

**Spare Parts Inventory Management System in an
Automotive Downstream Supply Chain Network**
A Case Study

A Dissertation

Submitted in Partial Fulfillment of the Requirements
for the Degree of

Master of Engineering
in
Production Engineering

by
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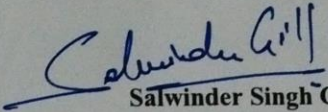
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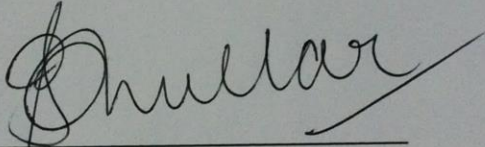
CERTIFICATE

I hereby declare that the thesis entitled "Spare Parts Inventory Management System in an Automotive Downstream Supply Chain Network – A Case Study" in an authentic record of my study carried out as requirement for the award of the degree of **Master of Engineering in Production Engineering** at **Thapar University, Patiala** under the supervision of **Mr. Supreet Bhullar**, Associate Professor, Mechanical Engineering Department, Thapar University, Patiala during July, 2012 to July, 2014. The matter embodied in this report has not been submitted in partial or full to any other university or institute for the award of any degree.

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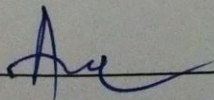

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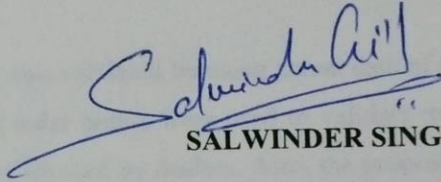
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ABSTRACT

The purpose of this study was to determine and validate the order point system in spare parts inventory management system (SPIMS) in the supply chain of an automotive organization. The objective was to control for costs.

A SPIMS as proposed by Nagarur et al. (1994) was adopted after due deliberations with regards to the alignment between the SPIMS of the dealers of the automotive manufacturing organization and that proposed by the dealers.

The SPIMS of the entire dealer network was studied; a critical analysis of SPIMS was carried out to ascertain the parity in the operational aspects of the system. It was observed that across the dealers the SPIMS was same and no modifications or customizations had been carried out, during analysis it was also observed to manage the SPIMS had been sponsored by the parent company.

The model proposed by Nagarur et al. (1994) was also validated by using actual data of last three years collected over a period of six months. The order points were used to validate the model, and results were improved from the actual system followed by dealers. Also, the proposed model by Nagarur et al. (1994) was compared with the theoretical model of order point.

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Abbreviations

RAM	Reliability Availability and Maintainability
LCC	Life Cycle Cost
VED	Vital Essential and Desirable
ETA	Event Tree Analysis
VMI	Vendor Management Inventory
SPIMS	Spare Part Inventory Management System
BDT	Break Down Tractor
KBSAS	Knowledge Based Service Automation System

CHAPTER 1

Introduction

Spare part inventories contribute huge extent of overall fraction of inventory investment in addition to raw materials, work in process and finished goods, etc. Most important task faced by automotive industry is spare part inventory management system.

1.1 Information Background

Customer satisfaction in automotive industry depends on the availability of product that has been connected to the value of both product support and product characteristics. Customer awareness about quality of product is exaggerated by how fine the product conforms to requirements as well as makes it fit for the future use and its reliability over time [Juran and Blanton, 1999]. Product characteristics like supportability, maintainability and product support also affects the customer satisfaction. In addition, it is not only exaggerated by the performance and value of hardware purchased, and also by the entire cost received, and also by the superiority of the product interaction and relationship experience of the product throughout the service life. Therefore, every products in automotives, specially the spare parts need support in there working life. The various forms of product supports that manufacturer offers the customers to help them increase maximum worth from product, that is known as product support [Juran and Blanton, 1999]. Most industrial and automotive products deteriorate and wear and tear wear with use. In general, because of technological and economical considerations, it is not possible to manufacture a machine or system which is maintenance-free.

Distinctive form of product support comprise training, installation, maintenance, and repair services, availability of spare parts, documentation, upgrades functionality, warranty schemes and customer dealing [Goffin, 2000]. Managers also need to give consideration to product support as it plays key role for many products for achieving satisfaction of customers and loyalty, and increase the repeat sales. It can be a significant source of profit and revenue [Kott, 2008]. Also, competitive advantage in marketing is provided; and product segregation becomes

complicated in many markets; automotive organizations are rising looking to product support as a prospective source of advantage [Loomba, 1996].

Generally, the industrialized machine or product at work has been linked with three basic concepts: maintenance and provision service, service delivery, and lastly, the restoration of spare parts (Figure 1). For the system to keep in unceasing operation and avoid sudden downtime, everyone should consider all the factors to study system presentation

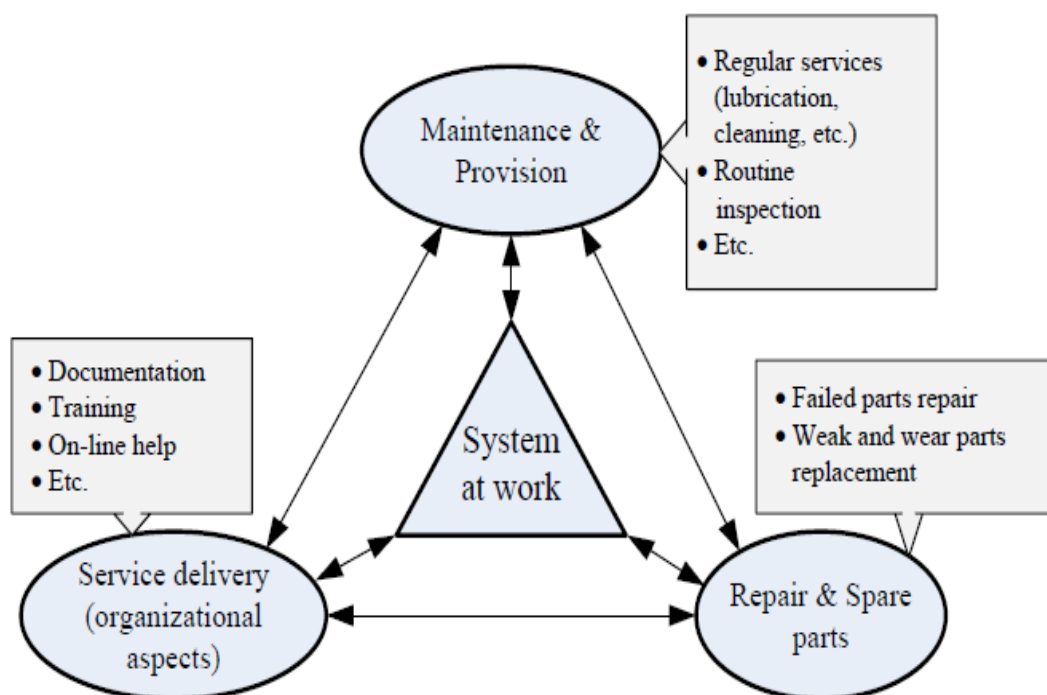


Figure 1. Three main factors influencing the system at work [adapted from Ghodrati et al., 2012]

The interdependent factors, and also the alteration in one factor affect the other factor and altering the performance of the system.

1.1.1 Service Delivery and Strategy Product Support

Product characteristics and product support needs depend on such as maintainability and reliability, the capabilities and customer's services, and the situation of the product which the product has been going to use. The merchandise support [Markeset and Kumar, 2003] conditions

have been constructed on both specification of design and conditions faced by the merchandise user. Two critical issues of spare parts are maintenance and product support. The often trunks from the poorly intended maintainability and reliability characteristics collective with poor product support strategies and maintenance, which in turn leads to unintended stoppages.

1.1.2 Factors influencing in Spare Part Products' Support

The issues influencing product support can be confidential as engineering aspects and organizational aspects. Spare part product features such as product consistency availability and maintainability (RAM), product life cycle cost (LCC), merchandise application factors such as ecological situations have to be employed on the industrial side of aspect, topographical distribution, social situation, and geopolitical and social conditions need to be located on the structural side [Kumar et al., 1992].

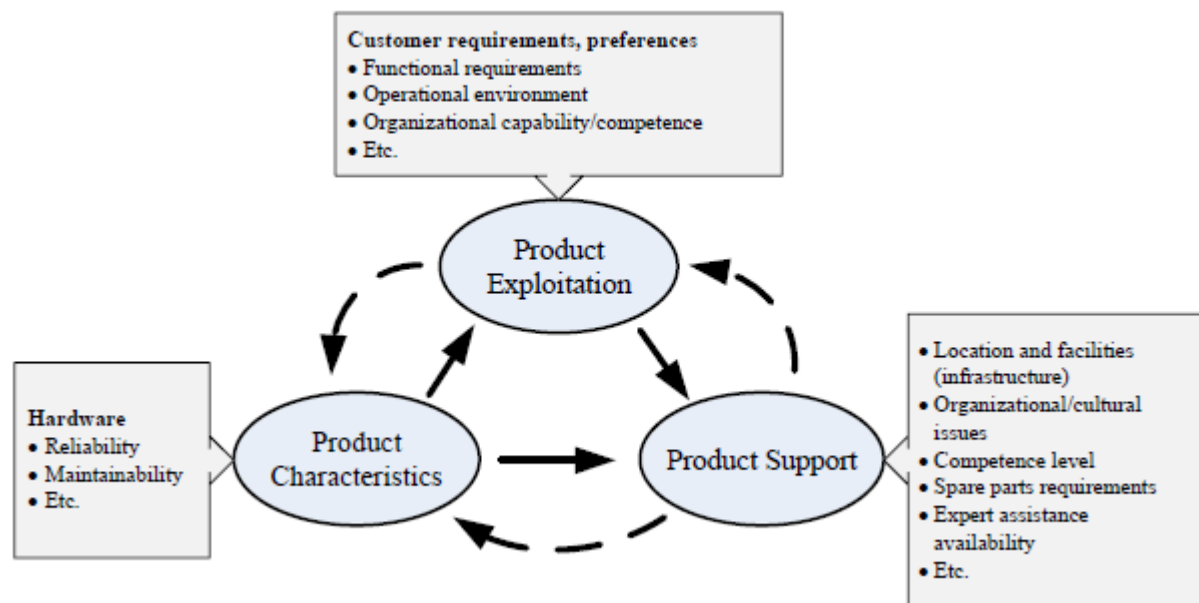


Figure 2. Connection between characteristics of product, product exploitation and product support [Adapted from Markeset and Kumar, 2003].

Functioning situation have been seriously measured in dimensioning spare part service delivery product support performance strategies. More often than not, the manufacturer or supplier's suggested program of maintenance for and components and systems is generally built on age

with the consideration of construction atmosphere. This led to many unpredicted system and failure of components. This creates poor system performance and a higher LCC due to unplanned repairs and as well as support. The ecological conditions, in which the equipment's have been operating, are the temperature, dust, humidity, etc. Frequently have a considerable influence on the maintenance need and product reliability characteristics and thus on the support requirements [Kumar et al., 1992].

1.1.3 Properties of Functioning Atmosphere on System Consistency

Maintainability, availability, Reliability and of the product have been considered significant and had an abundant impact on support of product. The reliability and nature of equipment perceptibly had a large impact on the key elements of support of product. Extraordinary dependability does not reject the need for the service, but surely reduces it. The products regularly require conservation, achieved at unvarying interval of time to ensure the reliability of product. Also the reliability of high upkeep do not mean that product would be free of maintenance, but it will need less maintenance [Markeset and Kumar, 2003].

The consistency of the system is the probability that it have to accomplish the required functions without the disappointment under given situations for an operating period of intended use. However, it has been found that most articles on reliability consider failure time as the only variable for estimating the reliability of the system. Another issues may also influence the reliability features of a system during its working lifetime, and these are usually not considered in reliability models [O Connor, 2002]. The environmental conditions, in which the equipment operates, such as temperature, humidity, dust, etc. often have considerable influence on the product reliability characteristics [Ghodrati and Kumar].

1.2 Spare Parts

Spare parts are technical equipments that are subject to planned maintenance or repair if failure situation occurs. Maintenance and repair to replace defective parts with new parts has generally been defined as spare parts [Fortuin and Martin, 1999]. The spare parts are used to keep goods or equipments that the company sells [Buker, 2001]. Spares are also called spares or service parts. Inventory of spare parts can be reserved at the manufacture location the locations of service, or can be kept at location which are near to the service customers. Technical systems and industrial

installations will fail and therefore it is needed for repair and restoration of the condition in which it is working. These classifications and installations are subjected to planned maintenance. In most of the circumstances, maintenance and repair requires pieces of equipment to replace defective parts. The common name for these parts used has been ‘spares’. Spare parts have been divided into categories of repairable and consumables. Repairable parts have been categorized as those parts which have been exchanged to different ones and have to be sent to restoration center in the case of disaster situations. These parts have to be technically repairable. Consumables parts are not technically repairable. These parts have to be replaced by new ones and scrapped in case of failure situation [Botter and Fortuin, 2000].

Apparently, the control and management of spare parts constitutes a complex matter. Common statistical models for inventory control lose their applicability, because the demand process is different from that assumed due to the machine characteristics, operating situation and unpredictable events during operation. Forecasting demand appears as an essential element in many models, which requires some historical demand figures. This data has been generally unavailable or invalid for new and less consumption parts. Unfortunately, the practical approach of spare parts inventory management and control are not validated in any way, and then controllability and objectivity are hard to guarantee [Fortuin and Martin, 1999]. The product reliability characteristics and operating environment-based spare parts forecasting method [Ghodrati and Kumar, 2005], as a systematic approach, may improve this undesirable situation.

1.2.1 Spare Parts Management

Significant role of spare parts management in achieving the anticipated availability of plant at a cost of optimism. Currently, the automotive organizations are going for wealth intensive, mass manufacture concerned with and refined technology. The stoppage for such plant and machinery has been exorbitantly luxurious. It has been observed in automotive industries that the non-availability of spare parts, when required for repairs, contributes to 50% of the total down time. Also, the cost of spare parts is more than 50% of the total maintenance cost in the industry. It is a paradox that the maintenance department has been complaining about the non-availability of the spare parts to meet their requirement and finance department has been facing the problem of increasing locked up capital in spare parts inventory. This amply signifies the vital importance of spare parts management in any organizations [1].

1.3 Special Features of Spare Parts

In the contemporary manufacturing scenario, automotive companies have been moving their focus from manufacturing to improving their customer support and after sales services. This after sales profit of spares has become a profitable area of business. Spare parts have been considered important as they are needed for efficient working of the equipments; this makes the availability of spares the important factor for all companies. In conditions like machine breakdown, the availability of essential spares can reduce machine downtime. Thus unavailability of spares can lead to many losses. Machine downtime could also result in lost revenues and customer dissatisfaction. As machines are essential for companies capital so machine downtime should be minimized resulting to proper customer satisfaction. Another point here is that it is not easy to keep various spares in stock. As it causes excess of items and lead to high inventory which further causes carrying cost. In this type of business managers should make exact stocking decisions from the available information of lead time, shortage cost and demand [Driessen et al. 2010].

1.4 Basic Questions of Inventory Management

The control over level of inventory and positioning of inventory has been considered as the two main purposes of inventory management. The importance of inventory management is the most vital task for the companies. Inventory control is a difficult task and has complex structures in many supply chains [Simchi Levi et al., 2004; Waters, 2009]. The main question of inventory that needs to be addressed has been as to how to control the stock efficiently and ensuring the availability of spare parts. Holding the spare parts in stores ties capital and resources of company which in result limit sales growth. Also the stocking level of parts decline with period of time. Therefore, storing high levels of inventory can lead to financial burden [Happonen, 2011]. All automotive companies determine important items for operations. They decide which items should be stocked, when to place an order, quantity of order. Also companies should measure level of customer service and movement of item and analyze inventory cost [Waters, 2009].

1.5 Demand Forecasting in Spare Parts

Demand for forecasting in spare parts has been considered crucial issues of inventory management have a challenge in the restoration and renovation engineering [Pham, 2006]. The animated contest arises due to the irregular nature of the component failures and corresponding random demand of the spare parts. Demand forecasting of spare parts refers to an estimation of the supreme likely impending requirement of spares on components failure under given conditions. Forecasting of spare parts also has a noticeable effect on executing the other issues of spare parts inventory management like procurement and holding policy. Spare parts inventory model differs substantially from regular inventory models since spare parts demands arise with the failure of components. Inventories of spare parts differ from other manufacturing inventories from functionality as well as from storing strategy point of view [Kennedy et al., 2012]

1.6 Spare Parts Problem in Inventory Management System

The exclusive difficulties faced by the organization in managing the spare parts are as follows [1]: Firstly, an element of uncertainty as to when a part may be required and also the quantity of its requirement. The importance of inventory management is the most vital task for the companies. Inventory control is a difficult task and has complex structures in many supply chains [Simchi Levi et al., 2004; Waters, 2009]. The main question of inventory that needs to be addressed has been as to how to control the stock efficiently and ensuring the availability of spare parts. Holding the spare parts in stores ties capital and resources of company which in result limit sales growth. Also the stocking level of parts decline with period of time. Therefore, storing high levels of inventory can lead to financial burden [Happonen, 2011]. All automotive companies determine important items for operations. They decide which items should be stocked, when to place an order, quantity of order. Also companies should measure level of customer service and movement of item and analyze inventory cost [Waters, 2009]. This generally arises due to the failure of a component, either due to wearing out or due to other reasons which cannot be predicted accurately. Finally, the consumption rates of spare parts in some cases are very high and for some are very low. These problems are to be faced by spare parts management [1].

1.7 Objective of Spare Parts Inventory Management

The objective of spare parts management is to ensure the availability of spares for maintenance and repairs of the plant and machinery as and when required at an optimum cost. Also, the spares should be of right quality [1]. There are many actions required to ensure the spare parts management effective. A good inventory control system helps systemizing the ordering procedure and also achieving an optimum level of inventory. In addition, selective efforts should be made to evolve optimum replacement policies for selected spare parts, for which cost of down time and cost of replacement are very high. For the spare parts which are very expensive and those which are to be imported, it is essential that the useful life for such spares is extended by appropriate applications of reconditioning and repair techniques. Also, efforts should be made to indigenize the spare parts in view of the hard-to-get foreign exchange involvement. Also, for similar industries establishing of spare parts bank goes a long way in reducing the total inventory holding of the expensive spare parts and also reduces the stock holding cost. For different industries, establishing spare parts banks and a suitable information system for the exchange of spares has been considered a viable option. The objective of this study is to make proper balance between spare parts availability and operational costs [Driessen et al., 2010]. In spare parts supply chain the stock out results extremely costly. Therefore spare parts inventory is named as special type inventory with special features. The calculation of accurate demand is always difficult to forecast [Huiskonen, 2001]. Lately, the application of computers for the processing of spare parts information and operating an effective spare parts control system has been helpful for the organization to ensure timely actions for an efficient and effective spare parts management.

The main goal of this study was to streamline the spare part inventory management system and unify inventory management policies of spare part dealers in order to strengthen the service. This has been done by examining account organization system. The main impartial behind the study was to optimize the invested capital in inventory while providing suitable service level to the customers

CHAPTER 2

Literature Review

2.1 Introduction

This chapter presents the summary of work carried out by different researchers on the spare part inventory management system in different industries and proposed different models and approaches to improve spare part inventory management system.

2.2 Literature Review

Nagarur et al. (1994) studied the spare part inventory system of a computer industry. The aim of this study was to relate stock quantities according to demand to avoid overstocking and under stocking of spares. They classified spare parts into four categories depending upon their cost and lead time. Forecasting models with the high degree of the accuracy were implemented, demand forecasting was determined and ordering point and safety stocks were computed. After determine the various models the business factor index model was adopted for this system which was used to calculate the ordering point of different class of items, with the help of these ordering points the inventory cost was resulted to minimum and also increased the efficiency for ordering spare parts.

Walker (1997) determined the base stock level for insurance type spares. The paper discussed that maintenance managers regularly face problem determination of suitable stocking level of spare parts. Inadequate stocking of spare parts can lead to machine downtimes. The study considered insurance type spares of low demand and high cost critical spares as they accounted a large part of investments for the industry. The paper used a simple graphical model to determine initial number of spares that should be purchased because of high downtime cost. The probability values taken in this method were 0.90, 0.95 and 0.99. This simple graphical method helped in choosing the initial number of insurance spares to be purchased for system which was having finite population sources of part failures. The method was suitable for poor quality of available data and it also indicates sensitivity of decision to order.

Kumar and Knezevic (1997) gave the spare part optimization inventory models for both series structures and parallel structures. According to the study it was not easy to predict required number of spares for achieving exact availability of spares on time. High availability can be achieved by ordering more number of spares. Ordering more number of spares results in increasing cost and space conditions. It was investigated to order required number of spares and determine them carefully and possibly optimize them. The study presented spares determination model for both series and parallel system and concluded the impartial which improve the availability with respect to minimizing space. The problem was solved with the help of simple algorithms. The model helped in predicting the spare requirements to achieve specified availability of stores with minimum space.

Kobbacy and Liang (1999) proposed an intelligent inventory management system that assisted in decreasing the gap connecting theory and practice of inventory management. The authors proposed an automatic demand and lead time detection to validate the model. The demand identification with numerical tests were discussed, they identified the lead time pattern. Probability distribution model for constant and probalistic demand were discussed with linear and seasonal demand. The empirical evaluation of this system with real data of manufacturing industries showed that system could lead to considerable saving of inventory cost.

Botter and Fortin (2000) suggested that facility part records were not accomplished by normal inventory procedures as conditions of inventory models were not satisfied. But the critical question of inventory switch has to be answered, which part have to be stocked? The place where it should be stocked? What quantity of item should be stocked? Using VED approach the authors identified the answers to the above questions. According to the authors the answer to the first question depended on the criticality of the item, as if the customer was in need for the item and item was not available, this lead to distinction of vital, essential and desirable parts. To answer second question two factors were used i.e. usage in units and price of the item, service response time was also important. The three scenarios resulted in developing a tool which was capable of reaching desired level if lowering inventory cost.

Dubelaar et al. (2001) studied the inventory sales and service relationship of a retail chain store operation. The effective inventory management was critical in retailing success of chain stores. The study entailed a survey was done of 101 chain store units and developed and tested a series of hypothesis about chain stores, seventy five percent responses were given to the mail survey.

Survey resulted in significant positive relationships between inventory, sales and service. On the basis of the study, it was proposed that theory was found between inventory and sales. The theory was found between inventory and sales. It was found that inventory was the function of square root of sales. As the sales increase the inventory will automatically increase. Greater product varieties of spares lead to higher inventory which in turn had a great impact on customer service. The results inspired retailers to retain data on sales, stock, merchandise variety and uncertainty in demand. The results proposed fine tuned inventories and improved performance of stores.

Kumar and Chandra (2001) developed a heuristic ordering policy for managing multi items of single vendor inventory system for random demand. The inventory points for every item was timely reviewed. The order was placed until projected stocks out cost of all items were beyond the desired certain multiple value of average ordering cost. The study offered rules for determining the items which needed be included in order and also determined up to level for every item. Two parameters were involved in rules that require estimation was done with simulation. These types of systems were related to real life situations. This system was valuable for independent convenience stores, grocery stores and small independent retailers. The ordering rules of this paper were backbone of proposed inventory system for small business operations.

Pérès and Grenouilleau (2003) studied the spare parts management in a space system. The study has been divided into three parts. The first one, dedicated to the characterization of the system structure which showcased the particularities related to the spare-elements procurement. The second part of the study dealt with modeling. After having exposed the bases of the problem to be solved, the authors proposed a macro-model. The study further elaborates each of the three elements of an orbital system, namely ground, flying and transport, with the help of Petri net. Operation specificities of every element have been listed and integrated into the model. A concrete application of this modeling has been given in the last part, which concerns the Columbus laboratory of the International Space Station. The authors have proposed the selection of a representative function and evaluation of several supply strategies. Through this study, the modeling of the supply logistic chain and the evaluation of the technico-economical relevance of its structure and control became possible. The authors concluded that the development of such a tool would allow the finding of a partial solution to the difficulty of implementation of this type of analysis

Braglia et al. (2004) implemented a multi attribute classification method for spare parts inventory management for a paper industry. A complex problem which was faced by spare part inventory management in industrial plants due to difficulty in data collection and large numbers of factors. The attributes taken into account were inventory, lost production cost, safety and environment, maintenance, logistic aspects of spare parts and spare parts classification. The authors proposed an Inventory policy matrix that link different classes of spare parts which were used to identify best control strategy of spare parts. The purpose of this study was to develop decision support tool for maintenance managers and adjust the basic approach to validate the inventory policy of each spare part in easy and quick way.

Levi (2004) considered the spare part inventory problem faced by electronic machine manufacturers with expensive parts that were located at various customer locations. According to the study these parts failed infrequently according to Poisson process. The study reported that as the failure occurred the customer was served at the central warehouse or at depots. The warehouse acted as the repair facility that replenishes the stock at field depots. The authors developed a continuous review policy, base stock policy for this two echelon multi item spare part system. The authors further formulated a model that minimized the system wide inventory cost with response time constraint at field depots. This study presented an efficient heuristic algorithm to study its computational effectiveness.

Ahn and Seo (2005) proposed an ordering model in the inventory system. The authors introduced the order range (s, S) in inventory system. 's' was considered as the ordering point of inventory and 'S' was considered as maximum level of inventory. The model used was multi item ordering model, ordering range was introduced instead of order points in the system. The model proposed in the study has dealt transportation lead time as transportation constraints. This model was tested with a numerical example and showed computational results that concluded the effectiveness of this model.

Ghodrati and Kumar (2005) studied that with continuous increase of technological development in twenty first century, the industry and industrial system have become more complex and make their availability more important. The product support and its issues related to spare parts played an important role. Lack of timely and incomplete support, such as the lacking of spare parts when required, generally caused unexpected downtimes that in turn led to losses.

As a result it has become important to forecast the correct support to keep system working. The paper implemented the proportional hazard model which examined the reliability of the system and operating environment, these were the two parameters to be considered. The results of this study indicated that operating environment of system had considerable amount of influence on system performance. The authors proposed than an optimal way to prevent unplanned stoppages was to forecast the required spare parts based on the technical characteristics and the system-operating environment.

You and Wu (2006) investigated the ordering and pricing problem over restricted time planning horizon for the inventory system with advance sales and spot sales. The study assumed was assumed that the planning horizon was divided in several cycles of sale. These cycles were divided into advance sales and spot sales. In advance sales customers were required to make advance reservations for replenishment of orders and in spot sales customer received the order during the time of purchase. But in actual, customer cancel their orders before receiving, this phenomenon was adopted by this paper and continuous time inventory model was proposed to deal with the system. Thus by determining advance sales and spot sales, order size, replenishment frequency this study maximized the total profit over finite period of planning prospect. Simple algorithms were developed to make optimal decisions and results were computed.

Cheung et al. (2006) suggested that effective service logistics lowered the cost and increase the service value by improving customer satisfaction and loyalty. The conventional way of the service logistics were information driven instead of knowledge-driven which were insufficient to meet the current needs. The purpose of this study was to present a knowledge-based service automation system (KBSAS) to enhance the competitiveness for manufacturing enterprises in service logistics. A prototype customer service portal was built based on the KBSAS and was implemented successfully in a semi-conductor equipment manufacturing company. It had been verified that the KBSAS provided high quality customer services with fast and efficient customer responses. The system also allowed the company to capture the valuable experience and tacit knowledge of the staff in performing customer and field services.

Ghodrati et al. (2007) studied that need of spare parts was dependent on the characteristics of product in question e.g. reliability and maintainability, and the characteristics of the environment in which the product was going to be used (e.g. temperature, humidity, and the operator's skills

and capabilities), which constitute the covariates. These covariates had a considerable effect on the system reliability characteristics and consequently on the required number of spare parts. The basic objective of this research study was to estimate the associated risks (i.e. risk of shortage of spare parts) in estimating the required number of spare parts due to not considering the characteristics of operating environment system. In this study, a modified form of event tree analysis (ETA) was introduced and implemented. In the new version the undesired states were formed as an alternative of barriers in combination with events and consequent changes as safety function in the event tree analysis. The ETA output reflected that there was a considerable operational risk due to the losses related with the non-consideration of working environment of event tree analysis the machine.

Razmi et al. (2009) studied the vendor management inventory (VMI) system and traditional system and its comparison on performance basis. The study applied a mathematical modeling was applied for measuring the performance of total cost of supply chain. The authors introduced the extent point between the total costs of both systems to minimum. Numerical examples and sensitivity analysis were related to illustrate the theory which helped in deriving the extent points and percentage difference of both VMI system and traditional system. The results indicated that VMI system worked better than traditional system and delivered lower cost in every condition also including the backorders. As the traditional system was farther from the extent point and VMI was closer to extent point and application of VMI was more justified. VMI system was more beneficial and delivered lower cost in all conditions.

Keshteli and Sajadifar (2010) derived the cost function of three echelon inventory system of two warehouse and 'N' retailers was considered in this paper. The study has been based on the cost function which was derived from three echelon system with one for one ordering policy. In this study independent Poisson demand was faced by the retailers under constant transportation times; the delivery time was equal to transportation time plus random delay of stock out at supplier in a two echelon inventory system. The three echelon inventory system considered here was different from two echelon inventory system. The warehouse was added as third echelon which leads to one more delay of shipment in new warehouse which increased the cost function of inventory system. The numerical examples helped in showing that the cost function tendency was convex and ensured to have minimum cost in inventory system.

Driessen (2010) presented a framework for planning and controlling the spare parts supply chain of the organization that maintain and use high value capital assets. This study developed a framework for controlling and planning spare parts and setting an agenda for future research. The study highlighted that decisions made in this framework were decomposed hierarchically and interfaces. The framework was used to increase the efficiency of decisions consistency and sustainability as how to plan and control the spare parts supply chain. Applicability of this framework was also investigated in different environments.

Rego and Mesquita (2011) reviewed that spare parts inventory was needed for repair and maintenance of the products, vehicles, industrial machines and equipments. Requiring high investment and significantly affecting customer satisfaction. Inventory management was complex problem due to large number of items and lumpy demands. The study represented a review on single location spare part inventory control, embracing demand forecasting techniques and inventory control decisions on different life cycle stages. It was identified that opportunities on inventory management decide whether to stock item or not, how much to order in first and last batch, demand forecasting and inventory control models integration and case studies on real applications.

Gebauer et al. (2011) aimed to offer recommendations in increasing spare parts logistics. The paper suggested that recommendations for, increasing spares logistics had been rare despite of the proven benefits of high performing spares logistics. According to the study spare part business was considered as profit pool of the capital goods industry having about 17 percent of industry's total revenue. The margins in spare parts revenue were 25 percent on an average as compared to 2-3 percent of the capital goods. Extensive benchmarking technique was conducted the paper attempted to provide a better understanding and changes for improving logistics performance in the Chinese market. The study analyzed that necessary changes achieved a cutting-edge logistics solution and showed how companies should implement the solution.

Ghodrati et al. (2012) studied the product support improvement of spare parts by considering the environment of operating system. The purpose of this study was to analyze influence of time dependent factors of industrial system on product support when spare parts were needed. According to the study the product support was affected by number of factors like operating environment system, reliability and maintainability. From the study the authors reported that lack of good support and critical spares led to unplanned stoppages. The authors suggested also said

that forecasting of spare parts on the basis of reliability and maintainability along with environmental conditions could be most effective strategy for untimely stoppages. It was generalized from the research that system operating environment should be considered while spare parts estimation was done. After studying the various factors which influenced product support the spare management software was used to check the results.

2.3 Summary of Literature Review

After studying the literature, it can be concluded that lot of work has been done in the field of spare parts inventory management in one way or another work in the area of spare part inventory management system has focused on the inventory of insurance type spares, spare part optimization models for both series and parallel structures. Other studies have suggested that service part inventories have not been managed by standard inventory methods and inventory models were not sound. Studies also relate to the sales and service relationship of the retail chain store operation. Research has also been done in the area of ordering policy of managing multi items of single vendor inventory system for random demands. Some researchers implemented the multi attribute classification method for spare parts inventory management in a paper industry. Authors have investigated the ordering and pricing problem over a finite time horizon of the inventory system. Also significant research has been done in the product support improvement of spare parts by considering system operating environment. Some authors have proposed a risk-based approach for the spare parts demand forecasting and spare parts inventory management for the effective allocation of limited resources. The investigators have also presented a framework for planning and controlling the spare parts supply chain for the organization that maintained and used high value capital assets and also implemented the proportional hazard model to the inventory system which examined the reliability of the system and operating environment these were the two parameters to be considered and also the lack of timely and incomplete support can cause unexpected downtimes. Research has also been done to assess various factors that influenced product support implemented the spares management software this was used to check the results of various factors. The vendor management inventory system and traditional inventory system have been compared on the performance basis

2.4 Gaps in Literature

- From the review of literature it is evident that the model proposed for spare part inventory management system has found limited reference and application in the manufacturing industry. The quantum of benefit arising from the embedding of this model in manufacturing or service industry has not been validated.
- The main focus related spare part inventory management system has been on the effect of demand forecasting, insurance of inventory, service part inventory, ordering policy, planning and controlling of supply chain, impact of time and unexpected downtimes spare parts inventory.
- Limited research has been carried out in the spare part inventory management system in computer industry. The focus on order points as criteria for managing spare parts inventory has been found limited mention in the literature review. The importance of order point in spare parts inventory management has been under played in most of the studies, except that of Nagarur et al., (1994). Also, the model proposed for spare parts inventory has not been validated in the literature, this serves as a reasonable argument to investigate the validity of the model in different settings.

2.5 Objective of the Study

The objective of the study was to validate the model of spare part inventory management system proposed by Nagarur et al. (1994) by applying it in the dealer network of an automotive organization, by carefully matching the parameters of the model with the SPIMS of the dealer network, data collected was gleaned for validation of the model. Comparisons of the results were also drawn with theoretical model related to SPIMS.

CHAPTER 3

Methodology

Nagarur et al. (1994) worked for developing a system for spare parts inventory. Extending their work, a case study has been carried out to validate the model. Also, an effort has been made to compare the results with actual data from the enterprise under study and also with the theoretical models available in the literature.

The model proposed by authors was basically for designing the structure of spare part inventory for a computer manufacturing organization that sells mainframe of computers, personal computers, computer accessories and accepts repairs for replacement and repairs of the components.

The model proposed by authors depicted the architectural configuration of information system and has also dealt with the determination of the order point considering a number of parameters.

Building on the research carried out by the authors, model was adopted for chain of spare parts dealers in the automotive industry in Punjab to validate the model.

The model proposed by authors has been built on the fundamentals that, if parts are under stocked the defective computers cannot be serviced will not be serviced due to shortages. If parts were under stocked, then defective computers could not be serviced due to shortages, resulting in dissatisfaction of the customer. On the other hand, if parts were overstocked, the holding costs will be high due to surpluses. Also, tracking individual part will be a major task as the number of spare parts runs in several thousands. Without a balanced system of managing inventory some parts have very high inventory and some situations shortages could be quite common. In this type of a service system, an efficient inventory management system is essential. The premise for the proposed model as suggested by authors was to design a computer based information system for inventory management for the spare parts in the service department.

- To relate stock quantities to demand, avoiding both over stocking and under stocking.
- To avoid losses due to spoilage, pilferage and obsolescence.
- To develop a model that will minimize total inventory cost while increasing efficiency of the order.

The model proposed by authors has proposed some theoretical design considerations on ordering policies.

Considering a computer industry the spare parts were classified into ABCD classification:

There were approximately 20,000 types of spare parts in the inventory system. Therefore it was necessary to classify these parts into groups and to establish appropriate levels of control over each category. These parts were based on the sources of supply and cost. The spare parts were classified into four groups, described below:

A: The parts could be procured overseas only and the unit cost was very high.

B: The parts could be procured overseas only and the unit cost was not high.

C: The parts were available locally and the unit cost was very high.

D: The parts were available locally and the unit cost was not high.

The advantage of this classification lies in relaxation of inventory control rather in tightening inventory control.

Less emphasis were on B and D class of items as they represented a bulk of inventory. This classification resulted in simplicity and ease of operation.

The demand forecasting models used by this proposed system were:

- Product reliability model.
- Regression models.
- Time series forecasting model.

The regression models and time series forecasting model were easy to use, and they needed less data, compared to reliability model. The choice of an appropriate model depends on the item class and the agreement between forecast data and empirical data. Models with high accuracy were needed; items belonging to class B and D do not needed any complicated and sensitive models. Items of class A and C need high accuracy models, the model which gave the least deviation of values from actual data were considered.

After determining the demand, the order points and safety stocks could be computed. After studying various models, business factor index (BFI) order point model was adopted for this proposed system by authors. The BFI order point technique was described as one that allows management the opportunity to identify and emphasize the success factors. The resultant effect

of this technique was to maximize the advantages of company. The BFI order point calculations were given by model proposed:

$$\text{Order Point} = (\text{Dem} \times \text{LT}) + (\text{Dem} \times \text{LT}) (\text{D}\% + \text{V}\% + \text{E}\% + \text{L} \%)$$

Where,

Dem= Average historical demand over a reasonable period of time or the forecast demand

LT = Normal current replenishment time

D = the effect the shortage of items will have on profit or production

V = the dollar value of the item

E = the deviation of demand from average usage

L = the lead time and lead time variation in replenishing the stock.

Researchers practiced BFI order point method, as the results indicated that this model best fit the individual needs of spare parts business in the way that usual conventional ordering points model were not able to do. The values of D, V, E and L are subjective and show the relative effects of various factors considered in ordering an item. These values were provided by the managers, who were involved in decision making process. The BFI approach not only facilitates management involvement in decision making rules, but also makes aware about the system, to improve it further.

The values of D, V, E and L were specified after discussing and consulting with the managers, and according to the ABCD classification. The input values were:

D = 18% (the variation in demand was not more than 100%)

V = 5% (the value of each order was more than 80,000 Baht)

E = 5% (this was a common stock), and

L = 25% (for A and B items) = 5% (for C and D items)

(The lead time for overseas procurement was 3 months and for local procurement it was 1 week).

These above values of different parameters resulted in the following formulas:

For A and B class items:

$$\begin{aligned} \text{Order Point} &= (\text{Dem} \times \text{LT}) + (\text{Dem} \times \text{LT}) (\text{D}\% + \text{V}\% + \text{E}\% + \text{L} \%) \\ &= (\text{Dem} \times \text{LT}) + (\text{Dem} \times \text{LT}) (18\% + 5\% + 5\% + 25\%) \\ &= (\text{Dem} \times \text{LT}) + (\text{Dem} \times \text{LT}) (53\%) \\ &= 1.53 (\text{Dem} \times \text{LT}). \end{aligned}$$

For C and D class items:

$$\begin{aligned}\text{Order Point} &= (\text{Dem} \times \text{LT}) + (\text{Dem} \times \text{LT}) (\text{D}\% + \text{V}\% + \text{E}\% + \text{L} \%) \\ &= (\text{Dem} \times \text{LT}) + (\text{Dem} \times \text{LT}) (18\% + 5\% + 5\% + 5\%) \\ &= (\text{Dem} \times \text{LT}) + (\text{Dem} \times \text{LT}) (33\%) \\ &= 1.33 (\text{Dem} \times \text{LT}).\end{aligned}$$

The value of variable Dem, the demand of the spare parts of previous month, was used to calculate the adjusted demand during lead time.

The ordering policy was also given by the authors; the basic idea (S, c, s) of model was adopted for the ordering policy of proposed system. Whenever the available inventory level of items hits 's', it triggers the replenishment of stock to 'S'. Also, at the same time, other spare parts within the same family, with available inventory at or below it can order point 'c', which was included in the replenishment of stock.

Adopting the model for the enterprise under study, the order point calculation has been refined as below:

$$\text{Order Point} = (\text{Dem} \times \text{LT}) + (\text{Dem} \times \text{LT}) (\text{D}\% + \text{E}\% + \text{L} \%)$$

Where,

Dem= Average historical demand over a reasonable period of time or the forecast demand

LT = Normal current replenishment time

D = the effect the shortage of items will have on profit or production

E = the deviation of demand from average usage

L = the lead time and lead time variation in replenishing the stock.

The parameter 'V' in determining the order point as proposed in the model was assumed to be zero, because there was no extra cost in the procurement of spare parts.

For the existing study lead time was assumed to be the average lead time, because the time taken for every delivery to replenish the stock was approximately same. The spare parts were procured only from a single warehouse.

Also, after validating the model proposed by authors with a case study, the existing model was compared with the theoretical model [2] of ordering points

The theoretical model [2] used to calculate the order point was:

Order point = (LT + SS + BS) × Unit sales per day

Where,

LT = lead time in days

SS = safety stock

BS = base stock

Also, on applying theoretical model the results were compared with existing model proposed by authors and model followed by the company.

CHAPTER 4

Case Study

4.1 Spare Parts Inventory Management system - a Case Study

The spare part inventory management system (SPIMS) of dealers was studied of XYZ Company. This research was limited to focus on the spare part dealers to the area of Punjab. To carry out the study, an elaborate schedule of visits to the dealers was chalked out. The objective of such visits was to get not only the snapshot of the SPIMS but also to capture the operational aspects of the SPIMS. The list dealers of tractor of XYZ Company visited has been tabulated in table.

Table 4.1: List of Dealers Visited

Sr .No.	Dealer Code	Palace
1	GRH110039	Guruharsahai
2	FRZ11206	Ferozepur
3	RMP11933	Rampura
4	MKT110712	Muktsar
5	GRD110045	Gurdaspur
6	FDK110027	Faridkot
7	BTI11407	Bathinda
8	BAR110019	Barnala
9	MGA110056	Moga
10	ABH11086	Abohar

A critical analysis of SPIMS was carried out to ascertain the parity in the operational aspects of the system. It was observed that across the dealers the SPIMS was same and no modifications or customizations had been carried out, during analysis it was also observed to manage the SPIMS had been sponsored by the parent company.

The analysis further revealed that SPIMS used by dealers involved both the aspects of push and pull system. As far as push system is concerned it was observed that dealers across Punjab had little option in adjusting for inventory as the consignments received from the parent company

had to be accepted. Analysis further revealed that there was flexibility in managing SPIMS with regard to tractors in the pull system. This led to narrowing down the population to be considered for research.

Out of a total of 2200 components, 800 components in pull category were considered for further research and analysis. The spare parts under pull category were segregated accordingly to ABC analysis. Items with high cost were categorized under ‘A’ class items, items with medium cost were categorized under ‘B’ class items and items with low cost were categorized under ‘C’ class items. A sample of 45 spare parts (15 critical items under each category of A, B and C) items in the inventory management system were taken after careful deliberations and discussions with the dealers on issues related to:

- Cost
- Demand
- Inventory turnover
- Critical spare parts as specified by dealers

The Company had its own spare part software. Ordering of spare parts was done online by the computers, and the orders were placed only through company software.

4.2 Ordering of Spare Parts

There was no proper forecasting system followed by the dealers, ordering of spare parts was totally intuition based or knowledge based. No proper forecasting was done as the demand was raised the spare parts were ordered depending upon the needs.

Table 4.2 Types of Orders Placed

Sr. No.	Type of Order	Duration in Days
1	BDT Order	7-8
2	Commercial Order	15-20
3	Emergency Order	10-12

Mostly the commercial order was placed by the dealers, in case of any emergency or any other reason the BDT or emergency orders were placed. The data for validating the work was considered as the commercial order data.

Table 4.3: Discount Terms on Type of Order Placed

FES Parts	Discount Terms	Freight Terms
BDT Order	MRP-25%	Freight Paid
All Commercial Orders	MRP-32%	Freight Paid
Emergency Order	MRP-25%	Freight Paid

Table 4.4: Order Validity

FES Parts	Terms
Regular Commercial Order	30 Days from the date Registration of Order
BDT / Emergency Parts Order	Until Complete Execution

4.3 Data Redundancy

Data redundancy in SPIMS is the field that was repeated in two or more tables. There was large problem of data redundancy in SPIMS.

Table 4.5: Data Redundancy

Sr. No.	Part No	Part Name
1	006502654C1	ADAPTOR SPLIN 4TH SPD DRVN GEAR
2	000031119B12	ADAPTOR SPLIN 4TH SPD DRVN GEAR
3	M06502654C1	ADAPTOR SPLIN 4TH SPD DRVN GEAR
4	006502306C3	AIR BREATHER
5	006507334B1	AIR BREATHER
6	006502306C2	AIR BREATHER
7	006502306C1	AIR BREATHER
8	005556008R91	AIR CLEANER CPTE
9	001231598R91	AIR CLEANER CPTE
10	0000111105P02	AIR CLEANER CPTE

These were some parts taken from the FES price list provided by the company, which have same material description but different part numbers

4.4 Transportation

Transportation of spare parts was only through courier. No return policy was followed by the company, orders were returned only in the case of wrong deliveries. Spare parts can be order on daily basis or when required.

4.5 Identification of Problem:

- Lead time was more, as parts were procured from the single central warehouse and there was no local warehouse.
- Stock out cost leading to customer dissatisfaction and losing the reputation of the company.
- Minimum and maximum levels of inventory were not controlled, as some parts were stocked in excess and some parts were falling below the desired level of inventory.
- Problem of obsolete spares and non moving items, as some parts gets deteriorated on the shelf and non moving parts were holding the inventory cost.
- Spurious spare parts were affecting the genuine spare parts, as in some cases the customer purchases the spare parts from local vendors.
- Requirements were uncertain, as the requirements changed seasons to season resulting from the usage of the product in different conditions.
- There was redundancy in products manufactured by the company, resulting to many problems for maintaining accurate data.
- Documentation of inventory was not properly maintained.

4.6 Data Collection

The following data was collected from the dealers to carry out the study:

- Demand data of commercial years 2011-2012, 2012-2013, 2013-2014 was collected in half yearly terms.
- Lead time data for spare parts was collected; lead time was the normal current replenishment time.

- Selling price and cost price data, selling price was the cost at which customer purchases the spare part and cost price was the price on which dealer procures the spare parts.
- Lost sale data, it was the data in which the shortages were faced by the dealers on the particular item.
- Base stock and safety stock data, base stock data was the minimum stock that dealer was maintaining and safety stock data was the maximum stock that dealer was maintaining.
- Carrying cost data, it refers to the total cost for holding inventory. (Appendix 1)

4.7 Data Analysis

The following data was analyzed from the collected data:

- Average demand data analyzed from the demand data of last three years.
- Deviation from the average demand calculated from last three years demand data.
- Average lead time data and the percentage of average lead time data.
- Total sales data of the spare parts.
- Total lost sales data and percentage lost sales data, which signifies the shortages of the spare parts.
- Carrying cost percentage data, the cost held in carrying an item in inventory.
- Calculation of ordering points using proposed model and theoretical model.
- Inventory cost and carrying cost on spare parts.

After analyzing the data to percentage values for each parameter, the data was substituted in the ordering model proposed by the authors. The sample list of spare parts has been given in Appendix 2.

CHAPTER 5

Results and Discussions

The calculations of order points using proposed model and theoretical model are provided in Appendix 3 and Appendix 4 respectively.

From the study that was conducted on this company, the analysis of data yielded the following results:

1. Comparison of order points of proposed model with the actual base stock of dealers. (Appendix 5)
2. Comparison of order points of conventional model with the actual base stock of dealers. (Appendix 6)
3. Comparison of order points of proposed model and orders point of conventional model. (Appendix 7)
4. Comparison of inventory cost and carrying cost of dealers with proposed model and conventional model. (Appendix 8 & 9)

5.1 Comparison of Order Points of Proposed Model With the Actual Base Stock of Dealers :

After categorizing the spare parts and calculating the order points using proposed model, it was concluded that results were significant from the actual method that dealers were practicing. The results found that in 'A' class items 73% of ordering points were significant from actual base stock of dealers using proposed model and remaining 27% results calculated by proposed model were equal to actual base stock that dealers were maintaining. In class 'B' items using proposed model 80% ordering points were significant from actual base stock of dealers and 20% of ordering points were equal to the actual base stock of dealers. In class 'C' items 93% results calculated using the proposed model were significant from the actual base stock of the dealers and 7% results were same as that of dealers were practicing.

5.2 Comparison of Order Points of Conventional Model With the Actual Base Stock of Dealers :

Results showed that in 'A' class items using theoretical model 66% results were significant from the actual base stock provided by the dealers. 27% results showed that ordering points calculated by theoretical model were same as provided by the dealers and 7% results indicated that order point calculated by theoretical model should be raised from actual base stock of dealers. In 'B' class items 67% results were significant from actual base stock of dealers and 20% results showed that ordering points calculated by theoretical model should be more than actual stock kept by the dealers and 13% results indicated the same results of theoretical model and actual stock maintained by the dealers. In 'C' class items 33% results indicated ordering points were significant from the actual base stock provided by the dealers calculated by theoretical model are less than the stock maintained by the dealers, 27% ordering point results calculated by theoretical model were same as provided by dealers, and 40% results showed ordering point calculated using theoretical model should be placed higher from the actual stock of dealers were maintaining.

5.3 Comparison of Order Points of Proposed Model and Order Points of Conventional Model :

In class 'A' items 60% of results were found to have same ordering points using proposed model and theoretical model and 40% results were differentiating both the models. In class 'B' items the results were same as that in case of 'A' class items. In class 'C' items 20% of results were found be same using the proposed model and theoretical model and remaining 80% results were found different on comparing the two models.

5.4 Comparison of Inventory Cost and Inventory Carrying Cost of Dealers With Proposed Model and Conventional Model :

On comparing total inventory cost and carrying cost with the inventory cost and carrying cost of proposed model and theoretical model for 'A' class items, results were found that proposed model costs 60% of the total cost of inventory and carrying cost of the actual base stock provided by dealers and the theoretical model costs 82% cost of dealers total inventory cost and carrying

cost. For 'B' class items results of total inventory cost and carrying cost for proposed model and theoretical model were 50% and 94% respectively from the actual inventory cost and carrying cost of dealers. For 'C' class items the total inventory cost and carrying cost for proposed model and theoretical model are 41% and 93% respectively from the actual inventory cost and carrying cost of dealers.

CHAPTER 6

Conclusions and Future Scope

6.1 Conclusions:

The objective of the present study was to validate the model proposed, through a case study of SPIMS of automobile dealers. Further, calculating the order points from the proposed model and comparing with the order points of theoretical model. The following conclusions have been drawn from the study:

- On comparing the results generated by the proposed model by Nagarur et al. (1994) and the model used by the dealers, a significant difference in spare parts inventory was observed. Drawing head to head comparison of items in the 'A' class category it was observed that the inventory levels suggested by the model proposed by Nagarur et al. (1994) were significantly lower in comparison to the model used by the dealers and some results were showing the level of spare parts inventory should be same as the dealers were maintaining, as discussed in the results.
- On comparing the results generated by the proposed model by Nagarur et al. (1994) and the model used by the dealers, a significant difference in spare parts inventory was observed. Drawing head to head comparison of items in the 'B' class category it was observed that the inventory levels suggested by the model proposed by Nagarur et al. (1994) were significantly lower in comparison to the model used by the dealers, and some results were showing the level of spare parts inventory should be same as the dealers and in some cases the results showed that inventory level of spare parts should be raised to a certain level, as discussed in the results.
- On comparing the results generated by the proposed model by Nagarur et al. (1994) and the model used by the dealers, a significant difference in spare parts inventory was observed. Drawing head to head comparison of items in the 'C' class category it was observed that the inventory levels suggested by the model proposed by Nagarur et al. (1994) were not as significant as compared to 'A' class and 'B' class items, and some results were showing the level of spare parts inventory should be same as the dealers and

in some cases the results showed that inventory level of spare parts should be raised to a certain level, as discussed in the results.

- From the results it has been concluded that proposed model gave more significant results of order points as compared to the spare part inventory model of dealers. Also, resulting in decreasing the inventory cost and inventory carrying cost.

6.2 Future Scope

As assumed by Nagarur et al. (1994) the demand remains relatively stable i.e. there are no sudden jumps in the demand as a result the determination of maximum stock has been calculated by summing up the economic order quantity and the maximum stock. The demand for spare parts can be abrupt, which would require addressing the contingency demand of spare parts in such a scenario the maximum stock and minimum stock values may vary incorporating these variations can be a part of future.

The order points were used to validate the model, and results were improved as compared to the actual system followed by dealers in the pull system type of spare parts for controlling a portion of inventory, a model should be proposed that may control the entire inventory system of spare parts related to push system and pull system of spare parts.

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APPENDIX 1

Inventory carrying cost of dealers.

SR.NO	INVENTORY CARRYING COST	PERCENTAGE
1	Building cost	5
2	Material handling cost	3
3	Labor handling cost	2
4	Inventory investment cost	9
5	Scrap and obselece cost	2

Total inventory carrying cost was accounted to be 21%.

APENDIX 2

Sample list of demand in spare parts

PART NAME	2013-2014(i)
ACRYLIC POWEROL SILVER	1.00
ACRYLIC POWEROL SILVER	1.00
ADAPTOR SPLIN 1ST/2ND SPD GEAR	2.00
ADAPTOR SPLIN 1ST/2ND SPD GEAR	2.00
ADAPTOR SPLIN 1ST/2ND SPD GEAR	4.00
ADAPTOR SPLIN 1ST/2ND SPD GEAR	4.00
ADAPTOR SPLIN 4TH SPD DRVN GER	1.00
ADAPTOR SPLIN 4TH SPD DRVN GER	2.00
ADAPTOR SPLIN 4TH SPD DRVN GER	2.00
AEROSOL PAINT - ACRYLIC GREY(SPARES)	1.00
AEROSOL PAINT - ACRYLIC GREY(SPARES)	10.00
AEROSOL PAINT - ACRYLIC GREY(SPARES)	5.00
AEROSOL PAINT - ACRYLIC GREY(SPARES)	1.00
AEROSOL PAINT - ACRYLIC GREY(SPARES)	1.00
AEROSOL PAINT - ACRYLIC GREY(SPARES)	20.00
AEROSOL PAINT - ACRYLIC GREY(SPARES)	20.00
AEROSOL PAINT - ACRYLIC GREY(SPARES)	2.00
AEROSOL PAINT - ACRYLIC RED(SPARES)	10.00
AEROSOL PAINT - ACRYLIC RED(SPARES)	10.00
AEROSOL PAINT - ACRYLIC RED(SPARES)	10.00
AEROSOL PAINT - ACRYLIC RED(SPARES)	20.00
AEROSOL PAINT - ACRYLIC RED(SPARES)	20.00
AIR CLEANER 3 STAGE- 235 DI	1.00
AIRCLEANER FILTER PRIMARY 7" INCH 605	5.00
AIRCLEANER FILTER PRIMARY 7" INCH 605	20.00
AIRCLEANER FILTER SAFETY 7" INCH 605	5.00
AIRCLEANER FILTER SAFETY 7" INCH 605	20.00
AL RADIATOR ASSEMBLY 605 - TTR	1.00
ARJUN LCD INSTRUMENT CLUSTER	1.00
ARJUN MAIN WIRING HARNESS	2.00
ARJUN MAIN WIRING HARNESS	1.00
ARJUN MAIN WIRING HARNESS	3.00
ARJUN PULL TO STOP CABLE D	12.00
ARJUN PULL TO STOP CABLE D	10.00

PART NAME	2013-2014(ii)
200LE PULL STOP (245)	1.00
235 DI AIRFLOW LH	1.00
235 DI AIRFLOW RH	1.00
ACRYLIC POWEROL SILVER	1.00
ACRYLIC POWEROL SILVER	40.00
ACRYLIC POWEROL SILVER	10.00
ADAPTOR OIL LEVEL GAUGE-COMPACT	20.00
ADAPTOR OIL LEVEL GAUGE-COMPACT	5.00
ADAPTOR SPLIN 1ST/2ND SPD GEAR	2.00
ADAPTOR SPLIN 1ST/2ND SPD GEAR	2.00
AEROSOL PAINT - ACRYLIC GREY(SPARES)	1.00
AEROSOL PAINT - ACRYLIC GREY(SPARES)	20.00
AEROSOL PAINT - ACRYLIC GREY(SPARES)	1.00
AEROSOL PAINT - ACRYLIC GREY(SPARES)	10.00
AEROSOL PAINT - ACRYLIC GREY(SPARES)	1.00
AEROSOL PAINT - ACRYLIC GREY(SPARES)	20.00
AEROSOL PAINT - ACRYLIC GREY(SPARES)	25.00
AEROSOL PAINT - ACRYLIC GREY(SPARES)	10.00
AEROSOL PAINT - ACRYLIC GREY(SPARES)	10.00
AEROSOL PAINT - ACRYLIC GREY(SPARES)	5.00
AEROSOL PAINT - ACRYLIC RED(SPARES)	20.00
AEROSOL PAINT - ACRYLIC RED(SPARES)	10.00
AEROSOL PAINT - ACRYLIC RED(SPARES)	10.00
AIR INTAKE DUCT 605 BSIIIA	10.00
AIRCLEANER FILTER PRIMARY 7" INCH 605	40.00
AIRCLEANER FILTER SAFETY 7" INCH 605	10.00
ARJUN MAIN WIRING HARNESS	2.00
ARJUN MAIN WIRING HARNESS	2.00
ARJUN MAIN WIRING HARNESS	2.00
ARJUN MAIN WIRING HARNESS	2.00
ARJUN PULL TO STOP CABLE D	10.00
ARJUN PULL TO STOP CABLE D	10.00
ARJUN PULL TO STOP CABLE D	10.00
ARJUN UPG. - FENDER ASSEMBLY LH-T	1.00

ARJUN UPGRADATION MAIN WIRE HARNESS	1.00
ARJUN UPGRADATION MAIN WIRE HARNESS	3.00
ARM KNUCKLE STEERING LH	2.00
ARM KNUCKLE STEERING RH	2.00
ASSEMBLY AIR FILTER (DONALDSON)	1.00
ASSEMBLY AIR FILTER (DONALDSON)	1.00
ASSEMBLY AIR FILTER (DONALDSON)	2.00
ASSEMBLY AIR FILTER (DONALDSON)	1.00
ASSEMBLY BALL JOINT (IMPORTED)	1.00
ASSEMBLY QUADRANT MTG BRACKET	3.00
ASSY CONNECTING TIE ROD REGULAR	1.00
ASSY GEAR SHIFTER LEVER	2.00
ASSY GEAR SHIFTER LEVER	1.00
ASSY GEAR SHIFTER LEVER	2.00
ASSY HOSE AIR CLEANER CI INT 4CYL L	1.00
ASSY.PUMP CPT LUB OIL	1.00
ASSY.PUMP CPT LUB OIL	2.00
AXIAL BALL JOINT DANA H3	1.00
BALL JOINT ASSY.- KNUCKLE ARM END	5.00
BAZEL	1.00
BEARING CLUTCH RELEASE CRPTO-TEX	2.00
BEARING LM48548/10 DANA H3	2.00
BEARING LM501349/10 DANA H3	2.00
BELT FAN	10.00
BOLT CYLINDER HEAD MOUNTING-12.9	10.00
BOLT HEX G15.875X2.31X209.55X12.9	10.00
BOLT HEX G15.875X2.31X69.85X8.8	20.00
BOLT HEX G19.05X1.59X41.28X8.8	2.00
BOLT HEXFL M6X1.00X20.5X8.8	10.00
BOLT HEXFL M6X1.00X20.5X8.8	10.00
BONNET LATCH ASSEMBLY	10.00
BONNET LATCH ASSEMBLY	2.00
BRACKET AIR CLEANER-ARJUN	2.00
BRACKET AIR CLEANER-ARJUN	3.00
BRACKET AIR CLEANER-ARJUN	2.00
BRACKET CPTE. REAR TOW-HOOK	1.00
BRACKET CPTE. REAR TOW-HOOK	1.00
BRACKET P.T.O. SHIFTER	2.00
BRACKET P.T.O. SHIFTER	5.00
BRACKET STABILIZER MTG LH (2WD)	1.00

ARJUN UPGRADATION MAIN WIRE HARNESS	1.00
ARJUN UPGRADATION MAIN WIRE HARNESS	2.00
ARJUN UPGRADATION MAIN WIRE HARNESS	1.00
ARJUN UPGRADATION MAIN WIRE HARNESS	2.00
ARM CPTE ROCKER	8.00
ARM CPTE ROCKER	5.00
ASSEMBLY DIPSTICK 2WD	5.00
ASSEMBLY OIL PUMP (NEW65-CRE)	1.00
ASSEMBLY OIL PUMP (NEW65-CRE)	1.00
ASSY CHECK CHAIN CPTE – CRE	2.00
ASSY CHECK CHAIN CPTE – CRE	1.00
ASSY CONNECTING TIE ROD REGULAR	2.00
ASSY FRONT GRILL COMPLETE	1.00
ASSY GEAR SHIFTER LEVER	1.00
ASSY GEAR SHIFTER LEVER	2.00
ASSY HEAD AND SIDE LAMP MTG BKT-LH	1.00
ASSY HEAD AND SIDE LAMP MTG BKT-LH	1.00
ASSY RADIATOR 605BS3A INLINE	1.00
ASSY RADIATOR 605BS3A INLINE	1.00
ASSY RADIATOR 605BS3A INLINE	1.00
ASSY RECOVERY BOTTLE 605 BS3A INLINE	1.00
ASSY. PISTON COOLING Alt # 000020778E05	3.00
AUX VALVE LEVER ASSY. CPTE. MPT	1.00
AUX VALVE LEVER ASSY. CPTE. MPT	1.00
AUX VALVE LEVER ASSY. CPTE. MPT	5.00
AUX VALVE LEVER ASSY. CPTE. MPT	1.00
AUX VALVE LEVER ASSY. CPTE. MPT	1.00
AUX VALVE LEVER ASSY. CPTE. MPT	1.00
BALL BEARING CONTROL VALVE	100.00
BALL G 22.2MM 641 50 456	20.00
BALL JOINT ASSY.- CYLINDER END	4.00
BALL JOINT ASSY.- CYLINDER END	4.00
BALL JOINT ASSY.- KNUCKLE ARM END	4.00
BAZEL	1.00
BEADING RUBBER FOR HOOD	5.00
BEARING CLUTCH RELEASE CRPTO-TEX	1.00
BEARING CLUTCH RELEASE CRPTO-TEX	1.00
BEARING CLUTCH RELEASE CRPTO-TEX	4.00
BEARING NEEDLE ROLLER 40 X 45 X 17	4.00
BEARING TRNS CONTR SFT RER-FAG	3.00

BRACKET STABILIZER MTG RH (2WD)	1.00
BRACKET STUB PIPE SUPPORT	5.00
BRACKET STUB PIPE SUPPORT	10.00
BRACKET VALVE LEVER	1.00
BRACKET VALVE LVR SFT FRT/REAR	2.00
BRACKET_605	2.00
BRACKET_605	5.00
BRACKET_FUEL_FILTER_605BS3A	5.00
BRACKET_FUEL_FILTER_605BS3A	3.00
BRAKE PEDAL RETURN SPRING	10.00
BREATHER	2.00
BRG BALL 20X47X14	10.00
BRG BALL 20X47X14	5.00
BRG BALL 35X62X14	10.00
BRG BALL 35X62X14	5.00
BRG BALL 35X62X14	5.00
BRG BALL 35X72X17	6.00
BRG BALL 35X72X17	10.00
BRG BALL 35X72X17	5.00
BRG BALL 35X72X17	10.00
BRG NDL RLR 1R 45X52X20	6.00
BRG NDL RLR 1R 45X52X20	4.00
BRG THRUST K 66.8X35.525X19.446	20.00
BRG TPR RLR 62.00X30.00X21.25	10.00
BRG TPR RLR 62.00X30.00X21.25	10.00
BRG TPR RLR 73.43X41.29X.21.43	10.00
BRG TPR RLR 73.43X41.29X.21.43	10.00
BUMPER-BONNET-H3	2.00
BUNDI TUBE 6530	1.00
BUSH BI-MET 28.033X30.975X25.00	12.00
BUSH BI-MET 29.000X32.025X24.50	12.00
BUSH BI-MET 29.000X32.025X24.50	16.00
BUSH NYLON 332 20 1190	10.00
BUSH P T O SHAFT REAR	10.00
BUSH STG KNCKL PVT PIN	8.00
CABLE DECOMP (235) (U/D)	1.00
CAP TANK RECOVERY	10.00
CAP-FUEL TANK	10.00
CASSET SEAL DANA H3	2.00
CENTRALISED FORK F/R	1.00

BELT FAN	10.00
BELT V CRANK SHAFT PULLEY TO PUMP P	1.00
BELT V CRANK SHAFT PULLEY TO PUMP P	1.00
BOLT CYLINDER HEAD MOUNTING-12.9	10.00
BOLT CYLINDER HEAD MOUNTING-12.9	10.00
BOLT HEX G12.7X1.27X42.164X8.8	50.00
BOLT HEX G12.7X1.27X42.164X8.8	50.00
BOLT HEX G15.875X2.31X38.10X8.8	50.00
BOLT HEX M20X2.5X154X10.9	4.00
BOLT HEXFL M6X1.00X20.5X8.8	10.00
BOLT HEXFL M6X1.00X20.5X8.8	10.00
BOLT HEXFL M6X1.0X30.5X8.8	4.00
BOLT HEXFL M8X1.25X130.9X8.8	12.00
BONNET LATCH ASSEMBLY	1.00
BONNET LATCH ASSEMBLY	5.00
BONNET LATCH ASSEMBLY	5.00
BONNET LATCH ASSEMBLY	1.00
BONNET LATCH ASSEMBLY	1.00
BONNET LATCH ASSEMBLY	3.00
BONNET LATCH ASSEMBLY	5.00
BONNET LATCH ASSEMBLY	5.00
BRACKET P.T.O. SHIFTER	2.00
BRACKET P.T.O. SHIFTER	3.00
BRACKET PULL TO STOP CABLE and TPS MOUNTIN	1.00
BRACKET RAIL STOPPER	5.00
BRACKET STUB PIPE SUPPORT	5.00
BRACKET STUB PIPE SUPPORT	3.00
BRACKET STUB PIPE SUPPORT	5.00
BRACKET STUB PIPE SUPPORT	3.00
BRACKET_FUEL_FILTER_605BS3A	4.00
BREATHER	30.00
BREATHER	20.00
BRG BALL 20X47X14	10.00
BRG BALL 20X47X14	10.00
BRG BALL 20X47X14	1.00
BRG BALL 20X47X14	1.00
BRG BALL 35X62X14	5.00
BRG BALL 35X72X17	5.00
BRG BALL 50X80X10	4.00
BRG BALL 50X90X20	1.00

CIRCLIP : PISTON PIN – NEF	50.00
CIRCLIP EXT - LUG 25 X 2	2.00
CIRCLIP EXT - LUG 40 X 1.75	2.00
CIRCLIP INT - LUG 26 X 1.5	25.00
CIRCLIP INT - LUG 38 X 1.5	25.00
CIRCLIP INT - LUG 38 X 1.5	25.00
CIRCLIP INT - LUG 45 X 2	1.00
CLAMP AIR CLEANER	5.00
CLIP SPRING-H3 --RING (4WD)	50.00
CLOG INDICATOR	5.00
COMPOUND ROLL PIN - DOUBLE PIN ASSEMBLY	20.00
COMPOUND ROLL PIN - DOUBLE PIN ASSEMBLY	20.00
COPPER WASHER	50.00
COUPLING 2ND SPEED P T O GEAR	1.00
COUPLING GEAR 4TH and DIRECT SPD	1.00
COUPLING HIGH SPEED 20MnCr5	2.00
COUPLING IDLER GEAR	1.00
COUPLING IDLER GEAR	3.00
COUPLING IDLER GEAR	1.00
COUPLING MALE PRESSURE PIPE	5.00
COUPLING MALE PRESSURE PIPE	5.00
COUPLING MALE PRESSURE PIPE	10.00
COUPLING P T O SHAFT	2.00
COUPLING P T O SHAFT	1.00
COUPLING P T O SHAFT	2.00
COUPLING P T O SHAFT	2.00
CRANKSHAFT CPTE W/DOWEL PINS- 575DI	1.00
CRANKSHAFT CPTE.W/DOWEL PIN -265DI	1.00
CYLINDER LINER WITH GRADING	16.00
CYLINDER SLEEVE FOR 88.9*110 STROKE ENGI	2.00
CYLINDER SLEEVE FOR 88.9*110 STROKE ENGI	1.00
DC PLUNGER OIL SEAL - THREE LIP	5.00
DC PLUNGER OIL SEAL - THREE LIP	10.00
DECALS OF UPG BHOOMIPUTRA 265DI MKM LH	1.00
DECALS OF UPG BHOOMIPUTRA 265DI MKM LH	1.00
DIA 450 FAN-NYLON6--7 BLDE-ARJUN650	1.00
DIA 450 FAN-NYLON6--7 BLDE-ARJUN650	2.00
DIA 450 FAN-NYLON6--7 BLDE-ARJUN650	6.00
DIA 450 FAN-NYLON6--7 BLDE-ARJUN650	1.00
DIAPHRAGM SPRING DOUBLE CLUTCH SPAR	3.00

BRG BALL 50X90X20	1.00
BRG BALL 50X90X20	2.00
BRG BALL 60X110X22	4.00
BRG BALL 60X110X22	2.00
BRG BALL 60X110X22	3.00
BRG BALL 60X110X22	3.00
BRG BALL 65X120X23	4.00
BRG CYL RLR C 40X80X18	1.00
BRG NDL RLR 1R 20X28X20.2	3.00
BRG NDL RLR 1R 30X38X20	4.00
BRG NDL RLR 1R 30X38X20	6.00
BRG NDL RLR 1R 30X38X20	8.00
BRG NDL RLR 1R 45X52X20	4.00
BRG NDL RLR 1R 45X52X20	6.00
BRG THRUST K 66.8X35.525X19.446	20.00
BRG THRUST K 66.8X35.525X19.446	5.00
BRG THRUST K 66.8X35.525X19.446	25.00
BRG TPR RLR 62.00X30.00X21.25	5.00
BRG TPR RLR 65.11X34.95X18.29	5.00
BRG TPR RLR 73.43X41.29X.21.43	20.00
BRG TPR RLR 73.43X41.29X.21.43	10.00
BRG TRANS DRIVE SHAFT ONESIDE	3.00
BRG TRANS DRIVE SHAFT ONESIDE	4.00
BULK HEAD UNION WITH NUT- ARJUN	4.00
BUSH BI-MET 29.000X32.025X24.50	12.00
BUSH BI-MET 29.000X32.025X24.50	12.00
BUSH CAM LINK	1.00
BUSH FL 12.776X15.875X16.00	25.00
BUSH FRT AXLE PIVOT PIN	6.00
BUSH FRT AXLE PIVOT PIN	2.00
BUSH STG KNCKL PVT PIN	12.00
BUSH STG KNCKL PVT PIN	4.00
CABLE HOUR METER BP	2.00
CAGE BULL PINION SHAFT BRG RH	1.00
CAM LINK SIDE SHIFT	1.00
CAM SHAFT - 2 CYL LS	10.00
CAP OIL FILLER WITH OIL SEAL	1.00
CAP OIL FILLER WITH OIL SEAL	5.00
CAP OIL FILLER WITH OIL SEAL	2.00
CAP OIL FILLER WITH OIL SEAL	2.00

APPENDIX 3

Results of order point using proposed model. Order point is denoted by O.P 1.

A Class items

SR.NO	PART NAME	D	E	L	(D+E+L)	(1+(D+E+L))	Dem*LT	O.P 1
1	GEAR CAMSHAFT	0.12	0.42	0.04	0.58	1.58	0.25	1
2	WATER PUMP ASSEMBLY	0.04	0.48	0.04	0.57	1.57	0.38	1
3	ASSLY PTO DRIVEN PLATE 6530(A3028PTV00)	0.52	0.09	0.04	0.65	1.65	0.78	2
4	ADAPTOR PLATE FOR HYDRAULIC LIFT	0.48	0.04	0.04	0.57	1.57	0.38	1
5	ALF-TRACTOR SEAT SLIDER 63 DEG. CMVRZS	0.45	0.06	0.04	0.56	1.56	1.72	3
6	ALTERNATOR A115.	0.5	0.04	0.04	0.58	1.58	5.08	9
7	AL RADIATOR WITH RECOVERY BOTTLE-2D	0.59	0.08	0.04	0.71	1.71	1.24	3
8	295 BS3A FLYWHEEL ASSEMBLY_CRPTO	0.58	0.07	0.04	0.69	1.69	2.25	4
9	AIR CLEANER DONALDSON FOR 75TC	0.75	0.09	0.04	0.8	1.80	0.71	2
10	DRIVEN PLATE ASSEMBLY	0.06	0.39	0.04	0.50	1.50	2.95	5
11	AL RADIATOR ASSEMBLY 605 – TTR	0.09	0.70	0.04	0.83	1.83	1.43	3
12	REAR AXLE-578 18 SPLINE	0.09	0.80	0.04	0.93	1.93	0.27	1
13	ASSEMBLY HOOD CPT. 4DI	0.68	0.07	0.04	0.79	1.79	0.83	2
14	Arjun Upg. - FENDER ASSEMBLY LH-TRACTOR	0.75	0.07	0.04	0.86	1.86	1.68	4
15	ASSY. POWER STEERING CE	0.44	0.10	0.04	0.58	1.58	0.34	1

B Class items

SR.NO	PART NAME	D	E	L	(D+E+L)	(1+(D+E+L))	Dem*LT	O.P 1
1	AIR INTAKE MANIFOLD	1.30	0.05	0.04	1.40	2.40	3.52	9
2	SHAFT REVERSE IDLER	0.10	0.44	0.04	0.58	1.58	2.25	4
3	COUPLING P T O SHAFT	0.10	0.45	0.04	0.60	1.60	0.36	1
4	PRESSURE PLATE FOR MAIN CLUTCH SPAR	0.07	0.28	0.04	0.39	1.39	2.95	5
5	PLATE CLUTCH DRIVEN 279.4MM –REPCO	0.07	0.68	0.04	0.79	1.79	1.23	3
6	HUB FRONT WHEEL (TIMKEN BRG)	0.09	0.85	0.04	0.98	1.98	0.49	1
7	PRESSURE PLATE-MAIN-ARJUN UPG CLUTCH	0.07	0.75	0.04	0.86	1.86	4.44	4
8	PTO SHAFT CENTRE – CRPTO	0.11	0.53	0.04	0.67	1.67	0.27	1
9	AIR FILTER 595 (DONALDSON)	1.36	0.04	0.04	1.45	2.45	3.13	8
10	ARJUN UPGRADATION MAIN WIRE HARNESS	0.08	0.56	0.04	0.68	1.68	0.34	1
11	ARJUN MAIN WIRING HARNESS	0.11	0.72	0.04	0.87	1.87	0.34	1
12	CON ROD ASSY.	0.12	0.98	0.04	1.14	2.14	0.14	1
13	CLUTCH PLATE ASSEMBLY	0.11	0.65	0.04	0.80	1.80	0.29	1
14	WATER PUMP LOW DISCHARGE	0.10	0.50	0.04	0.65	1.65	0.48	1
15	WATER PUMP (TIER 3)	0.10	0.68	0.04	0.82	1.82	0.30	1

C Class items

SR.NO	PART NAME	D	E	L	(D+E+L)	(1+(D+E+L))	Dem*LT	O.P 1
1	GASKET EXHAUST MANIFOLD	0.02	0.24	0.04	0.30	1.30	9.90	13
2	GASKET STUB PIPE 4 CYL NEF	0.02	0.19	0.04	0.25	1.25	9.02	12
3	SUCTION FILTER CONNECTION HOSE	0.08	0.35	0.04	0.47	1.47	2.39	4
4	TANK ASSEMBLY RECOVERY	0.06	0.71	0.04	0.81	1.81	0.81	2
5	SUCTION FILTER ASSY	0.01	0.43	0.04	0.48	1.48	15.05	23
6	OIL PRESSURE SWITCH	0.08	0.55	0.04	0.68	1.68	1.80	4
7	VALVE CPTE ISOLATOR	0.09	0.52	0.04	0.65	1.65	0.38	1
8	ENGINE OIL FILTER	0.01	0.57	0.04	0.63	1.63	14.18	24
9	SENSOR UNIT TEMPERATURE-PRICOL	0.08	0.47	0.04	0.59	1.59	1.23	2
10	AEROSOL PAINT - ACRYLIC GREY(SPARES)	0.03	0.80	0.04	0.87	1.87	4.33	9
11	SUCTION FILTER	0.11	0.93	0.04	1.09	2.09	0.29	1
12	TUBE STABILIZER--555/595 UPG(2 nos.)	0.06	0.18	0.04	0.28	1.28	0.70	1
13	SAFETY AIR ELEMENT	0.03	0.43	0.04	0.51	1.51	6.33	10
14	STEEL PLATE FOR OIB	0.09	0.77	0.04	0.91	1.91	2.24	5
15	SLEEVE CYLINDER - 432 CYL DI	0.08	0.52	0.04	0.64	1.64	1.31	3

APPENDIX 4

Calculation of order points using theoretical model.

B.S = base stock

S.S = safety stock

AVG DEM = average demand

AVG L.T = average lead time

D.D = Daily demand

O.P 2 = order point calculated using theoretical model

A Class items

SR.NO	PART NAME	B.S	S.S	AVG DEM	AVG L.T	D.D	O.P 2
1	GEAR CAMSHAFT	1	3	3.0	15	0.02	1
2	WATER PUMP ASSEMBLY	3	5	4.7	15	0.03	1
3	ASSLY PTO DRIVEN PLATE 6530(A3028PTV00)	5	8	9.5	15	0.05	2
4	ADAPTOR PLATE FOR HYDRAULIC LIFT	1	3	4.7	15	0.03	1
5	ALF-TRACTOR SEAT SLIDER 63 DEG. CMVR Z-S	5	15	21.0	15	0.11	4
6	ALTERNATOR A115.	15	30	62.0	15	0.34	21
7	AL RADIATOR WITH RECOVERY BOTTLE-2D	4	12	15.2	15	0.08	3
8	295 BS3A FLYWHEEL ASSEMBLY_CRPTO	5	10	27.5	15	0.15	5
9	AIR CLEANER DONALDSON FOR 75TC	2	5	8.7	15	0.05	1
10	DRIVEN PLATE ASSEMBLY	10	15	36.0	15	0.20	8
11	AL RADIATOR ASSEMBLY 605 - TTR	10	30	17.5	15	0.10	6
12	REAR AXLE-578 18 SPLINE	2	5	3.3	15	0.02	1
13	ASSEMBLY HOOD CPT. 4DI	4	8	10.2	15	0.06	2
14	ARJUN UPG. - FENDER ASSEMBLY LH-TRACTOR	5	15	20.5	15	0.11	4
15	ASSY. POWER STEERING CE	1	2	4.2	15	0.02	1

B Class items

SR.NO	PART NAME	B.S	S.S	AVG DEM	AVG L.T	D.D	O.P 2
1	AIR INTAKE MANIFOLD	15	20	43.0	15	0.23	12
2	SHAFT REVERSE IDLER	5	20	27.5	15	0.15	6
3	COUPLING P T O SHAFT	2	4	4.3	15	0.02	1
4	PRESSURE PLATE FOR MAIN CLUTCH SPAR	5	30	36.0	15	0.20	10
5	PLATE CLUTCH DRIVEN 279.4MM -REPCO	10	40	15.0	15	0.08	6
6	HUB FRONT WHEEL (TIMKEN BRG)	2	4	6.0	15	0.03	1
7	PRESSURE PLATE-MAIN-ARJUN UPG CLUTCH	10	40	54.2	15	0.30	20
8	PTO SHAFT CENTRE - CRPTO	2	5	3.3	15	0.02	1
9	AIR FILTER 595 (DONALDSON)	20	40	38.2	15	0.21	16
10	ARJUN UPGRADATION MAIN WIRE HARNESS	2	5	4.2	15	0.02	1
11	ARJUN MAIN WIRING HARNESS	2	4	4.2	15	0.02	1
12	CON ROD ASSY.	1	2	1.7	15	0.01	1
13	CLUTCH PLATE ASSEMBLY	1	2	3.5	15	0.02	1
14	WATER PUMP LOW DISCHARGE	2	4	5.8	15	0.03	1
15	WATER PUMP (TIER 3)	2	4	3.7	15	0.02	1

Class C items

SR.NO	PART NAME	B.S	S.S	AVG DEM	AVG L.T	D.D	O.P 2
1	GASKET EXHAUST MANIFOLD	30	60	120.8	15	0.66	59
2	GASKET STUB PIPE 4 CYL NEF	25	50	110.0	15	0.60	45
3	SUCTION FILTER CONNECTION HOSE	5	25	29.2	15	0.16	8
4	TANK ASSEMBLY RECOVERY	2	5	9.8	15	0.05	2
5	SUCTION FILTER ASSY	30	50	183.7	15	1.00	45
6	OIL PRESSURE SWITCH	5	15	22.0	15	0.12	5
7	VALVE CPTE ISOLATOR	2	4	4.7	15	0.03	1
8	ENGINE OIL FILTER	100	200	173.0	15	0.95	57
9	SENSOR UNIT TEMPERATURE-PRICOL	5	10	15.0	15	0.08	3
10	AEROSOL PAINT - ACRYLIC GREY(SPARES)	30	50	52.8	15	0.29	27
11	SUCTION FILTER	3	5	3.5	15	0.02	1
12	TUBE STABILIZER--555/595 UPG(2 NOS.)	2	8	8.5	15	0.05	2
13	SAFETY AIR ELEMENT	20	50	77.2	15	0.42	36
14	STEEL PLATE FOR OIB	8	12	27.3	15	0.15	6
15	SLEEVE CYLINDER - 432 CYL DI	4	16	16.0	15	0.09	4

APPENDIX 5

Comparison of order point of proposed model with the actual base stock of dealers.

A Class items

SR NO	PART NO	PART NAME	ACTUAL BASE STOCK	ORDER POINT 1
1	003064085R3	GEAR CAMSHAFT	1	1
2	006004080C3	WATER PUMP ASSEMBLY	3	1
3	006505467C91	ASSLY PTO DRIVEN PLATE 6530(A3028PTV00)	5	2
4	000010493P03	ADAPTOR PLATE FOR HYDRAULIC LIFT	1	1
5	007605339B91	ALF-TRACTOR SEAT SLIDER 63 DEG. CMVR Z-S	5	3
6	000020605E05	ALTERNATOR A115.	15	9
7	006002554A91	AL RADIATOR WITH RECOVERY BOTTLE-2D	4	3
8	006011498B91	295 BS3A FLYWHEEL ASSEMBLY_CRPTO	5	4
9	006000251F1	AIR CLEANER DONALDSON FOR 75TC	2	2
10	006504375C91	DRIVEN PLATE ASSEMBLY	10	5
11	006003547C92	AL RADIATOR ASSEMBLY 605 – TTR	10	3
12	006004365F91	REAR AXLE-578 18 SPLINE	2	1
13	008000503B12	ASSEMBLY HOOD CPT. 4DI	4	2
14	007538821C91	ARJUN UPG. - FENDER ASSEMBLY LH-TRACTOR	5	4
15	007202640C92	ASSY. POWER STEERING CE	1	1

B Class items

SR NO	PART NO	PART NAME	ACTUAL BASE STOCK	ORDER POINT 1
1	006005408B1	AIR INTAKE MANIFOLD	15	9
2	006502649C1	SHAFT REVERSE IDLER	5	4
3	005552640R2	COUPLING P T O SHAFT	2	1
4	006500157C91	PRESSURE PLATE FOR MAIN CLUTCH SPAR	5	5
5	001099328R92	PLATE CLUTCH DRIVEN 279.4MM -REPCO	10	3
6	007500051C1	HUB FRONT WHEEL (TIMKEN BRG)	2	1
7	006510211C91	PRESSURE PLATE-MAIN-ARJUN UPG CLUTCH	10	4
8	006502460R1	PTO SHAFT CENTRE – CRPTO	2	1
9	006001512B91	AIR FILTER 595 (DONALDSON)	20	8
10	007700965C91	ARJUN UPGRADATION MAIN WIRE HARNESS	2	1
11	007700832C91	ARJUN MAIN WIRING HARNESS	2	1
12	006004203F91	CON ROD ASSY.	1	1
13	000703852R1	CLUTCH PLATE ASSEMBLY	1	1
14	007700335C91	WATER PUMP LOW DISCHARGE	2	1
15	006004367F94	WATER PUMP (TIER 3)	2	1

Class C items

SR NO	PART NO	PART NAME	BASE STOCK	ORDER POINT 1
1	000020026E05	GASKET EXHAUST MANIFOLD	30	13
2	000020567E05	GASKET STUB PIPE 4 CYL NEF	25	12
3	000704741R2	SUCTION FILTER CONNECTION HOSE	5	4
4	006002260C91	TANK ASSEMBLY RECOVERY	2	2
5	007205324B1	SUCTION FILTER ASSY	30	23
6	000013085P04	OIL PRESSURE SWITCH	5	4
7	003045102R21	VALVE CPTE ISOLATOR	2	1
8	006002508F1	ENGINE OIL FILTER	100	24
9	005551425R2	SENSOR UNIT TEMPERATURE-PRICOL	5	2
10	20.178	AEROSOL PAINT - ACRYLIC GREY(SPARES)	30	9
11	003044368R96	SUCTION FILTER	3	1
12	007200280C2	TUBE STABILIZER--555/595 UPG(2 NOS.)	2	1
13	006000456F1	SAFETY AIR ELEMENT	20	10
14	006506426C1	STEEL PLATE FOR OIB	8	5
15	005555531R1	SLEEVE CYLINDER - 432 CYL DI	4	3

APPENDIX 6

Comparison of order point 2 with the actual base stock of dealers.

Calculation of order point using theoretical model is considered as order point 2.

A Class items

SR NO	PART NO	PART NAME	BASE STOCK	ORDER POINT 2
1	003064085R3	GEAR CAMSHAFT	1	1
2	006004080C3	WATER PUMP ASSEMBLY	3	1
3	006505467C91	ASSLY PTO DRIVEN PLATE 6530(A3028PTV00)	5	2
4	000010493P03	ADAPTOR PLATE FOR HYDRAULIC LIFT	1	1
5	007605339B91	ALF-TRACTOR SEAT SLIDER 63 DEG. CMVR Z-S	5	4
6	000020605E05	ALTERNATOR A115.	15	21
7	006002554A91	AL RADIATOR WITH RECOVERY BOTTLE-2D	4	3
8	006011498B91	295 BS3A FLYWHEEL ASSEMBLY_CRPTO	5	5
9	006000251F1	AIR CLEANER DONALDSON FOR 75TC	2	1
10	006504375C91	DRIVEN PLATE ASSEMBLY	10	8
11	006003547C92	AL RADIATOR ASSEMBLY 605 - TTR	10	6
12	006004365F91	REAR AXLE-578 18 SPLINE	2	1
13	008000503B12	ASSEMBLY HOOD CPT. 4DI	4	2
14	007538821C91	ARJUN UPG. - FENDER ASSEMBLY LH-TRACTOR	5	4
15	007202640C92	ASSY. POWER STEERING CE	1	1

B Class items

SR NO	PART NO	PART NAME	BASE STOCK	ORDER POINT 2
1	006005408B1	AIR INTAKE MANIFOLD	15	12
2	006502649C1	SHAFT REVERSE IDLER	5	6
3	005552640R2	COUPLING P T O SHAFT	2	1
4	006500157C91	PRESSURE PLATE FOR MAIN CLUTCH SPAR	5	10
5	001099328R92	PLATE CLUTCH DRIVEN 279.4MM -REPCO	10	6
6	007500051C1	HUB FRONT WHEEL (TIMKEN BRG)	2	1
7	006510211C91	PRESSURE PLATE-MAIN-ARJUN UPG CLUTCH	10	20
8	006502460R1	PTO SHAFT CENTRE – CRPTO	2	1
9	006001512B91	AIR FILTER 595 (DONALDSON)	20	16
10	007700965C91	ARJUN UPGRADATION MAIN WIRE HARNESS	2	1
11	007700832C91	ARJUN MAIN WIRING HARNESS	2	1
12	006004203F91	CON ROD ASSY.	1	1
13	000703852R1	CLUTCH PLATE ASSEMBLY	1	1
14	007700335C91	WATER PUMP LOW DISCHARGE	2	1
15	006004367F94	WATER PUMP (TIER 3)	2	1

C Class items

SR NO	PART NO	PART NAME	BASE STOCK	ORDER POINT 2
1	000020026E05	GASKET EXHAUST MANIFOLD	30	59
2	000020567E05	GASKET STUB PIPE 4 CYL NEF	25	45
3	000704741R2	SUCTION FILTER CONNECTION HOSE	5	8
4	006002260C91	TANK ASSEMBLY RECOVERY	2	2
5	007205324B1	SUCTION FILTER ASSY	30	45
6	000013085P04	OIL PRESSURE SWITCH	5	5
7	003045102R21	VALVE CPTE ISOLATOR	2	1
8	006002508F1	ENGINE OIL FILTER	100	57
9	005551425R2	SENSOR UNIT TEMPERATURE-PRICOL	5	3
10	20.178	AEROSOL PAINT - ACRYLIC GREY(SPARES)	30	27
11	003044368R96	SUCTION FILTER	3	1
12	007200280C2	TUBE STABILIZER--555/595 UPG(2 NOS.)	2	2
13	006000456F1	SAFETY AIR ELEMENT	20	36
14	006506426C1	STEEL PLATE FOR OIB	8	6
15	005555531R1	SLEEVE CYLINDER - 432 CYL DI	4	4

APPENDIX 7

Comparison of proposed model order point and theoretical model order point.

A Class items

SR NO	PART NO	PART NAME	ORDER POINT 1	ORDER POINT 2
1	003064085R3	GEAR CAMSHAFT	1	1
2	006004080C3	WATER PUMP ASSEMBLY	1	1
3	006505467C91	ASSLY PTO DRIVEN PLATE 6530(A3028PTV00)	2	2
4	000010493P03	ADAPTOR PLATE FOR HYDRAULIC LIFT	1	1
5	007605339B91	ALF-TRACTOR SEAT SLIDER 63 DEG. CMVR Z-S	3	4
6	000020605E05	ALTERNATOR A115.	9	21
7	006002554A91	AL RADIATOR WITH RECOVERY BOTTLE-2D	3	3
8	006011498B91	295 BS3A FLYWHEEL ASSEMBLY_CRPTO	4	5
9	006000251F1	AIR CLEANER DONALDSON FOR 75TC	2	1
10	006504375C91	DRIVEN PLATE ASSEMBLY	5	8
11	006003547C92	AL RADIATOR ASSEMBLY 605 - TTR	3	6
12	006004365F91	REAR AXLE-578 18 SPLINE	1	1
13	008000503B12	ASSEMBLY HOOD CPT. 4DI	2	2
14	007538821C91	ARJUN UPG. - FENDER ASSEMBLY LH-TRACTOR	4	4
15	007202640C92	ASSY. POWER STEERING CE	1	1

B Class items

SR NO	PART NO	PART NAME	ORDER POINT 1	ORDER POINT 2
1	006005408B1	AIR INTAKE MANIFOLD	9	12
2	006502649C1	SHAFT REVERSE IDLER	4	6
3	005552640R2	COUPLING P T O SHAFT	1	1
4	006500157C91	PRESSURE PLATE FOR MAIN CLUTCH SPAR	5	10
5	001099328R92	PLATE CLUTCH DRIVEN 279.4MM -REPCO	3	6
6	007500051C1	HUB FRONT WHEEL (TIMKEN BRG)	1	1
7	006510211C91	PRESSURE PLATE-MAIN-ARJUN UPG CLUTCH	4	20
8	006502460R1	PTO SHAFT CENTRE - CRPTO	1	1
9	006001512B91	AIR FILTER 595 (DONALDSON)	8	16
10	007700965C91	ARJUN UPGRADATION MAIN WIRE HARNESS	1	1
11	007700832C91	ARJUN MAIN WIRING HARNESS	1	1
12	006004203F91	CON ROD ASSY.	1	1
13	000703852R1	CLUTCH PLATE ASSEMBLY	1	1
14	007700335C91	WATER PUMP LOW DISCHARGE	1	1
15	006004367F94	WATER PUMP (TIER 3)	1	1

C Class items

SR NO	PART NO	PART NAME	ORDER POINT 1	ORDER POINT 2
1	000020026E05	GASKET EXHAUST MANIFOLD	13	59
2	000020567E05	GASKET STUB PIPE 4 CYL NEF	12	45
3	000704741R2	SUCTION FILTER CONNECTION HOSE	4	8
4	006002260C91	TANK ASSEMBLY RECOVERY	2	2
5	007205324B1	SUCTION FILTER ASSY	23	45
6	000013085P04	OIL PRESSURE SWITCH	4	5
7	003045102R21	VALVE CPTE ISOLATOR	1	1
8	006002508F1	ENGINE OIL FILTER	24	57
9	005551425R2	SENSOR UNIT TEMPERATURE-PRICOL	2	3
10	20.178	AEROSOL PAINT - ACRYLIC GREY(SPARES)	9	27
11	003044368R96	SUCTION FILTER	1	1
12	007200280C2	TUBE STABILIZER--555/595 UPG(2 NOS.)	1	2
13	006000456F1	SAFETY AIR ELEMENT	10	36
14	006506426C1	STEEL PLATE FOR OIB	5	6
15	005555531R1	SLEEVE CYLINDER - 432 CYL DI	3	4

APPENDIX 8

Comparison of inventory cost of dealers, proposed model and conventional model.

Model 1 denoted as proposed model from research paper.

Model 2 denoted as theoretical model.

A Class items

SR.NO	PART CODE	PART NAME	ACTUAL COST	MODEL 1	MODEL 2
1	003064085R3	GEAR CAMSHAFT	2313	2313	2313
2	006004080C3	WATER PUMP ASSEMBLY	7247	2416	2416
3	006505467C91	ASSLY PTO DRIVEN PLATE 6530(A3028PTV00)	15677	6271	6271
4	000010493P03	ADAPTOR PLATE FOR HYDRAULIC LIFT	3403	3403	3403
5	007605339B91	ALF-TRACTOR SEAT SLIDER 63 DEG. CMVR Z-S	18589	11153	14871
6	000020605E05	ALTERNATOR A115.	58317	34990	81644
7	006002554A91	AL RADIATOR WITH RECOVERY BOTTLE-2D	15938	11953	11953
8	006011498B91	295 BS3A FLYWHEEL ASSEMBLY_CRPTO	20531	16425	20531
9	006000251F1	AIR CLEANER DONALDSON FOR 75TC	8663	8663	4332
10	006504375C91	DRIVEN PLATE ASSEMBLY	45983	22992	36786
11	006003547C92	AL RADIATOR ASSEMBLY 605 - TTR	48244	14473	28946
12	006004365F91	REAR AXLE-578 18 SPLINE	10552	5276	5276
13	008000503B12	ASSEMBLY HOOD CPT. 4DI	28333	14167	14167
14	007538821C91	ARJUN UPG. - FENDER ASSEMBLY LH-TRACTOR	37741	30192	30192
15	007202640C92	ASSY. POWER STEERING CE	14661	14661	14661
			336192	199348	275449

Total inventory cost on A class items:

1. On actual stock provided by dealers is 336192(rupees)
2. On proposed model is 199348(rupees)
3. On theoretical model is 275449(rupees)

B Class items

SR.NO	PART CODE	PART NAME	ACTUAL COST	MODEL 1	MODEL 2
1	006005408B1	AIR INTAKE MANIFOLD	11288	6773	9030
2	006502649C1	SHAFT REVERSE IDLER	3822	3058	4586
3	005552640R2	COUPLING P T O SHAFT	1693	846	846
4	006500157C91	PRESSURE PLATE FOR MAIN CLUTCH SPAR	4753	4753	9506
5	001099328R92	PLATE CLUTCH DRIVEN 279.4MM -REPCO	9793	2938	5876
6	007500051C1	HUB FRONT WHEEL (TIMKEN BRG)	2496	1248	1248
7	006510211C91	PRESSURE PLATE-MAIN-ARJUN UPG CLUTCH	13552	5421	27104
8	006502460R1	PTO SHAFT CENTRE - CRPTO	3237	1618	1618
9	006001512B91	AIR FILTER 595 (DONALDSON)	35028	14011	28022
10	007700965C91	ARJUN UPGRADATION MAIN WIRE HARNESS	3503	1751	1751
11	007700832C91	ARJUN MAIN WIRING HARNESS	3804	1902	1902
12	006004203F91	CON ROD ASSY.	1940	1940	1940
13	000703852R1	CLUTCH PLATE ASSEMBLY	1953	1953	1953
14	007700335C91	WATER PUMP LOW DISCHARGE	3991	1996	1996
15	006004367F94	WATER PUMP (TIER 3)	4108	2054	2054
			104960	52262	99434

Total inventory cost on B class items:

1. On actual stock provided by dealers is 104960(rupees)
2. On proposed model is 52262(rupees)
3. On theoretical model is 99434(rupees)

C Class items

SR.NO	PART CODE	PART NAME	ACTUAL COST	MODEL 1	MODEL 2
1	000020026E05	GASKET EXHAUST MANIFOLD	168	73	330
2	000020567E05	GASKET STUB PIPE 4 CYL NEF	193	92	347
3	000704741R2	SUCTION FILTER CONNECTION HOSE	105	84	168
4	006002260C91	TANK ASSEMBLY RECOVERY	202	202	202
5	007205324B1	SUCTION FILTER ASSY	4242	3252	6363
6	000013085P04	OIL PRESSURE SWITCH	746	596	746
7	003045102R21	VALVE CPTE ISOLATOR	332	166	166
8	006002508F1	ENGINE OIL FILTER	18060	4334	10294
9	005551425R2	SENSOR UNIT TEMPERATURE-PRICOL	903	361	542
10	20.178	AEROSOL PAINT - ACRYLIC GREY(SPARES)	7200	2160	6480
11	003044368R96	SUCTION FILTER	727	242	242
12	007200280C2	TUBE STABILIZER--555/595 UPG(2 NOS.)	592	296	592
13	006000456F1	SAFETY AIR ELEMENT	6286	3143	11315
14	006506426C1	STEEL PLATE FOR OIB	3276	2048	2457
15	005555531R1	SLEEVE CYLINDER - 432 CYL DI	2024	1518	2024
			45055	18568	42267

Total inventory cost on C class items:

1. On actual stock provided by dealers is 45055(rupees)
2. On proposed model is 18568(rupees)
3. On theoretical model is 42267(rupees)

APPENDIX 9

Comparison of carrying cost on actual base stock of dealers, proposed model and conventional model.

Carrying cost for actual base stock of dealers is denoted by C.C actual.

Carrying cost of proposed model is denoted by C.C model 1.

Carrying cost of theoretical model is denoted by C.C model 2.

A Class items

SR.NO	PART CODE	PART NAME	C.C ACTUAL	C.C MODEL 1	C.C MODEL 2
1	003064085R3	GEAR CAMSHAFT	486	486	486
2	006004080C3	WATER PUMP ASSEMBLY	1522	507	507
3	006505467C91	ASSLY PTO DRIVEN PLATE 6530(A3028PTV00)	3292	1317	1317
4	000010493P03	ADAPTOR PLATE FOR HYDRAULIC LIFT	715	715	715
5	007605339B91	ALF-TRACTOR SEAT SLIDER 63 DEG. CMVR Z-S	3904	2342	3123
6	000020605E05	ALTERNATOR A115.	12247	7348	17145
7	006002554A91	AL RADIATOR WITH RECOVERY BOTTLE-2D	3347	2510	2510
8	006011498B91	295 BS3A FLYWHEEL ASSEMBLY_CRPTO	4312	3449	4312
9	006000251F1	AIR CLEANER DONALDSON FOR 75TC	1819	1819	910
10	006504375C91	DRIVEN PLATE ASSEMBLY	9656	4828	7725
11	006003547C92	AL RADIATOR ASSEMBLY 605 - TTR	10131	3039	6079
12	006004365F91	REAR AXLE-578 18 SPLINE	2216	1108	1108
13	008000503B12	ASSEMBLY HOOD CPT. 4DI	5950	2975	2975
14	007538821C91	ARJUN UPG. - FENDER ASSEMBLY LH-TRACTOR	7926	6340	6340
15	007202640C92	ASSY. POWER STEERING CE	3079	3079	3079
			70600	41863	58330

Total carrying cost on A class items:

1. On actual stock provided by dealers is 70600(rupees)
2. On proposed model is 41863(rupees)
3. On theoretical model is 58330(rupees)

B Class items

SR.NO	PART CODE	PART NAME	C.C ACTUAL	C.C MODEL 1	C.C MODEL 2
1	006005408B1	AIR INTAKE MANIFOLD	2370	1422	1896
2	006502649C1	SHAFT REVERSE IDLER	803	642	963
3	005552640R2	COUPLING P T O SHAFT	355	178	178
4	006500157C91	PRESSURE PLATE FOR MAIN CLUTCH SPAR	998	998	1996
5	001099328R92	PLATE CLUTCH DRIVEN 279.4MM -REPCO	2057	617	1234
6	007500051C1	HUB FRONT WHEEL (TIMKEN BRG)	524	262	262
7	006510211C91	PRESSURE PLATE-MAIN-ARJUN UPG CLUTCH	2846	1138	5692
8	006502460R1	PTO SHAFT CENTRE - CRPTO	680	340	340
9	006001512B91	AIR FILTER 595 (DONALDSON)	7356	2942	5885
10	007700965C91	ARJUN UPGRADATION MAIN WIRE HARNESS	736	368	368
11	007700832C91	ARJUN MAIN WIRING HARNESS	799	399	399
12	006004203F91	CON ROD ASSY.	407	407	407
13	000703852R1	CLUTCH PLATE ASSEMBLY	410	410	410
14	007700335C91	WATER PUMP LOW DISCHARGE	838	419	419
15	006004367F94	WATER PUMP (TIER 3)	863	431	431
			22041	10975	20881

Total carrying cost on B class items:

1. On actual stock provided by dealers is 22041(rupees)
2. On proposed model is 10975(rupees)
3. On theoretical model is 20881(rupees)

C Class items

SR.NO	PART CODE	PART NAME	C.C ACTUAL	C.C MODEL 1	C.C MODEL 2
1	000020026E05	GASKET EXHAUST MANIFOLD	35	15	69
2	000020567E05	GASKET STUB PIPE 4 CYL NEF	40	19	73
3	000704741R2	SUCTION FILTER CONNECTION HOSE	22	18	35
4	006002260C91	TANK ASSEMBLY RECOVERY	42	42	42
5	007205324B1	SUCTION FILTER ASSY	891	683	1336
6	000013085P04	OIL PRESSURE SWITCH	157	125	157
7	003045102R21	VALVE CPTE ISOLATOR	70	35	35
8	006002508F1	ENGINE OIL FILTER	3793	910	2163
9	005551425R2	SENSOR UNIT TEMPERATURE-PRICOL	190	76	114
10	20.178	AEROSOL PAINT - ACRYLIC GREY(SPARES)	1512	454	1361
11	003044368R96	SUCTION FILTER	153	51	51
12	007200280C2	TUBE STABILIZER--555/595 UPG(2 NOS.)	124	62	124
13	006000456F1	SAFETY AIR ELEMENT	1320	660	2376
14	006506426C1	STEEL PLATE FOR OIB	688	430	516
15	005555531R1	SLEEVE CYLINDER - 432 CYL DI	425	319	425
			9461	3899	8877

Total carrying cost on C class items:

1. On actual stock provided by dealers is 9461(rupees)
2. On proposed model is 3899(rupees)
3. On theoretical model is 8877(rupees)

