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Spare Parts Inventory Analysis for Automobile Sector

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Abstract—In this paper the objective is to determine the optimal allocation of spares for replacement of defective parts on-board of a usage. The minimization of the total supply chain cost can only be achieved when optimization of the base stock level is carried out at each member of the supply chain. A serious issue in the implementation of the same is that the excess stock level and shortage level is not static for every period.This has been achieved by using some forecasting and optimization techniques. Optimal inventory control is one of the significant tasks in supply chain management. The optimal inventory control methodologies intend to reduce the supply chain cost by controlling the inventory in an effective manner, such that, the supply chain members will not be affected by surplus as well as shortage of inventory.We focus specifically on determining the most probable excess stock level and shortage level required for inventory optimization in the supply chain so that the total supply chain cost is minimized .So, the overall aim of this paper is to find out the healthy stock level by means of that safety stock is maintained throughout the service period.

Keywords—Regression, Optimization, Inventory, Safety stock, Forecasting.

I. INTRODUCTION

The design and operation of spare part management systems is very important for automobile sector, Prior relevant system could be grouped in two categories. It is aimed to find optimal demand for a given spare parts management system; that is, how to determine optimal inventory level in order to reduce cost. This paper attempts to solve a comprehensive design problem for a spare part management system. Every automobile sector should proceed systematically and establish an effective Spare parts management system.Inventory encompasses all raw materials, work in process,and finished goods within the supply chain. ChangingInventory policies can dramatically alter the supply chain's efficiency and responsiveness. Inventory is an important cross functional driver of supply chain performance. Animportant role that can be satisfied by having the productready and available when the customer wants it to reduce the customer waiting time in the service sector. Inventoryis held throughout the supply chain in the form of raw materials, work in progress, and finished goods.

II. LITERATURE REVIEW

(Diaz and Fu, 1997). Repairables are generally more expensive, so the share of repairables in total service part investment is probably considerably higher. In this work, the focus will be on repairable items. Inventory costs have been a major research area to determine the most effective costs. The models are generally formulated as a cost minimization problem, with a cost function comprising holding costs, ordering setup costs, and either explicit penalty costs or a specified service level constraint.

Singh and Vrat (1984) explored a two-echelon repair-inventory system, developing a model for determining the location of a repair and storage facility, together with the allocation of serviceable spares to minimize the total expected system cost, defined as the sum of shortage, holding, and transportation costs. Previous studies regarding the spare part inventory management typically focused on local inventory of a single facility and little on the entire supply chain; see Huiskonen (2001). Mabini and Christer (2002) considered four cost factors in the total expected annual inventory cost; the cost of holding serviceable and non-serviceable modules and components, the purchase cost of replenishment modules and components, the repair cost of modules and components, and the aircraft delay cost due to module shortages. Vaughan (2005) presented a model where demand for the spare parts arises due to regularly scheduled preventive maintenance and random failure of units in service with constant failure rate. Through literature, the costs incurred due to shortage or backorders are higher than the cost for inventory and the regular order, because that the failure has already occurred. The METRIC approach is concerned with setting the initial levels of repairable spare part inventories and their distribution among various locations in a distribution network The goal is to minimize the sum of the expected backorders of all service parts at all local bases.

Other literature that emphasized the significance of backorders cost include Nahmias (1981), Erlebacher and Meller (2000), Huiskonen (2001), Daskin et al. (2002), Rustenburg et al. (2003), Ozsen et al. (2003), Shwarz et al. (2004), Vaughan (2005), and the books of Sherbrooke (2004) and Ghiani et al. (2004).

III. LINEAR REGRESSION

Linear regression models are extremely powerful, and have the power to empirically tease out very complicated relationships between variables. Generally speaking, the technique is useful, among other applications, in helping explain observations of a dependent variable, usually denoted y, with observed values of one or more independent variable denoted by x. this models helps us to predict the exact demand of the spares for the upcoming period.so,this model reduces the stock out in the service sector.

$$y = a+bx \quad (1)$$

$$\text{Slope } (b) = (N\Sigma XY - (\Sigma X)(\Sigma Y)) / (N\Sigma X^2 - (\Sigma X)^2) \quad (2)$$

$$\text{Intercept } (a) = (\Sigma Y - b(\Sigma X)) / N \quad (3)$$

Where,

X=Failure=Demand, a= intercept,b= slop

Linear regression line with slope and intercept

a)linear Regression Programme Using C:

```
#include<stdio.h>
#include<conio.h>
#include<math.h>
#include<string.h>
float mean(float *a, int n);
void deviation(float *a, float mean, int n, float *d, float *S);
void main()
{
float a[20],b[20],dx[20],dy[20];
float sy=0,sx=0,mean_x=0,mean_y=0,sum_xy=0;
float corr_coff=0,reg_coff_xy=0, reg_coff_yx=0;
char type_coff[7];
int n=0,i=0;
clrscr();
printf("Enter the value of n: ");
scanf("%d",&n);
printf("Enter the values of x and y:\n");
for(i=0;i<n;i++)
scanf("%f%f",&a[i],&b[i]);
mean_x=mean(a,n);
mean_y=mean(b,n);
deviation(a,mean_x,n,dx,&sx);
deviation(b,mean_y,n,dy,&sy);
for(i=0;i<n;i++)
sum_xy=sum_xy+dx[i]*dy[i];
corr_coff=sum_xy/(n*sx*sy);
printf("Enter the type of regression coefficient as 'x on y' or 'y on x': ");
fflush(stdin);
gets(type_coff);

if(strcmp(type_coff,"x on y")==1)
{
reg_coff_xy=corr_coff*(sx/sy);
printf("\nThe value of linear regression coefficient is %f",reg_coff_xy);
}
else if(strcmp(type_coff,"y on x")==1)
{
reg_coff_yx=corr_coff*(sy/sx);
printf("\nThe value of linear regression coefficient is %f",reg_coff_yx);
}
else
printf("\nEnter the correct type of regression coefficient.");
getch();
}
float mean(float *a, int n)
{
float sum=0, i=0;
for(i=0;i<n;i++)
sum=sum+a[i];
sum=sum/n;
return (sum);
}
```

```
void deviation(float *a, float mean, int n, float *d, float *s)
{
float sum=0,t=0;
inti=0;
for(i=0;i<n;i++)
{
d[i]=a[i]-mean;
t=d[i]*d[i];
sum=sum+t;
}
sum=sum/n;
*s=sqrt(sum);
}
```

b). Linear Regression To Find Demand

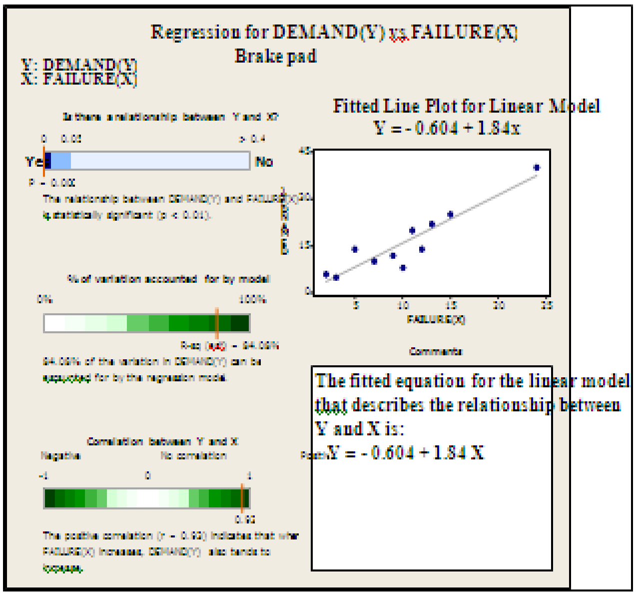
By using the regression model the spare requirement for the 13thperiod has been predicted so, this demand prediction gives some automobile service sector to plan for their future spare requirement. the unavailability of the spare in the spare inventory will make the service period of the vehicle to extend so this prediction will some what reduce the uncertainity in the spare demand on the same time it is necessary to maintain the healthy stock level of spare inventory in the automobile service sector .that will be provided by designing the 'Periodic inventory system and 'Quantity based inventory system to the service sector .By using the regression the future requirement for the automobile service sector in the spare inventory will be obtained.This will be done only when we know the exact failure of the critical components and demand for the spares. For our case study we have taken Tata car models and their critical components are obtained and spare requirement for each spare is obtained by the regression equations.

1) Brake Pad

A. regression table for brake pad

MODEL	FAILURE (X)	DEMAND (Y)	XY	X^2
1	3	5	15	9
2	2	6	12	4
3	10	8	80	100
4	9	12	108	81
5	5	14	70	25
6	7	10	70	49
7	12	14	168	144
8	11	20	220	121
9	13	22	286	169
10	15	25	375	225
11	24	40	960	576
12	16	21	336	256
TOTAL	111	197	2700	1503

Intercept (a): -0.604
Slope (b): 1.84
Regression line equation :
Y=-0.6042735042735+1.84X
Demand of brake pad Y=23.3≈≈*24*

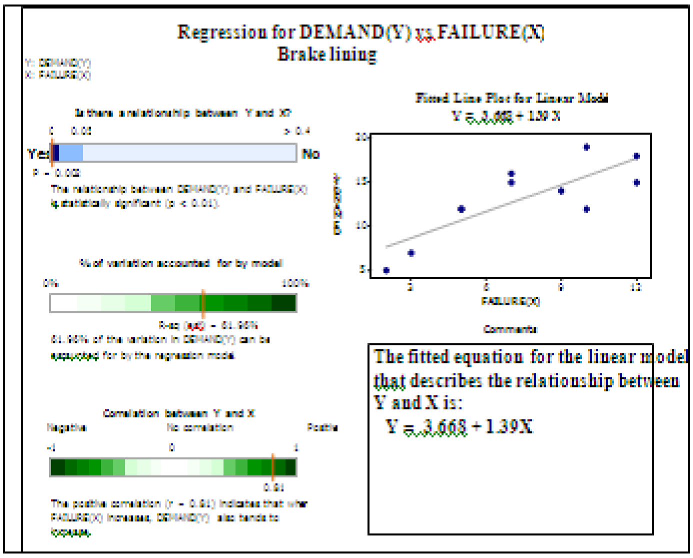


A. Regression graph for brake pad 5a

2. Brake Lining

B. regression table for brake lining Table 5.b

MODEL	FAILURE (X)	DEMAND (Y)	XY	X^2
1	3	7	21	9
2	2	5	10	4
3	5	12	60	25
4	9	14	126	81
5	5	12	60	25
6	7	16	112	49
7	10	12	120	100
8	12	18	216	144
9	10	19	190	100
10	7	15	105	49
11	12	15	180	144
12	9	13	117	81
TOTAL	82	158	1317	730



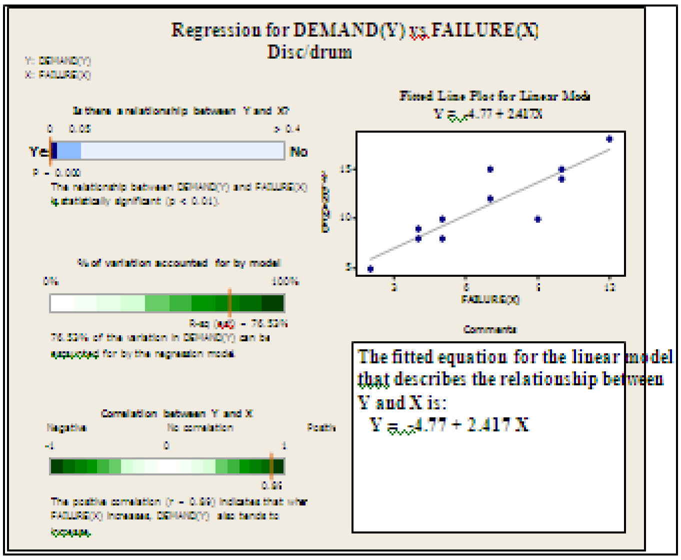
B. Regression graph for brake lining

Intercept (a):3.668
Slope (b): 1.39
Regression line equation=Y=3.66+1.393X
Demand of brake lining Y=21.7≈≈22

3. Disc/Drum

C. Regression table for disc/drumTable 5.c

MODEL	FAILURE(X)	DEMAND(Y)	XY	X^2
1	2	5	10	4
2	5	6	30	25
3	10	14	140	100
4	9	8	72	81
5	4	8	32	16
6	5	8	40	25
7	7	12	84	49
8	12	18	216	144
9	7	12	94	49
10	4	9	36	16
11	10	12	120	100
12	20	12	240	400
TOTAL	75	124	1114	609



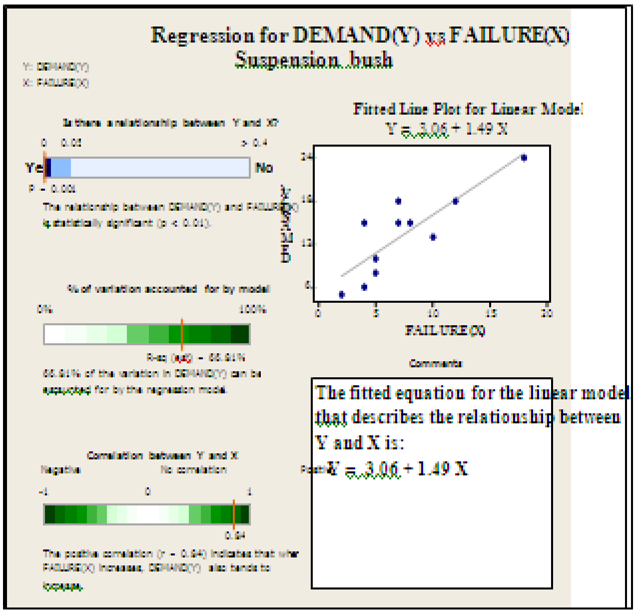
C. Regression graph for disc/drum

Intercept (a): -4.77
Slope (b): 2.417
Regression line equation
Y=-4.77+2.417X
Demand of disc/drum Y=26.651≈≈27

4. Suspension Bush

D. Regression table for suspension bushTable 5.d

MODEL	FAILURE (X)	DEMAND (Y)	XY	X^2
1	2	5	10	4
2	5	8	40	25
3	10	13	130	100
4	7	18	126	49
5	4	15	60	16
6	5	10	50	25
7	8	15	120	64
8	12	18	216	144
9	7	15	105	49
10	4	6	24	16
11	18	24	432	324
12	13	12	156	169
TOTAL	82	159	1469	816



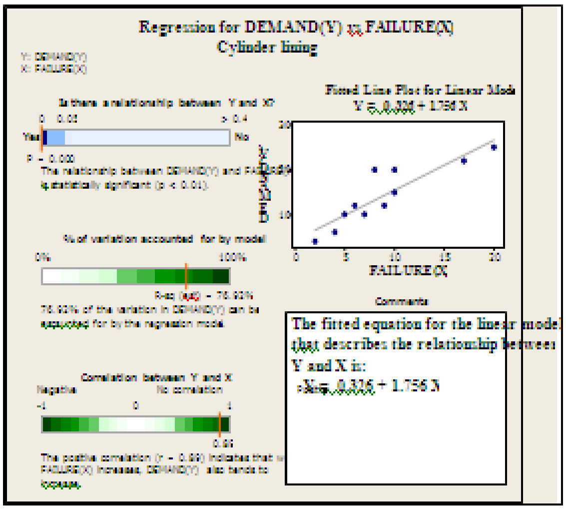
D. Regression graph for suspension bushFig 5.d

Intercept (a): 3.06
Slope (b): 1.49
Regression line equation:
Y=3.06+1.49X
Demand of suspension bush Y=22.43 □ □23

5. Cylinder Lining

E. Regression table for suspension bush Table 5.e

MODEL	FAILURE (X)	DEMAND (Y)	XY	X^2
1	2	4	8	4
2	4	6	24	16
3	7	10	70	49
4	6	12	72	36
5	5	10	50	25
6	9	12	108	81
7	10	15	150	100
8	8	20	160	64
9	10	20	200	100
10	17	22	374	289
11	20	25	500	400
12	18	20	360	324
TOTAL	98	176	2076	1164



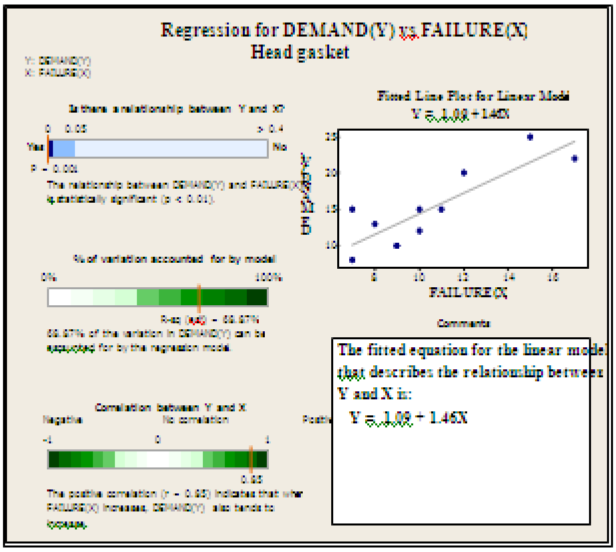
E. Regression graph for cylinder lining Fig 5.e

Intercept (a): 0.326
Slope (b): 1.756
Regression line equation: Y=0.326+1.756X
Demand of cylinder lining Y=23.154≈≈23

6. Head Gasket

F. Regressiontable Head GasketTable 5.f

MODEL	FAILURE (X)	DEMAND (Y)	XY	X^2
1	7	8	56	49
2	9	10	90	81
3	10	12	120	100
4	8	13	104	64
5	10	15	150	100
6	9	10	90	81
7	11	15	165	121
8	7	15	105	49
9	12	20	240	144
10	17	22	374	289
11	15	25	375	225
12	10	16	160	100
TOTAL	115	181	2029	1303



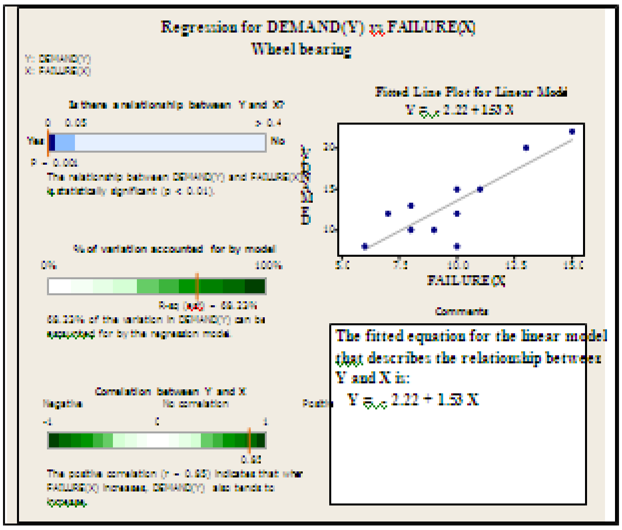
F. Regression graph for Head GasketFig 5.f

Intercept (a): 1.09
Slope (b): 1.46
Regression line equation:
 $y=1.09+1.46X$
Demand of head gasket Y=20.07≈≈20

7. Wheel Bearing

G.Regression table for wheel bearingTable 5.g

MODEL	FAILURE (X)	DEMAND (Y)	XY	X^2
1	6	8	48	36
2	8	10	80	64
3	10	12	120	100
4	8	13	104	64
5	10	15	150	100
6	9	10	90	81
7	11	15	165	121
8	7	12	84	49
9	10	8	80	100
10	15	22	330	225
11	13	20	260	169
12	10	13	130	100
Total	107	158	1641	1109



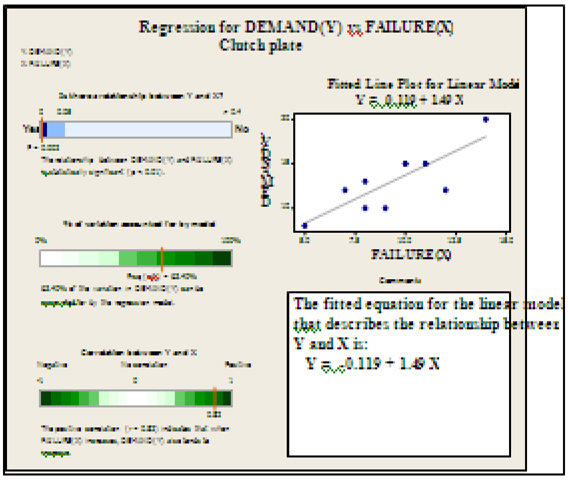
G. Regressiongraph forwheel bearingFig 5.g

Intercept (a): -2.22
Slope (b): 1.53
Regression line equation:
Y=-2.22+1.53X=17.6 □ □18.

8. clutch plate

H. Regression table for clutch plateTable

MODEL	FAILURE (X)	DEMAND(Y)	XY	X^2
1	5	8	40	25
2	8	10	80	64
3	10	12	120	100
4	9	13	117	81
5	12	15	180	144
6	6	10	60	36
7	8	15	120	64
8	11	12	132	121
9	9	15	135	81
10	13	15	195	169
11	11	10	110	121
12	10	11	110	100
TOTAL	102	146	1399	1006



H. Regression graph for clutch plateFig 5.h

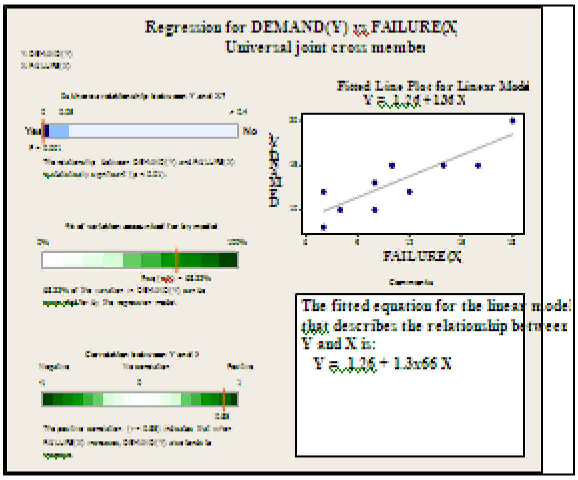
Intercept (a): -0.119
Slope (b): 1.49
Regression line equation:
Y=-0.119+1.49X
Demand of Clutch plate Y=19.2≈≈20

9. Universal joint cross member

I. regression table for Universal joint cross member

MODEL	FAILURE (X)	DEMAND (Y)	XY	X^2
1	7	8	56	49
2	10	10	100	100
3	12	12	144	144
4	10	13	130	100
5	14	15	210	196
6	8	10	80	64
7	11	15	165	121
8	7	12	84	49
9	11	15	165	121
10	18	20	360	324
11	16	15	240	256
12	18	18	324	324
TOTAL	124	163	2058	1524

Intercept(a):1.26
Slope(b):1.36
Regression line equation:Y=1.26+1.36x
Demand of universal joint cross member =18.94≈≈19



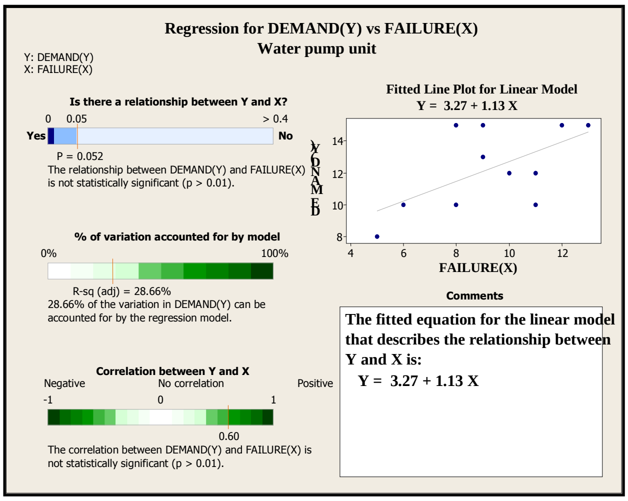
I. Regression graph universal joint cross member Fig 5.i

10. Water Pump Unit

J. Regression table for water pump unit Table 5.j

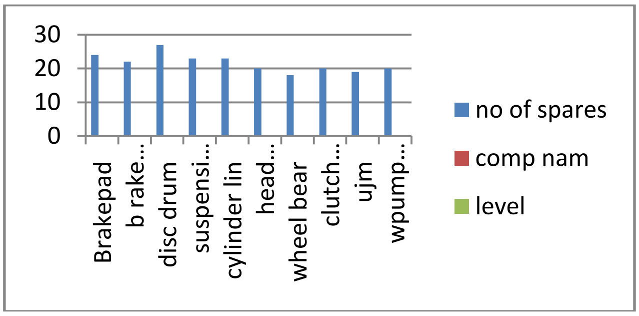
MODEL	FAILURE (X)	DEMAND (Y)	XY	X^2
1	5	8	40	25
2	9	10	90	81
3	12	12	144	144
4	8	13	104	64
5	10	15	150	100
6	8	10	80	64
7	11	15	165	121
8	7	12	84	49
9	10	15	150	100
10	14	20	280	196
11	11	15	165	121
12	10	13	130	100
TOTAL	105	158	1582	1065

Intercept (a): 3.27
Slope (b): 1.13
Regression line equation:
Y=3.27+1.13X
Demand of water pump unit
Y=17.722054380664698≈≈18



J. Regression graph for water pump unitFig 5.j

Now the results of forecasted demand for the automobile spares using linear regression have been summarized in the table as follows.



From this method we can find that **DISC/DRUM and cylinder lining has** more demand comparatively to others.

IV. DETERMINATION OF STOCK LEVEL

A company needs to decide how many items at least it wants to keep on stock. This is an important decision because it can cost a large amount of money when the wrong decision is made. This decision can be wrong in two ways: too much or too little. In the first case the company holds too many items on stock and this will result in high holding costs.

In the other case there is a large probability of needing an item when it is not on stock, which results in (high) penalty costs. Therefore it is necessary that a company makes the best possible decision. The objective is to compute the minimum level of inventory for which it is necessary to place a new order when the stock drops below this level. While determining the reorder level, maximum &minimum stock following factor plays the vital role.

A. Determination for Reorder Level for automobile sector.
Data's collected from service sector:
Annual demandof totalspare parts, D = 6000
Average Lead time = 5 weeks
Ordering cost = 120
Probability of delay = 0.38
Assume a service level = 0.95
Max lead time = 3 weeks
Standard deviation =25
Carrying cost per unit year = 12.5% of purchase price
Purchase price, K = 10

- P-system- inventory levels for multiple stock items reviewed at same time - can be reordered together
- Q-system- each stock item reordered at different times - complex, no economies of scope or common prod./transport runs

Order quantity $= \sqrt{\left(\frac{2CoD}{P*Ce\%}\right)}$

$= \sqrt{\left(\frac{2*120*600}{10*0.14*0.125}\right)}$

$= 1073.3126 \approx 1073$ units

1) Determination Of Reorder Level For "Q System"

i) Demand during lead time, PLT $= \left(\frac{6000}{52}\right) \times 5$

= 576.92

≈ 577 units

ii) SD in demand during lead time = $\left(\text{Lead time}^{1/2}\right) \times \text{Standard deviation per week}$

$= \sqrt{5} \times 25$

= 55.90 ≈ 56 units

iii) Safety stock = k * δ

= 1.64*56

= 91.676 ≈92units

iv) Average demand during delivery delays

$= \left(\frac{\text{D}\times\text{Maximumdel ay}}{\text{No .ofweeksperyr}}\right) \times \text{Probabilityofminimumdelay}$

= 131.53≈ 132units

v) Reorder level = Demand during lead time

+Variation in demand during lead time

+Average demand during delivery (Avg. stock)

= 577+92+132

= 801 units

2) Determination of Maximum Inventory Level ForPeriodicsystem

i) Review period $= {EoQ}/{D}$

$= {1073}/{6000}$

= 0.178 years*52

= 9.256 weeks

The review period can either be 9weeks (or) 10weeks

ii) Specification of review period

Total cost when review period = 9 week

Total cost =Ordering cost + Carrying cost

=(52/9)*120+ (6000/52*9)/2* 10*0.125

= Rs 1342.3675

= Rs 1343

Total cost during review period =10 weeks

Total cost = Ordering cost + Carrying cost

(52/10)*120+ (6000/52*9)/2*10*0.125

= 1345.15

≈ Rs 1346

The total cost is minimum when the review period is 9 weeks

Hence the review period is 9 weeks

Demand during lead time and review period

$=\left(\frac{6000}{52}\right) \times (3+9)$

= 1385 units (Approx.)

Safety stock during lead time and review period

$= (3+9)^{1/2} \times \sigma \text{ } per \text{ } week \times k$

= 142.028 units

Where k = 1.64, Service level = 0.95

Avg. demand at delivery delay (Reserve stock)

$=\left(\frac{\text{D}\times\text{Maxdelay}}{\text{No .ofweeksperyear}} \times \text{Probabilityof max delay}\right)$

$= \frac{6000}{52} \times 3 \times 0.38$

= 132 units

Maximum inventory level = Demand during lead time & review period+ Safety stock during lead time & review + Avg. demand during delivery delay

= 1385+142+132

=1659 units

V. CONCLUSION

All the works that carried out here in this paper aims to keep up optimal inventory level in an automobile sector. This is the case for all problem sizes, for various part types and spare type. By doing so far the shortages in the spare parts and unavailability of spares can be made minimum compared to the previous methods which are adopted in the automobile sector. In future the further analysis is made to check out for the spare parts unavailability by using other optimization techniques.

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