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Inventory Management of Spare Parts in Andal Depot Eastern Railway India

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Abstract: although inventory management has significantly developed in the past years as a management discipline, its application is still minimal in the service industry and government. In contrast, it is an important tool for any company that is running a competitive business. The management of some companies considers inventory as an asset, not a liability.

In this paper, an attempt has been made to enhance the profit through optimization of transportation costs and repair costs of inventory management system for andal depot in eastern railway using general algebraic modeling system (gams). It is found during the data collection period that andal depot or the entire indian railway depot is following the conventional methods for their analysis and management, they have not adopted any latest analysis tool for the depot management of spare parts. The raw data collected from the andal depot has been analyzed on the basis of their average annual consumption in terms of rupees through abc analysis. Spare parts items are classified under three classes namely a, b and c respectively. Out of 1468 items 89,157 and 1222 items falls under a, b and c class items respectively and criticality of the items in each class is discussed.
Keywords: inventory management; abc analysis; general algebraic modeling system (gams);

I. INTRODUCTION

A. Back drop of inventory management

Competitiveness in today's marketplace depends heavily on the ability of a company to handle the challenges of reducing lead-times and costs, increasing customer service levels, and improving product quality. Traditionally, sourcing (procurement), production, distribution and marketing have been working independently. Unfortunately, although they may seem to be working towards a common goal, Indian Railways Depots follow different approaches. Purchase decisions depend upon purchasing of less cost spare parts and supply of spare parts through throughput. In the business management theory of constraints, throughput is the rate at which a system achieves its goal. Oftentimes, this is monetary revenue and is in contrast to output, which is inventory that may be sold or stored in a warehouse, while purchase prices without any consideration for high inventory levels or long lead-times. Thus Supply chain management is the effective coordination and integration of different organizations with different objectives like to find the total Inventory cost of Andal Depot, to maintain necessary records for maintaining the stocks within the desired limits, replenishment of stock whenever necessary, to determine demand for spare parts in a year by using 'ABC' analysis in terms of money further to overcome the problem of delay in delivering spare parts on time and transportation problems. To study the inventory management constraints and problems and to optimize the Inventory spare parts costs using General Algebraic Modeling System. The great potential for improvement in these objectives through effective supply chain management mechanisms has recently been realized by the Indian Railways spare parts Depots generally. The inventory management problem is one of the ways to maintain an adequate supply of some item to meet an expected pattern of demand, while striking a reasonable balance between the holding costs of the items fall under inventory management. The items may be commodities supplied by a store or thus may be spare machine parts and other related spare parts based on A, B, C items i.e. in vogue with the Andal Depot and they may contain railway engine spare parts, electrical and air conditioning spare parts. So it is indispensible to find out the solution through mathematically formulated Inventory control system. Therefore there are different Inventory Management systems like EOQ, ABC, and FSN etc. As far as maintaining Inventory system is concerned there are certain specific systems such as (i) administrative cost of placing an order, which is called as reorder cost or set cost; (ii) cost of maintaining an inventory, called inventory holding cost or carrying cost, which includes storage charge, interest, insurance, etc., a (iii) shortage cost is a loss of profit, goodwill, etc., when run out of stock. Cost in general refers to an expenditure whether is notional or actual attributable to a thing or product. All the above should be optimized for efficient supply chain management. In view of effective Inventory control Management General Algebraic

Modeling system (GAMS) is used.

II. LITERATURE SURVEY

A. Cong Guo & Xueping Li (2014)

in his research on a multi-echelon inventory system with supplier selection and order allocation under stochastic demand has stated an integrated supplier selection and inventory control problems in supply chain management by developing a mathematical model for a multi-echelon system. In particular a buyer firm having N identical retailers procures a type of product from a group of potential suppliers, which may have different prices, ordering costs, and lead times and have restriction on minimum and maximum total order size, to satisfy stochastic demand (i.e. collection of items at random ordered in time) a continuous review that implements the order quantity, re-order point (Q, R) inventory policy is considered in the proposed paper.

B. Marcello Braglia et al. (2014)

in their research have stated that The spare parts inventories management in industrial plants represents a very complex problem due to the difficulties concerning data collection, the number of factors to be considered, and the large amount of the items involved. A new multi-attribute technique to define the "best" strategies of spare inventories management is presented. They have introduced the concepts of AHP (analytical hierarchical process) for solving the inventory problems and to manage the inventory at optimum level.

C. Irene Roda et al. (2014)

in their research they have found with the comparative analysis between theory and practice, developed with the support of a literature analysis, following results have been achieved:

1) Some criteria like AHP, ABC analysis etc. have been identified as the ones with the highest potentials for spare parts classification, both for what concern their citations in scientific literature, as well as their understanding in industrial practice.

2) An extensive review over the classification methods has been allowed to identify pros and cons of various approaches proposed in literature or used in industry, revealing some concerns on their problems for industrial application, which can be summarized as computational complexity, exposure to uncertainty and to subjectivity when using qualitative data.

D. Noor-Ajian Mohd-Lair et al. (2014)

in their research have stated that software integrated with EOQ can easily lead to estimate the amount of quantity and when to order. They found that the results showed that the EOQ without considering opening balance performs better with lower average inventory level than the Kadex method. They found that the prediction technique that was integrated with software SPIM also needs to be improved for better forecasting because in the mentioned method the data were assumed as per their previous year demands.

E. Nazim Baluch et al. (2013)

have found in their research that the spare parts inventories management in a service sector represents a very complex problem due to the difficulties concerning data collection, the number of factors to be considered, and the large amount of the items involved. Maintenance spare parts store room is a service provider; to dispense efficient and effective services it needs to focus on the best practices of spare parts management. In order to accomplish best practices the maintenance store room ought to (i) adopt the idea that the storeroom is a service provider (ii) organize the storeroom and staff for efficiency (iii) ensure inventory accuracy - it is of utmost importance; perform routine and daily cycle counting as part of the storeroom duties (iv) properly slot parts depending on part volume and characteristics. When the storeroom operates in a best practices mode, then it is easy to see productivity gains not only in the storeroom, but also throughout the organization.

F. Vaisakh P.S. et al. (2013)

in their research stated that spare parts classification method is based on item movement on stores and their criticality. After analyzing the different items at stores they found that there is lot of spare parts which comes under non-moving category resulting in higher cost. Higher inventory cost is mainly due to higher storage cost and inventory holding cost. Non-moving items need to be controlled in order to reduce inventory cost. So they performed VED analysis on the non-moving items, which are identified by the FSN analysis. The non-moving items are classified into vital Non Moving Vital (NV), Non Moving essential (NE), and Non Moving desirable (ND) items based on the criticality rate. They found that there are lots of items that are non-moving but are desirable resulting in hold up cost and occupying space.

G. Jose Roberto do Rego et al. (2011)

in their research stated that inventory management is complex due to large number of different items and low demands. They have identified a clear gap in the comparison of different criteria for the decision of stock or not to stock in more representative data setting. The classification of items in categories is an important tool to prioritize managerial efforts and define the parameters for inventory control. The choice of the inventory control model for each given spare parts is a critical activity into the general process of inventories management with multiple items. In order to classify the items, in addition to the measures of criticality and uncertainty of demands, the evaluation of the current life cycle phase of the spare parts should be included. For inventory management the initial orders are necessary for items in class A which has short time series to demand forecast.

H. Huafei Chen (2011)

in his research on uncertainty demand of Inventory control has stated that the overall operations of supply chain are affected by the increase of demand uncertainty. Inventory control is an important part in supply chain management. Three-echelon inventory model of manufacture regarded as core enterprise is modeled, which assumes that uncertainty demand subjects to normal distribution. Redundancy inventory in the node enterprise of supply chain is discussed under the two inventory replenishment strategy (continuous review inventory and periodic review inventory).

I. Eugene Levner et al. (2011)

in their research on a network approach to modeling the multi-echelon spare-part inventory system with backorders and interval-valued demand have stated spare-part inventory management problems with outsourcing and backordering. The problem is characterized by deterministic repair time/cost, and supply and demand that lie within prescribed intervals and that vary over time. They have minimized the total transportation costs and repair costs by developing a network model for problem analysis and presented a network flow algorithm for solving the problem.

J. Yang Fan (2010)

in his research on development of Inventory management system has stated that a hierarchical federation Multi-Agent Organization structure and the co-operation among Agents are based on improved contract net protocol, which enhances system performance on the whole.

K. Barlas et al. (2010)

have developed a System Dynamics simulation model of a typical retail supply chain. The intent of their simulation exercise was to build up inventory policies that enhance the retailer's revenue and reduce Inventory costs at the same instant. Besides, the research was also intended towards studying the implications of different diversification strategies.

L. Markus et al. (2009)

have developed a supply network model that takes as input the bill of materials, the (nominal) lead times, the demand and cost data, and the required customer service levels. In return, the model generates the base-stock level at each store-the stocking location for a part or an end-product, so as to minimize the overall inventory capital throughout the network and to guarantee the customer service requirements.

M. P. Radhakrishnan et al. (2009)

developed a new and efficient approach that works on Genetic Algorithms in order to distinctively determine the most probable excess stock level and shortage level required for inventory optimization in the supply chain such that the total supply chain cost is minimized. Many well-known algorithmic advances in optimization have been made, but it turns out that most have not had the expected impact on the decisions for designing and optimizing supply chain related problems.

III. METHODOLOGY

Indian Railways has seventeen zones and these zones which are further sub-divided into many divisions. Each division has a divisional Headquarters. In Eastern Railway nearly twenty four Depots which are situated at different places out of which Andal spare parts maintenance Depot is selected for the study. The secondary data have been collected from the Andal Depot for the research. The data reveal that there are 1468 spare parts are available with Andal Depot. All the items have been classified under ABC categories. The English letters ABC denotes Always Better Control. Under A category 89 items, under B category 157 items and under C category 1222 items have been classified on the basis of Book Average Rate of the spare parts.** Further in this research General Algebraic Modeling system (GAMS) is used as a method for finding out the optimal value of Inventory. GAMS is used as an aid in order to facilitate the precise determination of the most probable excess stock level and shortage level requirements as an Inventory optimization technique.

A. ABC Analysis

ABC analysis is a basic analytical management tool which enables top management to place the effort where the results will be greatest. This technique is popularly known as "Always Better Control" and has universal applications. This technique tries to analyse the distribution of any characteristic by money value of importance in order to determine priority. In materials management, this technique has been applied in areas needing selective control such as inventory, criticality of items etc.

ABC analysis underlines a very important principle "VITAL FEW TRIVIAL MANY". For better and more economic control of items in inventory, the items should be classified according to their significance or priority for re-ordering. In ABC analysis the items are categorized into three main categories on the basis of Book average rate.

1) More costly and valuable items are classified as A. These are large investment items but not much in number i.e. VITAL FEW. Those items need more closer and careful control. These items should be ordered frequently but in smaller size. A periodic review policy should be followed to minimize the stock out of such items and top level inventory staff should control these items.

2) Average usage value items are classified as B. These are less important than the "A" class items but are costly enough to have more attention on their use. These items cannot be overlooked but need lesser degree of control than those in class A.

3) Low usage value items are put in class C. These items can be stored at an operative place where people can help themselves without any requisition formality. These can be charged to an overhead account. No doubt loose control of C items will increase their investment cost and expenditure on wasteful use but this will not be so much to offset the savings in recording cost.

ABC analysis focuses its attention on the management where it is needed in due proportion. An objective of such classification is to separate out the group C items which is large in number and which may particularly require a large amount of record keeping and attention but which is relatively unimportant from the point of view of keeping inventory investment at reasonable levels. Here the items are classified in terms of their usage value. Usage value is not the price of an item but it is the product of usage over a period generally for example a year and its unit price. It is generally found that an industrial or business undertaking has a large number of items whose Inventory management has to be undertaken by the firm. These items differ in terms of their value, prices, usage, etc. Moreover, each item has its own specific problems of procurement and the lead time. Therefore it is not desirable that all the items should get equal attention in Inventory Management process, naturally Inventories of those items whose usage value is high should attract more attention than those having low usage. This selective Inventory Control System is known as the ABC analysis**.**

B. General Pattern For Inventory Classification

Inventory items are classified under three categories based on their usage value their requirements and costs. A class items are very costly and having high usage value, B class items are of moderate cost and usage value and C class items are cheaper and may have low or moderate usage value so these items are ordered in bulk to get extra discount from the suppliers. The following criterion is used in general practice for the ABC classification.

1) Category A: 5% to 10% items; nearly 65% of usage value.
2) Category B: 10% to 20% items; nearly 20% of usage value.
3) Category C: 70% to 85% items; nearly 15% of usage value.

(Source: SHARMA S.C. & BANGA T.R.," Industrial Organization and Engineering economics," Khanna Publishers and Mehta P.L., "Managerial Economics," S.Chand Publications)

C. Assumptions Of Abc Analysis

1) Though, usually the Inventory items are classified into three categories namely A, B and C only but nothing prohibits a firm to undertake the analysis on the basis of a larger categorization.

2) It is necessary for an effective ABC analysis that all the items should be included for the classification.

Though according to ABC analysis category 'C' gets only a simple attention, the management should nevertheless has to be careful in its approach.

ABC analysis is not the ultimate exercise in Inventory Management; it needs supplementing with detailed knowledge and monitoring.

D. Steps Involved In 'Abc' Analysis

Step 1: Find the annual usage value of each item by multiplying the number used of the items during the year with the unit cost of the items.

Step 2: Arrange the items in descending order on the basis of their usage value.

Step 3: Write down the total items and the usage value and convert them into percentages

Step 4: Plot the graph between percentage of total cost and percentage of items in each class.

E. Inferences Based On Abc Analysis

1) For A class Items

a) As 'A' class Items account for 70% of the total cost so these items are ordered more frequently but in small quantities in order to reduce inventory holding cost.
b) Requirements of such items are planned in advance for expected future consumption.
c) Purchase of 'A' class items are looked into by the top executives in purchasing department.
d) Since 'A' class items are to be stocked as minimum as possible, so maximum efforts are made to expedite the delivery in specified time interval.

2) For B class Items

a) Policies for 'B' class items are generally in between 'A' class items and 'C' class items.
b) Orders for 'B' class items are placed less frequently than 'A' class items.

3) For C class Items

a) As 'C' items do not involve much capital tie up i.e. only 5% of the total cost, the stock for these items are kept liberally.
b) Annual or half yearly consumption orders are placed to reduce paper work and ordering cost and to get advantage of quantity discounts for bulk purchase.

F. Limitations Of Abc Analysis

1) 'ABC' analysis mainly provides a guideline for Inventory Management, it needs to be supplemented by basic understanding and judgment as there are certain items which may fall under 'C' category or 'B' category but are otherwise very critical.
2) The 'ABC' analysis, to be effective, needs to be constantly undertaken and periodically reviewed by management, as the number of items and value of items keep on changing over a time period.
3) The practical problem in the use of 'ABC' analysis is that generally thousands of items fall in category 'C' as a result a lot of time is spent on managing inventory of items of this category leading to much shorter time duration for the efficient management of 'A' class items.
4) Though there are various techniques of selective Inventory control like High Medium Low (HML), Fast Slow Non-moving (FSN), Vital Essential Desirable (VED) etc. 'ABC' analysis is the most popular technique.

Table 4.1 Percentage analysis of spare parts data based on the ABC Analysis

Class	No. of Items	Percentage (%)
A	89	89/1468 = 6.06
B	157	157/1468 = 10.69
C	1222	1222/1468 = 83.25
Total	1468	100

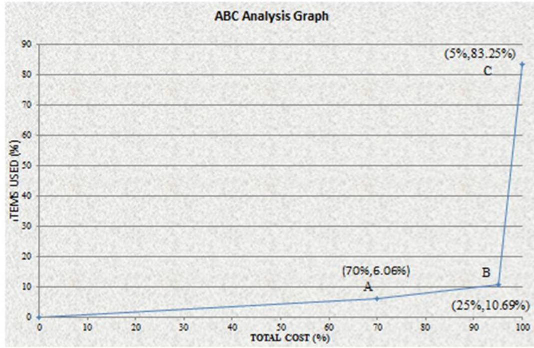

Fig. 4.1 ABC analysis Graph

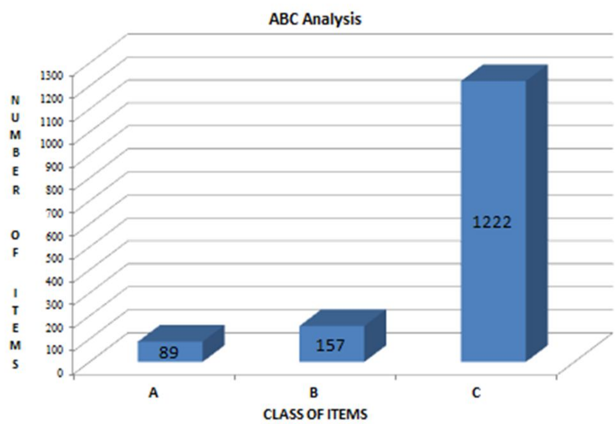

Fig. 4.2 Bar chart of ABC Analysis

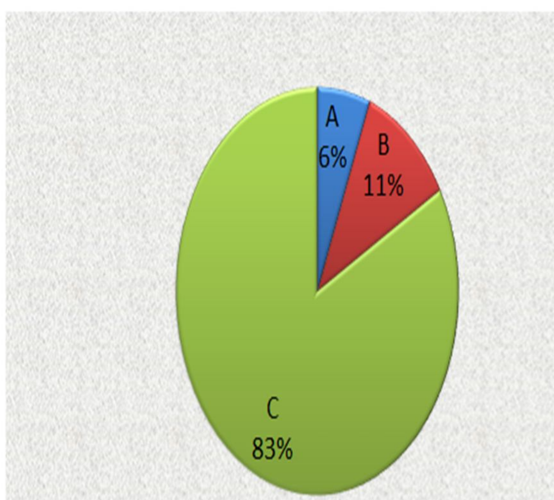

Fig. 4.3 Pie chart of ABC percentage Analysis

IV. OPTIMIZATION OF INVENTORY COST BY USING GENERAL ALGEBRAIC MODELING SYSTEM (GAMS)

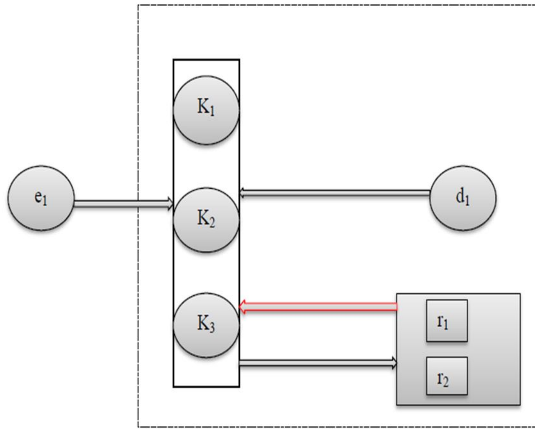

Fig. 5.1 Flow of Spare Parts in ANDAL Depot

e_1 – External supplier

Ki (1, 2, 3) – Bases

d_1 – Depot

r_1– Fast repair center

r_2- Slow repair center

In the above Fig. 3.1 e_1 is external supplier it will supply the spare parts to the bases or depot only when the requirements of spare parts is not fulfilled either by Depot or Repair center. There are three bases K_1, K_2 and K3 respectively available for the servicing, maintenance and for assembling the spare parts in an engine. If any items are found to be damaged it is sent to either r_2 or r_1 i.e. slow or fast repair center respectively as per the need and after repairing again it will send it to different bases as per the requirement.

A. over view of gams

The General Algebraic Modeling System (GAMS) is specifically designed for modeling linear, nonlinear and mixed integer optimization problems. The system is especially useful especially with large, complex problems pertinent to organization. General Algebraic Modeling System (GAMS) is available for use on personal computers, workstations, mainframes and supercomputers.General Algebraic Modeling System (GAMS) allows the user to concentrate on the modeling problem by making the setup simple. The system takes care of the time-consuming details of the specific machine and system software implementation.General Algebraic Modeling System (GAMS) is especially useful for handling large, complex, one-of-a-kind problems which may require many revisions to establish an accurate model. The system models problems in a highly compact and natural way. The user can change the formulation quickly and easily, can change from one solver to another, and can even convert from linear to nonlinear with little trouble.

B. System Features

General Algebraic Modeling System (GAMS) lets the user concentrate on modeling. By eliminating the need to think about purely technical machine-specific problems such as address calculations, storage assignments, subroutine linkage, and input-output and flow control, General Algebraic Modeling System (GAMS) increases the time available for conceptualizing and running the model, and analyzing the optimization results. General Algebraic Modeling System (GAMS) structures good modeling habits itself by requiring concise and exact specification of entities and relationships. The General Algebraic Modeling System (GAMS) language is formally like to commonly use programming languages. Using GAMS, data are entered only once in familiar list and table form. Models are described in concise algebraic statements which are easy for both humans and machines to read. Hence we can say it is an integrated man machine system. The entire sets of closely related constraints are entered in one statement. General Algebraic Modeling System (GAMS) automatically generate each constraint equation, and let the user make exceptions in cases where generality is not desired. Statements in models can be reused without having to change the algebra when other instances of the same or related problems arise. The location and type of errors are pinpointed before a solution can be attempted. General Algebraic Modeling System (GAMS) handles dynamic models involving time sequences, lags and leads and treatment of temporal endpoints.General Algebraic Modeling System (GAMS) is flexible and powerful in optimization operations. Models are fully portable from one computer platform to another when General Algebraic Modeling System (GAMS) is loaded to each platform. The user can easily program a model to solve for different values of an element and then generate an output report listing the solution characteristics for each case. Models can be developed and documented simultaneously because GAMS allows the user to include explanatory text as part of the definition of any symbol or equation. GAMS is being enhanced and expanded on a continuing basis.

C. Parameters Used For The Optimization Of Inventory

Sets

k- Base for servicing and maintenance of Railway engine

t- Time period for the requirement of the spare parts (in days)

e- External supplier

d- Depot

r- Fast repair center

s- Slow repair center

Parameters

dd_{tk}- demand at base k in day t

$c_{1\ ek}$- transport and purchase cost from supplier e to base k

$c_{2\ dk}$- transport cost from depot

$c_{3\ rk}$- cost of repairing and transport from fast repair center to base k

$c_{4\ sk}$- cost of repairing and transport from slow repair center to base k

$c_{6\ k}$- cost of holding inventory

u_{tk}- maximum capacity at base k per day

c_d- maximum capacity with external supplier

Integer variables

X_{tek}- amount from e to k in t

Y_{tdk} – amount from d to k in t

U_{trk} – amount from r to k in t

V_{tsk} – amount from s to k in t

H_{tk} - amount carried in period t at base

D. Constraints

1) $\sum_e x_{tek} + \sum_d y_{tdk} + \sum_r u_{trk} + \sum_s v_{tsk} = ck(t,k)$ $\forall$ k,t

2) $\sum_k y_{tdk} \leq c_d$ $\forall$ t,d

3) $\sum_k x_{tek} \leq ce_e$ $\forall$ t,e

4) $\sum_k u_{trk} = cr_{tr}$ $\forall$ t,r

5) $\sum_k v_{tsk} = cs_{ts}$ $\forall$ t,s

6) $Cr_{t+1}, r_1 + cs_{t+2}, s_1 = Fr \times \sum_d \sum_k y_{tdk}$ $\forall$ t

7) $Ck_{tk} + h_{t-1}, k = dd_{tk} + h_{tk}$ $\forall$ t,k

8) $Ck_{tk} \geq u_{1k}$ $\forall$ t,k

9) $X_{tek} \geq 0$

10) $Y_{tdk} \geq 0$

11) $U_{trk} \geq 0$

12) $V_{tsk} \geq 0$

13) $H_{tk} \geq 0$

Cost and amount of items from external supplier to the base on day t

$\sum_t \sum_e \sum_k C_{1ek} X_{tek}$ .... (i)

Cost and amount of items from depot to the base on day t

$\sum_t \sum_d \sum_k C_{2dk} Y_{tek}$ .... (ii)

Cost and amount of items from fast repair center to the base on day t

$\sum_t \sum_r \sum_k C_{3rk} U_{trk}$ ....(iii)

Cost and amount of items from slow repair center to the base on day t

$\sum_t \sum_s \sum_k C_{4sk} V_{tsk}$ ………………….(iv)

Cost and amount of holding items at base on day t

$\sum_t \sum_k C_{6k} H_{tk}$ ………………………..(v)

Objective function

Min. $\sum_t \sum_e \sum_k C_{1ek} X_{tek} + \sum_t \sum_d \sum_k C_{2dk} Y_{tek} + \sum_t \sum_r \sum_k C_{3rk} U_{trk} + \sum_t \sum_s \sum_k C_{4sk} V_{tsk} + \sum_t \sum_k C_{6k} H_{tk}$

Sets

k /k1*k3/

```
t     /t1*t6/
e     /e1*e1/
d     /d1*d1/
r     /r1/
s     /r2/
ts(t)       /t1*t4/
tt(t)      /t1*t5/
tx(t)      /t5,t6/
```

Parameters

```
dd(t,k)
c1(e,k)
c2(d,k)
c3(r,k)
c4(s,k)
c6(k)
fr /.1/
ul(k)
c(d)
ce(e)
dd(t,k)  = uniformint(3,4)*100;
c1(e,k)  = uniformint(10,12)*100;
c2(d,k)  = uniformint(2,3)*100;
c3(r,k)   = uniformint(20,25)*100;
c4(s,k)   = uniformint(10,15)*100;
c6(k)    = uniformint(10,12)*10;
ul(k)    =700;
c(d)    =1500;
ce(e)   =200;
```

Integer variables

```
x(t,e,k)
y(t,d,k)
u(t,r,k)
v(t,s,k)
nf(t,r)
nx(t,e)
h(t,k)
a(t,r)
b(t,s)
Positive variable
ck(t,k)
cr(t,r)
cs(t,s);
h.up(t,k)= 200;
x.up(t,e,k)= 100;
y.up(t,d,k)= 800;
u.up(t,r,k)= 300;
v.up(t,s,k)=300;
```

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V. RESULTS AND DISCUSSION

Sets, parameters and equations used for the optimization of transportation cost, repair cost related to this thesis work for ANDAL Depot EASTERN RAILWAY using General Algebraic Modeling System (GAMS)

A. Results

Table 6.1 Spare parts requirements at each base during six days

Bases Days	K 1	K 2	K 3
t1	300	400	400
t2	300	300	300
t3	300	400	300
t4	400	400	400
t5	400	400	300
t6	400	300	300

The above table depicts the requirement of the spare parts at each base during the working days. Total requirement of spare parts on day 1,day 2, day 3, day4, day 5 and day 6 at different bases are 1100, 900, 1000,1200,1100, 1000 items respectively.

Table 6.2 Spare parts supplied at each base during six days

t1.d1	300	400	400
t2.d1	300	300	300
t3.d1	300	400	190
t4.d1	400	400	510
t5.d1	400	400	100
t6.d1	400	300	300

The above table depicts the supply of the spare parts at each base during the working days. On day 1 total 1100 items are supplied to the bases from the depot. Similarly for all days the items are supplied to the bases from the depot as per the requirement. On day 5 it is observed that only 900 items are supplied to the bases, it may be because of some shortage or the base may have stored it previously.

Table 6.3 Repaired items supplied back to bases

Days	Supplied items to Bases
t6.r1	90
t3.r2	110
t4.r2	90
t5.r2	89
t6.r2	131

90 items which have been sent to repair center on day five is supplied back to the bases on day six as the damaged items are sent to the fast repair center.110 items on day 3, 90 items on day four, 89 items on day five and 131 items on day six sent from the bases on day 1, day 2, day 3 and day 4 respectively are supplied back to the bases as they are sent to slow repair center which takes two days for the repair work.

Table 6.4 costs of items from different source

Sources	Costs (in Rs) per order
e_1	4400
d_1	600
r_1	5800
r_2	3800

Table 6.4 is showing the transportation and repair costs per order for the spare parts supplied from external supplier (e_1), depot (d_1) and repair centers i.e. (r_1), (r_2) fast and slow repair centers respectively.

Table 6.5 Optimized cost using GAMS

Actual cost (in Rs)	Optimized cost (in Rs)
23,00,000	18,91,000

using GAMS technique for the optimization it is found that total optimized cost for transportation and repair is Rs. 409000 which is 17.78 % of the total expenditure on transportation and repair centers from different sources i.e. from depot, external supplier and repair centers.

VI. CONCLUSION

A. A huge problem that a majority of the Railway Depots aiming to reduce the supply chains costs besides improving customer service levels face is that of the administration of the dynamic demand.

B. The present research tends to address problems from the operational perspective i.e. inventory management and control; planning and scheduling; information sharing, coordination, monitoring; and operational tools.

C. By using General Algebraic Modeling System (GAMS) technique for the optimization it is found that total optimized cost for transportation and repair is Rs. 409000 which is 17.78 % of the total expenditure on transportation and repair.

D. Inventory optimization application with the help of GAMS organizes the latest techniques and technologies thereby assisting the enhancement of Inventory Control and its management.

VII. RECOMMENDATIONS

A. It is recommended that uniformity must be followed by all the Depots as far as Price List (PL) numbers of the spare parts are concerned which will enable the Depots in the exchange of required spare parts.

B. It is found that Andal Depot follow unscientific procedures as far as distribution of spare parts to the service centers. It means it is randomly picking up the spare parts hence it is recommended that for servicing work a scientific procedure like using state of art technology for making distribution may be followed.

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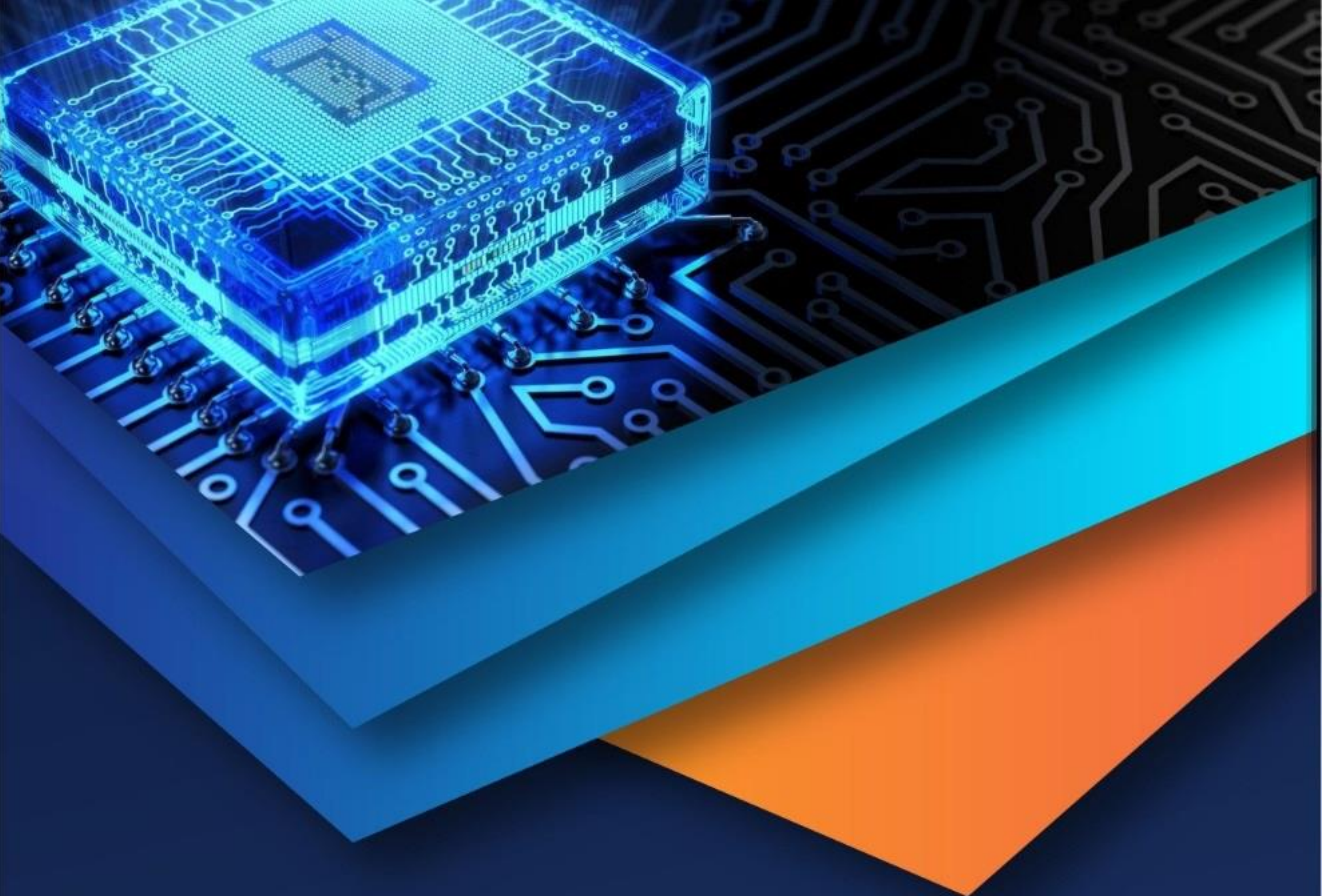

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