Continuous improvement: based on a systemic approach in electrical components company

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Abstract: The objective of this article is to develop method study as the most accurate tool of setting standards of performance and continuous improvement activities for measuring productivity in an electrical components company. The study discusses the steps of the method study approach and presents a case study from industrial sector where the approach has been applied with 27 products (distribution boards). This article identifies the advantages and reasons for use of method study which is relatively cheap, easy to apply and has a wide range of applications. The results of this research showed important facts perceived by the method study in productivity improvement. There are some problems concerning material handling; there is a delay due to the transportation. It has been found that storage areas are insufficient. Both the storage areas and workstations are not well organized. A new design of the working tables and provision of newly designed buffer containers will result in well-organized workstations. Operations will be improved and time will be dramatically reduced by using the proper tool. The main limitation is that the 27 products used in the study are less than 50% of the total products. The practical implication of this research is implementing and using methods improvement for specific benefits of the organization and that management now knows which advantages are to be expected. This paper describes the work-study approach, which has been successfully used for productivity improvement. It helps to discover non-value added areas of waste. Recommendations and suggestions are given.

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1. Introduction

Work-study is a term used to embrace the techniques of method study, and work measurements which are employed to ensure the best possible use of human and material resources in carrying out a specified activity. Work-study is thus especially concerned with productivity, since it is used to increase the amount of product from a given quantity of resources without further capital investment. Productivity is the ratio between output and input. Productivity is frequently measured as the output of goods or services in a given number of man –hours. This is why work-study is considered as a direct means of rising productivity. Work-study consists of motion (method) study and time study (work measurement).

Work-study has been applied in different fields as follows:

Yeomans K1, Payne KA1, and et. Al. (2013) decided that time and motion (T&M) studies quantify time-related outcomes. Any given intervention process can be broken down into a set of pre-defined tasks for repeated observations, allowing estimation of the mean task durations in support of health economic analyses. Chuan Huang, E.P. et al. (2013) said that to identify the timeliness of the overall and of each essential step in the deployment of a piston-type mechanical devices MD during emergency department (ED) resuscitation, and to identify factors associated with delayed MD deployment by video recordings, and time-motion study. Mallidou, A.A. et al.(2013) reported that re-organizing healthcare aides' routine practices may minimize the short one-to-three minute intervals spent on direct care activities, which can be interpreted as interruptions to continuity of care or waste of time. Fewer interruptions may allow healthcare aides to use their time with residents more effectively. Al-Saleh,K.S. (2011) presented a study carried out at the Motor Vehicle Periodic Inspection (MVPI) station to improve and enhance the bottleneck inspection point by using different applications to reduce the inspection time using motion and time study techniques. PharmD, S.M.W.,et al.(2011) present a direct time and motion observation study completed with pharmacy faculty members in family medicine residency clinics. All activities were timed, recorded, and classified into specific categories of activity types. Pharmacy practice faculty in family medicine residency programs dedicate most of their time (51%) to patient care activities, followed by (21%) teaching pharmacy learners. Abbey Mphil, M. et al.,(2011) described and analyzed the work activities of bedside Intensive Care Unit (ICU) nurses during the day shift. Time and motion observational methodology was used to observe 10 bedside ICU nurses during the day shift, Monday to Friday. All activities undertaken by the nurses during their shift were timed and recorded. The major work activity groups for the ICU nurses were; 'direct care' 1857 activities and 40.5% of their time, 'indirect care' 986 activities and 32.4% of their time, 'personal' activities 140 activities and 21.9% of their time and 'unit-related' 98 activities and 5.0% of their time. Abdul,S.S. et al.(2010) reported that the adoption of electronic medical record (EMR) system is gradually increasing. However, various time–motion studies reveal conflicting data regarding time effectiveness on workflow due to computerization. One of the major issues for physicians is their uncertainty with EMRs' potential impact of time on workflow. Rebmann,T. et al.(2009) presented a study intended to quantify and compare the time required to administer organophosphate antidotes using traditional equipment vs. auto-injectors in different treatment conditions. Wiedenmayer, K.A. et al.(2009) reported that an observational time-motion study investigated logistic, programmatic and safety-related advantages and limits in the delivery of a fully liquid DTP–HepB–Hib combination vaccine versus a lyophilized combination vaccine requiring reconstitution. Van de Werf, E. et al.(2009) decided that time measurements were performed on daily treatment delivery with the aim to quantify the impact of quality assurance (QA) using an electronic portal imaging device (EPID) on RT delivery time and to validate the time burden of intensity modulated radiation therapy (IMRT) as an example of advanced technology. Van de Werf, E. et al.(2009) decided that time measurements were performed on daily treatment delivery with the aim to quantify the impact of quality assurance (QA) using an electronic portal imaging device (EPID) on RT delivery time and to validate the time burden of intensity modulated radiation therapy (IMRT) as an example of advanced technology. Lindsell CJ, Raab D, et al. (2008) reported that time-and-motion observations of the assay process were conducted in a community ED with an annual census of 35,000. Observations were made in duplicate by trained observers. Gavin C. Harewood, MD, and et al(2008) presented study adopted a time-and-motion approach to assess efficiency in the endoscopy unit of a large teaching hospital and to identify strategies enhancing efficiency. Ko.C.S., Cha.M.S. and Rho.J.J.(2007) presented two approaches for determining standard time in a multi-pattern and short life-cycle production system. By applying these approaches, the company can establish a basic data system for operating a wage incentive program electively. Washington.M.L. et al (2005) presented work study to reduce vaccination time for 497 children. Kreulen, C.M. et al. (2000) reported that class II copy-milled ceramic inlays according to time-and-motion study required about 125 min of working time. Working time increased by applying composite basing and making large restorations. The dentist influenced working times, while efficiency increased over time. Dentists needed more laboratory time to produce an inlay than the dental technician did.

Previous mentioned studies revealled that work-study is a systematic recording and critical examination of existing and proposed ways of doing work, as mean of developing and applying easier and more effective methods and reducing costs. The main aim for the present work is to increase the productivity after conducting a method study in the assembly workshop of the electrical components company.

2. Results

2.1 Product description

Electrical Industries Company in Egypt is implementing a new development plan for its factory. The present study concerns with 27 products. The product consists mainly of housing, TP+N pan assembly an internal cover and a door as shown in figure (1)

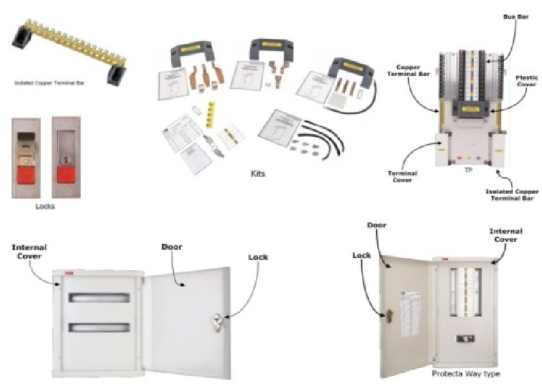

Figure (1) Main Components of the products

2.2 Methodology

2.2.1 Motion study for the present method

Motion study is the systematic recording and critical examination of existing and proposed ways of doing work and the development and application of easier and more effective methods. Before improvements can be made, the current productivity level of the company must be measured. This measurement is then used as a baseline to determine if improvement projects have satisfied the aims and have resulted in genuine improvement. Motion study helps to discover non-value added areas of waste.

The objectives of motion study are:

a. The improvement of processes and procedures;
b. The improvement of factory, shop and work place layout and the design of plant and equipment;
c. Economy in human effort and the reduction of unnecessary fatigue;
d. Improvement of materials' usage, machines and manpower;
e. Identification of barriers to productivity;
f. Improving time management.

2.2.2 The motion study outputs of the present method

Generally, the assembly workshop has adopted the product layouts for subassembly of the TP and the door. In product layouts, a job is divided into a series of tasks arranged in sequence and the products are transported between operations. For final assembly of the TP, internal cover and door in the housing, the assembly workshop adopted the fixed-position type of layout as shown in Fig (2). In fixed-position layouts, the item being worked on remains stationary, workers, materials, and equipment are moved as needed. This is proper layout in contrast to product layouts, since fixed-position layouts are usually used in large products such as ships, aircrafts and space mission rockets.

Figure (2) Photograph of the housing distribution on the table

The motion study for the product implies preparation and analysis of the following charts as right/ left hand charts, multiple activity charts, flow process charts, flow diagram chart and outline process charts:

T15, T19:T25 Assembly processes

Left Hand Description	Right Hand Description
Adjust the T.P.	Adjust the T.P.
Pick the bus bar holder	Pick screw driver
Pick and adjust screw	Hold the screw driver
Adjust the bus bar holder	Hold the screw driver
Hold the bus bar holder	Screwing
Pick and adjust screw	Hold the screw driver
Pick and adjust the bus bar holder	Hold the screw driver
Hold the bus bar holder	Screwing
Pick the Aluminum bar	Hold the screw driver
Pick and adjust screw	Hold the screw driver
Adjust the Aluminum bar	Hold the screw driver
Hold the Aluminum bar	Screwing
Pick and adjust screw	Hold the screw driver
Adjust the Aluminum bar	Hold the screw driver
Hold the Aluminum bar	Screwing
Pick and adjust screw	Hold the screw driver
Pick and adjust the metal end	Hold the screw driver
Hold the metal end	Screwing
Pick and adjust screw	Hold the screw driver
Pick and adjust the metal end	Hold the screw driver
Hold the metal end	Screwing
Pick the hexagonal nut	Hold the screw driver
Adjust the hexagonal nut	Hold the screw driver
Hold the hexagonal nut	Screwing
Storing	Storing

Summary

Now			Suggested		
Method	Left H.	Right H.	Left H.	Right H.	Method
Operation ○	0	2			Operation ○
Transportation ⇨	3	6			Transportation ⇨
Delay D	0	0			Delay D
Storing ▽	5	0			Storing ▽
Inspection □	0	0			Inspection □
Total	8	8			Total

Fig (3) Right/ Left hand charts

Chart Number					
Part name: T.P.			Part Number		
Product: Protecta 4 way +DIN Rail			Prepared by Eng.: Yasser Bouka Revised by		
O.N	Distance	Symbol	O.T	Activity	Type of Activity
T1	310	⇨	1200.0	Transport P.A. from the paint storage area.	Non Productive
T2		○	21.0	Threading.	Productive
T3		○	21.4	Paint removal.	Productive
T5	4	⇨	273.5	Transport to labeling operation.	Non Productive
T6		○	63.4	Labeling.	Productive
T8	7	⇨	436.0	Transport to parts assembly process	Non Productive
T15		○	63.2	Fix the isolated cupper terminal bars (start of parts assembly process).	Productive
T19		○	20.8	Fix the hexagonal nut with the isolated cupper terminal bars.	Productive
T20		○	14.2	Fix the jumper between the isolated terminal bars.	Productive
T21		○	47.4	Fix the cupper terminal bars.	Productive
T22		○	17.0	Fix the hexagonal nut with the cupper terminal bars.	Productive
T23		○	28.6	Fix the bus bar holders.	Productive
T24		○	28.0	Fix the Aluminum bar.	Productive
T25		○	36.6	Fix the metal stopper.	Productive
T27	11	⇨	165.0	Transport to bus bar fixing process.	Non Productive
T28		○	48.8	Fix the bus bar.	Productive

Fig (4). Flow Process Chart

Chart number sheet 1 of 1	Brief			
The Recorded Subject: Protecta 4 way +DIN Rail	Activity	The Present Situation	The suggested	Saving
	Operation ○	410.4		
Activity: T.P.	Transportation ⇨	2074.5		
	Delay D	4524.0		
	Inspection □			
	Storing ▽	1980.0		
	Distance in meters	332.0		
Location: Assembly workshop	Time (Man-Minute)			
Worker Name :	Cost Worker:			
Registered by :Yasser Bouka	Materials:			
Revised by:	Total			

O.N	Description Operation	Quantity	Distance in Meter	Time in Sec	Symbol ○	⇨	D	□	▽	Notes
T1	Transport P.A. from the paint storage area.		310	1200.0		•				
T2	Threading.			21.0	•					
T3	Paint removal.			21.4	•					
T4	Waiting for labeling process			1954.0			•			
T5	Transport to labeling operation.		4	273.5		•				
T6	Labeling.			63.4	•					
T7	Waiting for parts assembly process			1540.0			•			
T8	Transport to parts assembly process		7	436.0		•				
T15	Fix the isolated cupper terminal bars (start of parts assembly process).			63.2	•					
T19	Fix the hexagonal nut with the isolated cupper terminal bars.			20.8	•					
T20	Fix the jumper between the isolated terminal bars.			14.2	•					
T21	Fix the cupper terminal bars.			47.4	•					
T22	Fix the hexagonal nut with the cupper terminal bars.			17.0	•					
T23	Fix the bus bar holders.			28.6	•					
T24	Fix the Aluminum bar.			28.0	•					
T25	Fix the metal stopper.			36.6	•					
T26	Waiting for bus bar fixing process			1030.0			•			
T27	Transport to bus bar fixing process.		11	165.0		•				

Fig (5) .Man/Material flow process chart

The route distance between the central store and the assembly workshop is 150m. Also, the route distance between the painting workshop and the assembly workshop is 310m. This operation takes a long time and the adapted transportation method is unsafe. The flow process chart shown in figure (5) is a good tool for recording facts in method study. It is a device for visualizing a procedure for the purpose of improving it. Although the assembly workshop has adopted the product type of layouts for the subassembly of the TP-way type and the door, the flow of the TP-way type is inadequate. This is due to the improper location of the workstations. This arrangement implies intensive transportation and results in increasing the time and distance travelled in transportation activities. It also results in large number of in-process units in the line, which consequently causes delay. Additionally, it needs more workers for transportation. On the other hand, if the door assembly line is properly arranged, it would cause a smooth flow between the workstations. No transport activities are needed and a minimum number of in-process units are maintained in the assembly line. The assembly workshop adopts the fixed-position type of layouts in the subassembly of the TP row type and the housing. These products are not suitable for such type of layout. This arrangement causes:

a. The workers are standing all the time during working;
b. Fatigue of the workers consequently increases the standard time;
c. Increase in the distance travelled by the workers;
d. Large number of in-process units in the assembly line;
e. Large floor area;
f. Most of workers walk back and forth to multiple assembly stations to do their work. Walking from station to station wastes time that could be better used on production.

3. Discussion

This section includes the comments and remarks given by the work-study team from their observations and the collected data from the motion and time study charts. It also contains the suggestions and recommendations given by the work-study team to minimize the losses, maximize the outputs, improve the working conditions to the benefit of the workers' health and comfort, and to increase the productivity. General comments and suggestions which concern with the majority of activities for the assembly of the different products are given as below:

a. Although the factory is run by efficient, effective and experienced personnel, the factory in general, and the assembly workshop specially, are not well organized. This is attributed to the modifications, modernizations and alteration going on the factory while doing the work-study. This makes the factory in transient state, and it is hoped to finish such temporary stage as soon as possible. Generally, all levels of management, administration and workers try their best to run the factory smoothly and efficiently. There are many remarks and suggestions may increase the productivity of the factory;

b. Product Variety: there are large variations in products, models, parts option in the assembled product. Hence, the production is always interrupted during order for changeover (setup). This type of manufacturing policy is known as make-to-order policy. It is suggested to adopt the mixed, batch- model manufacturing system.

In the mixed model case, different parts or products are made by the manufacturing system, but the system is able to handle these differences without the need for a changeover in setup. This means that the mixture of different product can be produced continuously rather than in batches. The requirement for continuous production of different products is that the manufacturing system be designed so that whatever adjustments need to be made from one part or product type to the next, these adjustments can be made quickly enough that it is economical to produce the units in batch sizes of one. It is suggested to use many assembly lines. These lines are multi- station manual line with fixed routing. Discussion of the assembly workshop by the following:

3.1Operations;
3.2 Products and parts design;
3.3 Quality requirements;
3.4 Materials utilization;
3.5 Workplace layout;
3.6 Materials handling;
3.7 Working conditions.

3.1 Operations

The following recommendations are given after studying each of the operations. The results obtained by operations are necessary for productive and non-productive time as shown in figure (4) and figure (6).

A. Decreasing non productive operation
B. Increasing productive operations

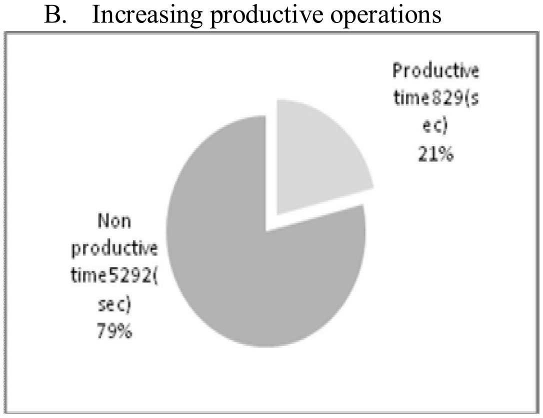

Figure (6) Productive and Non-Productive Time

3.1.1 Decreasing non-productive operation such as delay time in the form of

a. Waiting time between workshops and assembly workshop.

3.1.2 Increasing productive operations by:

a. Increasing the number of assemblers gradually;
b. Number of assembly lines can be increased gradually (start by 2 lines to 4 lines);
c. Assembly process sheet and inspectioncheck-list must be placed in every workstation.

3.1.3 Eliminating unnecessary operations

3.1.4 Combined operations

Operation for example stick label (ON – OFF) on internal cover can be combined in one label (ON-OFF OFF-ON). It is more effective than using separate labels.

3.2 Products and parts design

The design can be changed to simplify or eliminate some operation. The certain component parts recommended being standard and making limit time for customer requirements from changing the design on the assembly line.

3.3 Quality requirements

3.3. 1 Positive quality requirements

a. An agreement has been reached by all assemblers to acceptable quality level;
b. The assemblers inspect their work before inspector.

3.3.2 Negative quality requirements

a. The tolerance and other standards for inspection are unknown;
b. The same standards are not necessary for all customers;
c. The main causes of rejections for parts are threading, warping, locks defects and door closing.

3.3.3 Suggestions quality requirements

a. The inspection requirements for the operation must be written in every workstations;
b. The quality can be improved by using the incentive for zero defect workstation;
c. The finished quality of the repair painting products can be improved by painter instead of assembler;
d. The defective work can be reduced by reducing temporarily store time and improving material handling system.

3.4 Materials utilization

3.4.1 Positive materials utilization

a) The material used is suitable for job but the bolts can be replaced by special screw bolts for sheet metal directly without drilling;
b) Indirect materials which are used in connection with the assembly process such as paint, compressed air and electricity suitable, controlled and economized.

Negative materials' utilization

a. Some bolts are purchased in condition that do not suitable for work;
b. The pallets which are used to transport material between stations use the assembly workshop space excessively;
c. The location of stores and temporally stores can be improved to reduce handling and

transportation in and out of assembly workshop.

3.4.2 Suggestions materials utilization

a. Carton store must be improved, some carton conditions are not suitable for work;
b. Some material must be bought in more quantities such as bolts;
c. Material storage layout inside assembly workshop must be selected carefully.

3.5 Workplace layout

3.5.1 Negative workplace layout

Disadvantages and drawbacks due to present layout, there are excessive manual effort, disorganized storage, excessive walking and service areas (toilet) not conveniently located. The layout lacks of temporally storage areas.

3.5.2 Suggestions workplace layout

a. Some jigs and fixtures designed by workers are used. It is recommended to get it redesigned by a specialist;
b. It is recommended to make adequate working areas for subsidiary operations such as repair operations;
c. It is recommended to make facilities for storage and removal to scrap.

3.6 Materials' handling

a. It is recommended to use common signals such as lights and bells, etc;
b. Notifying workers that more material is required, save delay.

The location of stores and stockpiles could be changed to reduce handling and transportation

3.7 Working conditions

It is recommended to make sufficient lighting, and to install air conditions in assembly workstation to provide comfort, comfortable chairs for assemblers and cool drinking water near to assembly lines. Also safety factors must be taken in consideration.

3.7.1 Work study of the improved method

The factory follows the order-type production. There are a large number of product models. Even for the one model, there are variations in options according to the customer's requirements. For the reasons, there are a large number of product varieties. The assembly workshop should have the capacity to cope with such product varieties. It is a complex and challenging task to deal with product variety, as the products are made in batches (according to orders), and a changeover in physical step is required between batches. Changeover (setup) results in interruption of the production in the assembly line. These capabilities are often difficult to engineer. In manually operated manufacturing systems, human errors can cause problems (eg. operators do not perform the correct operations on different work unit types). Changing the physical setup is often the most challenging problem, and its solution becomes more difficult as part or product variety increases. Endowing a manufacturing system with flexibility increases its complexity. The material handling system must be designed to hold a variety of part shapes. Inspection becomes more complicated because of part variety. The suggested assembly workshop is shown in figure (7).

It consists of two assembly lines, each has three main cells (Tp, doors and housing cells).

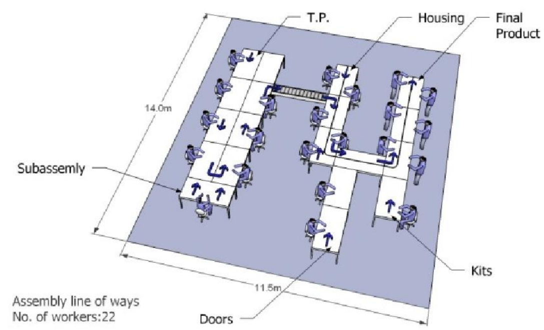

Fig (7) Assembly line for way-type products

In this improved method, the work study team tried to take all previews into consideration, the remarks and recommendations as shown in figure (7). It is necessary to obtain the approval of the company management for the improved method before proceeding to implement it.

3.7.2 Manual assembly lines

The majority of assembled products are usually made on a manual assembly line. Factors favoring the use of manual assembly lines include the following:

a. Demand for the product is high or medium;
b. The products made on the line are identical or similar;
c. The total work required to assemble the product can be divided into small work elements;
d. It is technologically impossible or economically infeasible to automate the assembly operations.

3.7.3 Assembly workstations

A workstation on manual assembly line is a designated location along the work flow path at which one or more work elements are performed by one or more workers. The work elements represent small portions of the total work that must be accomplished to assemble the product.

A given workstation also includes the tools (hand tools or powered tools) required to perform the task assigned to the station. Most of the workstations in the assembly line have the operation of fixing parts by screws and nuts, picking up a screw, putting up a screw, putting it in the hole is time consuming. It is suggested to use automatic feeder screw driver.

Some workstations are designed for workers to stand up, while others allow the workers to sit. When the workers stand, they can move around the station area to perform their assigned task. This is common for assembly of large products, such as cars, trucks and major appliances. For smaller assembled products (such as small appliances, electronic devices and subassemblies used on larger products), the workstations are usually designed to allow the workers to sit down while they perform their tasks. This is more comfortable and less fatiguing for the worker and is generally more conductive to precision and accuracy in the assembly task. It is recommended to use a table like that shown in fig (8).

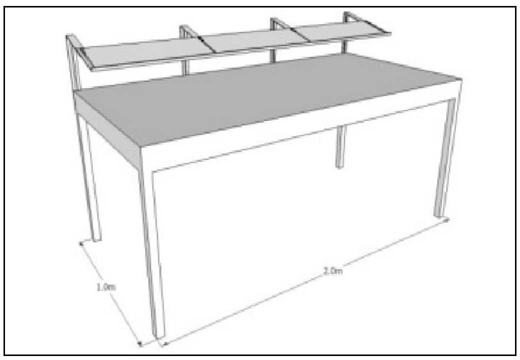

Fig (8): The suggested table

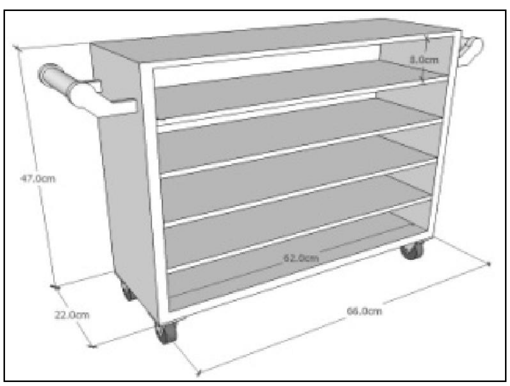

Fig (9) The suggested Buffer Containers

3.97.4 Types of assembly Lines

Because of the versatility of human workers, manual assembly lines can be designed to deal with differences in assembled products. Three types of assembly line can be distinguished: (1) single model, (2) batch model, and (3) mixed model. According to the above facts and presentation, it is recommended to adapt a batch model assembly line. However, the designer of a manual assembly line should not overlook certain factors, which may improve line performance. Following are some of the considerations:

a. Sharing work elements between two adjacent stations. If a particular work element result in a bottleneck operation at one station, while the adjacent station has an idle time, it might be possible for the element to be shared between the two stations perhaps alternating every other cycle;
b. Utility workers: they can be used to relieve congestion at stations that are temporarily overloaded;
c. Preassembly of components. To reduce the total amount of work done on the regular assembly line, certain subassemblies can be prepared off-line, either by another assembly cell in the plant or by purchasing them from an outside vendor that specializes in the type of processes required. Although it may seem simply same a mean of moving the work from one location to another.

There are some good reasons for organizing assembly operations in this manner.

a. The required process may be difficult to implement on the regular assembly line;
b. Task time variability for the associated assembly operations may result in a longer overall cycle time if done on the regular line;
c. An assembly cell set up in the plant or a vendor with certain special capabilities to perform the work may be able to achieve higher quality.

In the improved method, subassembly cells (each consists of some workstations) have been proved for the production of the TP, the door, mounting kits, neutral terminal and earth terminal bar kits, etc. Storage buffers between stations. A storage buffer is a location in the production line where work units are temporarily stored. Reasons to include one or more storage buffers in a production line include:

a. To accumulate work units between two stages of the line when their production rate are different;
b. To smooth production between stations with large task time variations;
c. To permit continued operation of certain sections of the line.

At the end of the subassembly line in the form of containers suitable for the shape, size and quantity of the subassembly. For example, TP is stacked in shelved containers as shown in figure (9).

3.7.5 Workshop layout

Proper layout is one of the keys of success in factory management. It signifies arrangement of machines, work stations, transport, storing of materials and processing of different parts. The layout for the same product maybe numerous but which costs less to process is the best. These are vary in size and type of plant.

The assembly workshop layout in the present work has been designed to fulfill the objects and to verify the principles of the layout. The old layout suffers from waste on transport and delays .This waste has been minimized in the improved layout. The transport has been reduced and the delay has almost been eliminated. Basic layout types are product, process and fixed-position. Product layout uses standardized processing operations to achieve smooth, rapid, high volume flow. Process layout can handle varied processing requirements. In fixed-position layout, the product remains stationary, and workers, materials and equipment are moved as needed. It is used for production of large products such as buses. The main advantages of product layouts are:

a. A high rate of output;
b. Low unit cost due to high volume; the high cost of specialized equipment is spread over many units;
c. Labor specialization that reduces training costs and time, and result in a wide span of supervision;
d. Low material-handling cost per unit; material handling is simplified because units follow the same sequence of operations;
e. A high utilization of labor and equipment;
f. Routing and scheduling encompassed in initial design of the system; they do not require much attention once the system is operating;
g. Accounting, purchasing, and inventory control are fairly routines.

The adopted layout represents a combination of the product and the fixed-position layouts. This is to benefit from the advantages and avoid the disadvantages of both layouts. The U-shaped layout is used in designing the assembly line. Although a straight production line may have intuitive appeal, a U-shaped line has a number of advantages that makes it worthy of consideration. One disadvantage of a long, straight line is that it interferes with cross travel of workers and vehicles. A U-shaped line is more compact; it often requires approximately half the length of a straight production line. In addition, a U-shaped line permits increased communication among workers on the line because workers are clustered, thus facilitating teamwork. Flexibility in work assignments increases because workers can handle not only adjacent station but also stations on opposite sides of the line. Moreover, materials enter the plant and finished products leave it, thus U-shaped line minimizes material handling.

3.7.6 Work-station layout

The work-station layout has been designed to verify the following:

a. Using the operator's hands to push the part in transportation between workstations;
b. Proper arrangement of the workstation;
c. Flow ability of the parts during processing;
d. Utilization of transportation.
e.

4. Flow diagrams:

To verify the flow ability of the product during processing, the routes of the parts in the assembly workshop have been modified. It is worth noting that the new design of the work-station causes flexibility in changing the flow line according to the product being produced. The flow line of the product can be easily and fastly changed according to the production program. In the improved method, some operations have been cancelled. The time and distance for each operation is expected to decrease dramatically. The exact time and distance will be measured after implementation of the new method. By using the flow diagram of the different parts in the assembly workshop, it could be seen that the parts are flowing smoothly and easily from first operation to the last one. Once the part has undergone the first operation, it travels from operation to operation until reaches the final operation. The transportation time is expected to be reduced to minimum. The distances traveled will also be reduced.

5. Conclusion

a. There are some problems concerning the material handling, suggestions have been given to solve these problems, such as designing special carts and cradles;
b. There is a delay due to the transportation, which is minimized by suggesting a new layout and improving the material handling;
c. It has been found that storage areas are not enough and not well organized. Enough storage areas have been provided in a suggested layout;
d. Workstations are not well organized. Recommendations and suggestions are given;
e. Operation will be improved and the time will be dramatically reduced by using the proper tool such as automatic feeding screw.

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