesman and other Geometric Problems”*, International Journal of Logistics Management, Vol. 45, pp.753-782
18. Coyle, J. J., Bardi,E. J., and Langley, C.J., (2003), The Management of Business Logistics: A Supply Chain Perspective, 7th Edition, Thomson South Western.
19. Dornier, P. P., Ernest, R., Fender, M., and Kouvelis,P., (1998), Global Operations and Logistics: Text and Cases, John Wiley & Sons, Inc