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Optimization of Workplace Layout by Using Sensitivity Analysis: A Case Study

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Abstract: ***Now a day there is competition in market to make available the product in a optimum quantity and within a forecasted dates with a good quality. To fulfill this condition we need to install new quality tools available in market which are costly and forced to uninstall the unnecessary operations. In this paper the case study is discussed which helps to optimize the workplace layout by using method study & Sensitivity analysis. Case study is carried out on Assembly of rear axle carrier of a tractor from Automobile Industry.***

Keywords: **- Time and Motion Study, Workstation Design, Sensitivity analysis, Stop Watch.**

I. INTRODUCTION

The productivity improvement is the vital part of manufacturing system to satisfy the market demand which will be based on the efficiency of man i.e. operator is highly depending on how well the workstation is designed ergonomically, where as the efficiency of machine is more depends upon its utilization. Whereas the efficiency of both i.e. man and machine is highly affected by methodology adopted in the manufacturing system. As unnecessary and unproductive movements and operation will cause the fatigue to operator as well as improper machine utilization. To analyze the task in the manufacturing, proper production scheduling is very important. In the present work, assembly task at one of the leading tractor manufacturing company in India is studied to achieve optimum performance evaluation of the productivity. In the present work the study regarding the workplace layout, number of components involved, movement of workers, available tools and their location etc. were analyzed.

This layout critically analyzed and found the scope of implementation. In reduction to time study we have again analyzed the system in total and divided into parts and tried to record the time for every operation. In flow process chart the analysis of work station has been carried out and in this analysis we found that in critical analysis helped us to remove unwanted activities. Work ergonomics study revealed that the Heart rates and total comfort of worker is higher level as compared to existing one.

II. LITERATURE REVIEW

A significant amount of research work on Time study and Motion study, Modeling and Simulation, Productivity improvement and Ergonomic study has been published Mr. Gurunath V Shinde 1, Prof.V.S.Jadhav *2, investigate lots of money on man, machine, material, method (4m),improving ergonomics of workplaces is cost saving. Ergonomics found great need when market demand is high and manufacturers need more output within short period. This study was conducted on assembly workstation of welding shop. This work was conducted on an assembly station in welding shop. The shop was facing problem of less efficiency of workers due to poor ergonomics and in some severe cases hazardous health issues are found. This work was conducted on an assembly station in welding shop. The shop was facing problem of less efficiency of workers due to poor ergonomics and in some severe cases hazardous health issues are found [1]. Baba Md Deros 1 , Nor Kamaliana Khamis 1,Ahmad Rasdan Ismail 2, suggested the concept of high demand for products in the manufacturing industry had driven the human workers to work faster and adapt to their un-ergonomically designed workstation. This study was conducted at an automotive component manufacturer and shows current assembly workstation at company a need to be redesign to eliminate awkward postures and anthropometric mismatches to lower MSDs problem and improve productivity among assembly workers [2]. Mr. Gurunath V. Shinde 1, Prof.V.S.Jadhav 2, identify complex tasks which lead to less efficiency of worker. Various approaches had been developing including direct observations, questionnaires, interview, etc. for ergonomic evaluation of workstation. This technique of ergonomic analysis is very useful to identify complex tasks and root cause of each complex task which is useful in simplifying it and hence to reduce stress on various workers movements [3].

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III. PROBLEM IDENTIFICATION AND IMPLEMENTATION

For problem identification time study and motion study technique is used. Using this time study and motion study technique time required for each operation is calculated by using stop watch technique for existing setup. After calculating of time for each operation, flow process chart has been prepared. From study of flow process chart the unwanted activity where critically analyzed.

Table 1:- Total Parts for Station

Sr. No.	Name of Part	No. of Parts
1.	Retainer	1
2.	Oil Seal	2
3.	Gasket	1
4.	Axle	1
5.	Ball Bearing (Axle)	1
Total Part for Station 1		**6**

This study was conducted at a workstation for the assembly of Rear Axle Carrier. This assembly operation involves 27 components. The entire component was assembled by manual process. The total assembly process was carried out on three different process stations. The assembly of the component of each as follows:

Table 2:- Total Parts for Station 2

Sr. No	Name of Part	No. of Parts
6.	Circlip (Rear Axle)	1
7.	Pr. Bearing (Carrier)	1
8.	Spacer (Carrier)	1
9.	Carrier	1
10.	Collar	1
11.	Bolts	4
12.	Washer	4
Total Part for Station 2		**13**

1

Table 3:- Total Parts for Station 3

Sr. No.	Name of Part	No. of Parts
13.	Long D – headed wheel bolt	8
Total Part for Station 3		**8**

Total Part for Station 1, 2 & 3:- (6+13+8) = **27.**

IV. ANALYSIS OF WORK PLACE LAYOUT

The existing layout for the assembly of Rear Axle Carrier (RAC) is as shown in Figure 1. As shown in Figure No. 1 it consists of three in line assembly workstation namely station 1, 2 and 3. Material flow was successive from station 1 to station 2 then from station 2 to station 3. To assist the operator for the material flow roller conveyor (manually operated), and cranes are used. Assembly operation at station 1 involves the assembly of 6 components as shown in table no.1 out of which retainers are stores in the retainer rack which was located just behind the operator as shown in Fig. No.1. Also the oil seal, gasket, bearing and the axle are located surrounding the workplace as shown in Fig. No.1. During each assembly operator has to move at each of these locations and collects the parts for the assembly. Similarly the components required assembly station 2 and 3 is to be connected by the operator from the various storage locations surrounding the workplace as shown in the Fig. No.1.

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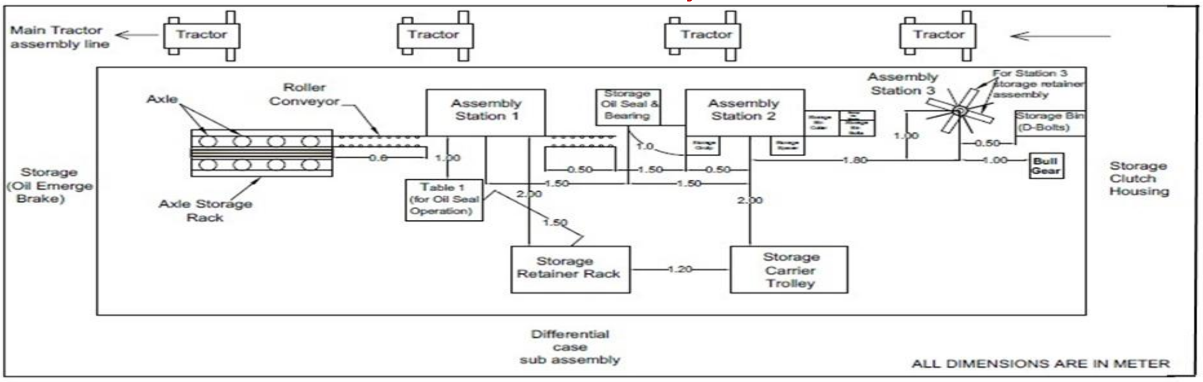

LAYOUT :- REAR AXLE CARRIER ASSEMBLY OF TRACTOR (Existing)

Fig. 1:- Rear Axle Carrier Assembly of Tractor (Existing)

V. FLOW PROCESS CHARTS

From the above workplace layout and the nature of assembly involved requires several activity at each station 1, 2 and 3. For example at assembly station 1 total 51 activities of the time 6.04 min are involved. At assembly station 2 total 38 activities of the time 5.21 min and 24 activities of the 4.02 min are involves at station 3. Accordingly the flow process chart of the material for each of the assembly station is developed. The sample flow process chart for station 1 is shown in Table No. 4.

FLOW PROCESS CHART - MATERIAL TYPE (STATION 1)

TABLE 4:- Sample Flow Process Chart - Material Type (Assembly Station 1)

FLOW PROCESS CHART MATERIAL TYPE				
CHART NO. SHEET NO.	SUMMARY			
Subject charted Used bus engines	ACTIVITY	PRESENT	PROPOSED	SAVING
	OPERATION ○ TRANSPORT ⇨ DELAY D INSPECTION □ STORAGE △	38 08 02 01 02	34 05 02 01 02	04 03 - - -
ACTIVITY Stripping cleaning and degreasing prior to inspection METHOD: PRESENT	DISTANCE (m)	-	-	-
LOCATION: Degreasing Shop	TIME (man-min)	-	-	-
OPERATIVE(S): CLOCK Nos.	COST LABOUR MATERIAL	- - -	- - -	- - -
CHARTED BY: APPROVED BY: DATE:	TOTAL	-	-	-

	DESCRIPTION	**QTY**	**DISTANCE (m)**	**TIME (sec)**	**SYMBOL**					**REMARKS**
					○	⇨	D	□	△	
1.	Retainer stored in trolley near assembly station 1		-	00						
2.	Pickup the retainer from retainer rack		-	6.82						

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3.	Move to table 1		1.5	11.64						
4.	Pickup the oil seal from table 1		-	6.48						

Similarly material flow process chart for the assembly station 2 and assembly station 3 is also developed. In the same way for Assembly station 1 total 8 readings are taken and the mean is taken as follows:

The mean time required per day is as follows

Table 5:- Eight reading mean time for assembly station 1

Day	**Time in min**
1	5.641
2	5.647
3	5.635
4	5.605
5	5.601
6	5.658
7	5.575
8	5.707
Mean time	**5.633 min**

Total mean time required for **station 1** = **5.633 min.**

Similarly **mean time required** for the assembly station 2 and assembly station 3 are determined.

Mean Total time required for the operation =

= Time of Station 1 + Time of Station 2 + Time of Station 3

= 5.633 + 4.825 + 3.513

= 14.37 min.

VI. CRITICAL ANALYSIS BY USING FLOW PROCESS CHARTS

From the above developed flow process chart each of the activity involved at all the 3 station were critically analyzed for the evaluation of the purpose of the each activity. This evaluation is done by finding the answers to the Primary and Secondary questions such as what is achieved through that activity, is that activity is necessary, can it be eliminated, what else might be done etc. from this critically analysis unnecessary and unproductive activities for the assembly operation at each of the workstation is determined. Accordingly the critical analysis charts for unnecessary and unproductive activities are developed. The sample critical analysis chart for station1 in table no. 6. Similarly critical analysis chart for the assembly station 2 is also developed.

TABLE 6:- Sample Critical Analysis Chart (Assembly Station 1)

SUBJECT OF CHART: - Rear axle carrier (RAC) assembly station 1, 2 and 3. **CHART NO. :-**			
ACTIVITY	**PRIMARY QUESTIONS**	**SECONDARY QUESTIONS**	**REMARKS**
<u>PURPOSE</u> 2) Pickup the retainer from retainer rack 3) Move to table 1 4) Pickup the oil seal from table 1 5) Move retainer and oil seal to assembly station 1	**What is achieved?** ➢ Retainer is pickup by the operator from retainer rack and then move up to table 1 from where he pickup the oil seal and move up to station 1 where he place the oil seal on station 1. **Is the activity necessary?** ➢ Yes, this activity is necessary for performing the operation for a human operator.	**What else might be done?** ➢ The retainer is stored in a bin which is mounted above side of gravity conveyor. This gravity conveyor can be mounting on the left side of assembly station 1 for incoming of retainer on a platform of assembly station 1. Similarly the bin for oil seal can be stored on a right side of assembly station 1 within maximum working area.	For eliminating the unwanted movement of operator, here we used the gravity conveyor for incoming of retainer and place bin for storing oil seal within maximum area. So we can eliminate the unnecessary motion of the operator and save the production time and can increase productivity.

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VII. PROPOSED IMPROVEMENT IN THE WORKPLACE LAYOUT

On the critical analysis for assembly station 1 it was found that activity no. 2, 3, 4, 5, 6, 39, and 40 where unnecessary and can be replaced by making certain suitable arrangement in the workplace layout. For example activity no. 2 to 6 involves movement of the worker from the workstation to the storage location for picking and transporting retainers and oil seals to assembly station 1. This amount of the worker can be eliminated by gravity conveyor for the retainer located near the station 1 which will make constant supply of retainer at the assembly station; similarly special storage bin for the oil seal can be located within the reach of the operator near the assembly station 1. This will eliminate the need of movement of worker for each assembly operation and will result in saving of time. Similarly activity 39 and 40 involved movement and pickup of the bearing of the worker. This activity was consuming the total time of 1.481 min. These are tabulated below: **Previous layout:-** From this table it is seen that

Table 7:- Existing layout unnecessary operation for station 1 and Station 2

Station	Operation No.	Description for Existing layout
Station 1	Operation 2	Pickup the retainer from retainer rack
	Operation 3	Move to table 1
	Operation 4	Pickup the oil seal from table 1
	Operation 5	Move retainer and oil seal to assembly station 1
	Operation 6	Placed the oil seal on station 1
	Operation 39	Pick up the bearing on table 1
	Operation 40	Move bearing to station 1
Station 2	Operation 58	Pick up the bearing from storage (labour 2)
	Operation 59	Move bearing to assembly station 2 (labour 2)

Previous layout can be reduced by making the suitable arrangements as:-

By changing previous process as

Table 8:- Existing layout unnecessary operation for station 1 and Station 2

<table>
<tr><th>Station</th><th>Operation No.</th><th>Description for Actual (Improve) layout</th></tr>
<tr><td rowspan="7">Station 1</td><td>Operation 2</td><td rowspan="2">By providing the gravity conveyor system near assembly station 1 instead of retainer rack to avoid operation 2 and 3.</td></tr>
<tr><td>Operation 3</td></tr>
<tr><td>Operation 4</td><td rowspan="3">This operation is canceled out by providing bin system near assembly station 1. So as to avoid the operation on table 1.</td></tr>
<tr><td>Operation 5</td></tr>
<tr><td>Operation 6</td></tr>
<tr><td>Operation 39</td><td rowspan="2">By providing bin for storage of bearing near assembly station 1. So as to avoid operation 39 and 40.</td></tr>
<tr><td>Operation 40</td></tr>
<tr><td rowspan="2">Station 2</td><td>Operation 58</td><td rowspan="2">By providing bin near assembly station 2 to store bearing and subsequently to avoid the operation 58 and 59.</td></tr>
<tr><td>Operation 59</td></tr>
</table>

After critical analysis total **mean time required as given in the table:-**

Table 9:- Eight reading mean time for assembly station 1 and assembly station 2

Day	Time in min
1	1.369
2	1.518
3	1.480
4	1.450
5	1.537
6	1.443
7	1.513
8	1.538
Mean time	**1.481 min**

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After critical analysis total mean time required for **station 1, 2 and 3 = 1.481min.**
From the above suggested changes the proposed improved workplace layout is as shown in Fig. No. 2.

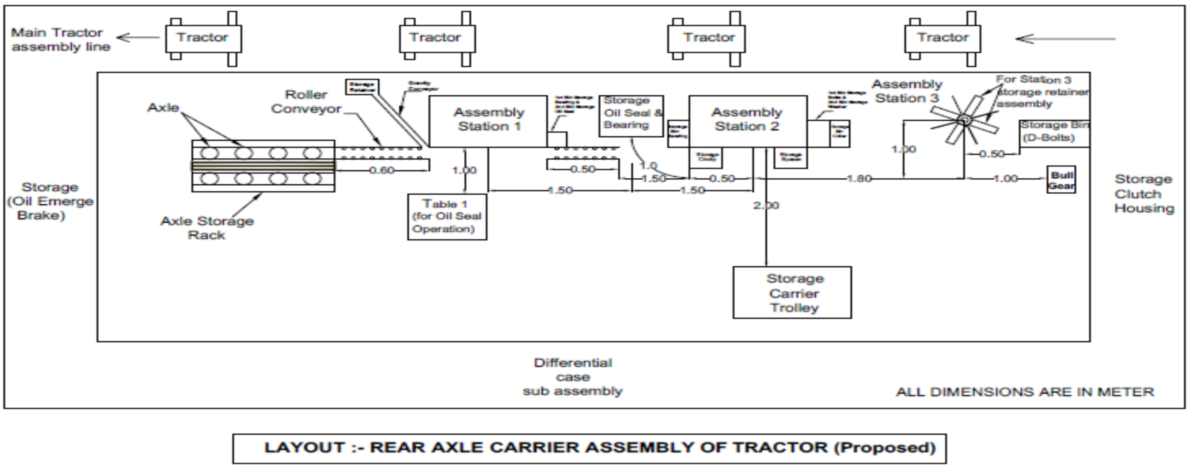

Fig. 2:- Rear Axle Carrier Assembly of Tractor (Proposed)

Total time for whole activity by using stop watch = 14.37 min.
Total time after critical analysis which can be reduced = 1.48 min.
Time can be reduced = 14.37 - 1.48 = 12.49 min.
Previous total time for whole activity (Company Data) = 13.37 min.
Total time save after implementing the suggestion = 13.37 - 12.49 = **48 sec.**

Total time saves for 8 hour shift:-

Total time save after implementing the suggestion for **one** RAC assembly = **48 sec.**
Total time save for assembly of **two** RAC assembly = **1.36 min.**
For 8 hour shift **70 tractors assemble.**
Total time optimize (1.36 x 70) = **1 hour 35 min time save for 8 hour shift.**

VIII. RESULT AND DISCUSSION

SENSITIVITY ANALYSIS

In the sensitivity analysis we have analysis the time required for existing work layout and the proposed work layout. The sensitivity analysis method in which we have obtained the result for minimizing time and improve the production. This result is plotted on the graph for existing layout and proposed layout.

Plot the graph for above equation existing data:-

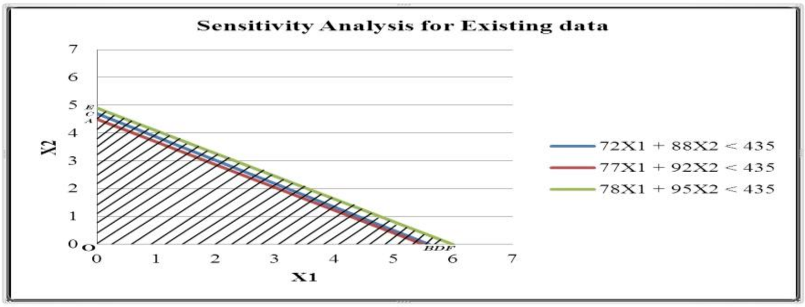

Fig. 6:- Sensitivity analysis for existing data

The minimum value of Z > 0 is Z_{min} = 23.64.
Minimum time required to complete the process is Z_{min} = 23.64.
Hence minimum time required to complete the process $X_1 = 0$, $X_2 = 4.9$ and
Z_{min} = 23.64.

Plot the graph for above equation proposed data:-

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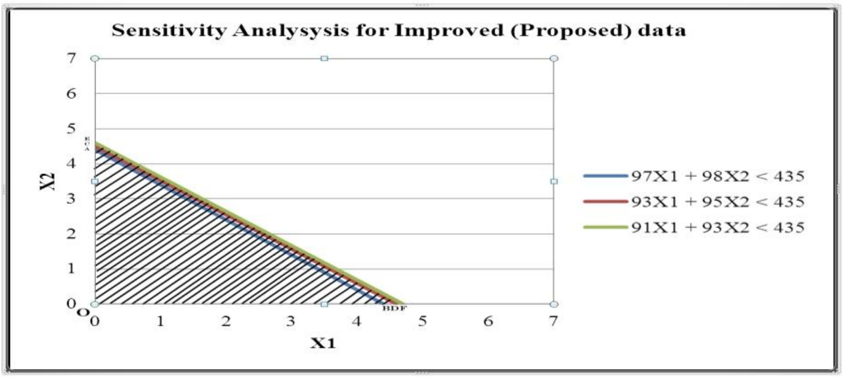

Fig. 7:- Sensitivity analysis for proposed data

The minimum value of Z > 0 is Z_{min} = 20.59.
Minimum time required to complete the process is Z_{min} = 20.59.
Hence minimum time required to complete the process X_1 = 0, X_2 = 4.6 and
Z_{min} = 20.59.

Existing layout **Z_{min} = 23.64** minimum time/day for assembling component for assembly station. Improved layout **Z_{min} = 20.59** minimum time /day for assembling component for assembly station. For solving sensitivity analysis method reduced improved (proposed) assembly station time and to increase production rate for improved (proposed) layout.

IX. COMPARISON BETWEEN EXISTING LAYOUT AND PROPOSED LAYOUT BY USING SENSITIVITY ANALYSIS

In the case where we have carried out the optimization of existing layout by using sensitivity analysis. As the production rate is very much depends on the time, so to improve in time required automatically increases production rate. In sensitivity analysis we have analyze the existing layout and proposed layout, so from this we have found the time required for carried out assembly of component is maximum **Z_{min} = 23.64** and for proposed layout the time required **Z_{min} = 20.59** is minimum. From this obtained data we have plot the graph for existing layout and proposed layout. In which graph shown the variation of production with respect to time.

X. CONCLUSION

In my project work in which I have theoretically studied time study, motion study and ergonomics on the leading tractor manufacturing company. The result I found in critical analysis is that by the time study and motion study some of the unnecessary operations are combined and modified the flow process in proposed one helps us to reduce time by certain modification in nearby assembly station. These said modifications in workplace layout are designed ergonomically as well. With this improved layout the total time 48 sec per cycle was found to be reduced. Hence the above result helped us to reduce time and motion ultimately improves production.

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