Productivity Improvement through Process Analysis for Optimizing Assembly Line in Packaging Industries

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Abstract

Assembly line balancing is to know how tasks are to be assigned to workstations, so that the predetermined goal is achieved. Minimization of the number of workstations and maximization of the production rate are the most common goals. This paper presents the actual case different components manufactured at industries in which productivity improvement is a prime concern and there is a necessity for balancing the operations at various strategic workstations in order to apply group technology and minimize the total production cost and number of workstations.

Index terms— a ssembly line balancing, workstations, production cost.

1 Introduction

ine Balancing means balancing the production line, or any assembly line. The main objective of line balancing is to distribute the task evenly over the work station so that idle time of man of machine can be minimized. Lime balancing aims at grouping the facilities or workers in an efficient pattern in order to obtain an optimum or most efficient balance of the capacities and flows of the production or assembly processes.

Assembly Line Balancing (ALB) is the term commonly used to refer to the decision process of assigning tasks to workstations in a serial production system. The task consists of elemental operations required to convert raw material in to finished goods. Line Balancing is a classic Operations Research optimization technique which has significant industrial importance in lean system. The concept of mass production essentially involves the Line Balancing in assembly of identical or interchangeable parts or components into the final product in various stages at different workstations. With the improvement in knowledge, the refinement in the application of line balancing procedure is also a must. Task allocation of each worker was achieved by assembly line balancing to increase an assembly efficiency and productivity.

i. Line Balancing ii. Single-Model Assembly Line iii. Mixed Model Assembly Line iv. Multi Model Assembly Line v. Non Value Added Costs This work is in continuous to the previous paper "Assembly Line Balancing: A review of developments and trends in approach to industrial application" which is published in "Global Journal of Researches in Engineering" of "Industrial Engineering", Vol. 13

(iv) Smoothness Index???? = ?? (?????????? ? ??????) 2 ?? ??=1**(4)**

Where,

Stamp -maximum station time (in most cases cycle time), STi -station time of station i.

(v) Balance Delay???? = [{(??) * (????) ? (? ?????? ?? ??=1)} {(??) * (????)} * 100% ?]**(5)**

2 b) Definations used in Line Balancing

The definitions of the some of the terms used in the course of case studies have been illustrated below:

3 c) Time Study in Line Balancing

Time study is a technique used to establish a time standard to perform a given assembly operation. It is based on the measuring the work content of the selected assembly, including any personal allowances and unavoidable delays. It is the primary step required to determine the opportunities that improve assembly operations and set production standards.

4 i. Operations Analysis

The operation analysis is a method used to identify and analyze the productive and non-productive activities described above by deployment of Lean elements and is concerned with developing techniques to improve productivity and reduce unit costs. Any operation improvement is a continuing process and with sufficient study of all the operations, they can be practically improved.

5 II.

6 Aims and Objectives of the Work

The aim of this work is to minimizing workloads and workers on the assembly line while meeting a required / maximum output. The aims and objectives of the present study are as follows:-

? To reduce production cost and improve productivity.

? To determine number of feasible workstation.

? To identify the location of bottleneck and eliminate them.

? To determine machinery and equipment according to assembly mechanism.

? To equally distribute the workloads among workmen to the assembly line.

? To optimize the production functions through construction of mix form of automation assembly and manual assembly.

? To minimize the total amount of idle time and equivalently minimizing the number of operators to do a given amount of work at a given assembly line speed.

7 III. Methodology: Steps for Improvement

Based in the study and works of other experts and authors, it has been observed that for the mixed model assembly line balancing, different steps and procedures have been planned, which have been shown in fig. **??**. Figure **??** : Steps followed for study of line balancing case study In the case of this work, the first step following methodology has been adopted for the study of line balancing under mixed model constant.

8 a) Product Selection Criteria

Product selection is critical as it provides focus to the project and produce tangible improvements in a timely manner. Trying to solve all problems at the same time creates confusion, inefficient use of resources and delays. Product selection refers to the process of identifying a "product" or "family" of similar products to be the target of an improvement project or study.

The selection of product was based on the following criteria: ? Customer importance and importance of the product to customer. ? Potential to improve overall operations. ? Potential to impact other products.

Different product family classification methods are available, the most dominant in usage being the following methods: a) A-B-C Classification Method b) Part-Process Matrix Method

Step 1 ? Study of present methodology

Step 2 ? Collection of data of present methodology Step 3 ? Analysis of data of present methodology

Step 4 ? Design of proposed methodology

Step 5 ? Collection of results of proposed methodology The time study was done in order to meet the key objectives of increasing productivity, determining the production capacities, evaluating standard cost and balancing the activities through proper planning and plant layout. ? It involves working conditions, which should be good, safe, and comfortable. Good working conditions have positive impact on the overall productivity. ? Material handling involves motion, storage and quantity of materials throughout the process. ? Other important operation analysis approaches is to simplify the operator body motion i.e. analyzing the operator's physical activity and reduce the work content. This approach helps to eliminate wasted motion, make operator tasks easy and reduce operator fatigue. ? Line layout to establish a production system that allows producing the desired quantity of products with desired quality at minimum cost.

9 c) Operations Analysis

An ideal layout is considered to be the one that provides adequate output at each work station without causing bottlenecks and interruptions to the production flow. A variety of assembly line layouts, as shown in Fig. 2, Fig. **??** Applying Lean thinking, the first step in increasing the assembly line productivity was to analyze the production tasks and its integral motions. The next step was to record each motion, the physical effort it takes, and the time it takes, also known as time and motion study. Then motions that were not needed can be eliminated also known as non-value added activities and any process improvement opportunity exists must be identified. Then, all the standardized tasks required to finish the product must be established in a logical sequence and the tools must be redesigned. If required, multiple stations can be designed and the line must be balanced accordingly. The distribution of work on each of these stations must be uniform. The productivity can be improved by incorporating a dedicated material handling system. This allows assembly operators to concentrate on the essential tasks.

Some of the most critical components of an assembly line are given as follows: ? Process design or standardization ? Line balance ? Material handling ? Parts procurement and feeding ? Work-in-process management ? Man power ? Line size ? Line configuration Then, the work elements will be assigned to these numbers of stations, one at a time, by meeting cycle time requirements and precedence constraints.

IV.

10 Case Study

The three step productivity improvement methodology was applied to a real problem consisting of a manual assembly line. The assembly line contains mobile phone package assembly operations. The process involves initial disassembly, light assembly and inspection operations. Each package came in a master box which contains ten such packages as shown in Fig. 5. Once all the packages are ready, were placed in an empty master box and the master box was moved to bar-coding area and then to the shipping area. In the original assembly method, the input buffer has no pre-specified capacity. The master boxes were piled at both input and output sides of the assembly table in stacks using storage pallets. Each pallet holds approximately 40 to 60 master boxes. The individual packages were then removed from the master box on to the table, all at a time, and the assembly is carried out on each package by four different operators. The subassemblies and the headset components were pushed from one person to the next person on the table without an appropriate material handling arrangement. Once the assembly was completed, the packages were arranged in an empty master box and placed on storage pallet. These finished master boxes were then carried to bar coding area manually by an operator.

11 b) Present Work Study

The first step in productivity improvement methodology was the present work study. For the current scenario, almost all the models produced have the similar processing steps. Hence, the product selection step has less significance in this context. In the next step, the current process was studied and all the assembly work elements were listed. Time studies were then carried out and the data obtained was analyzed to identify bottle neck situations and establish production standards. The precedence network diagram is drawn by the plant engineers for the original assembly process as shown in Fig. 7.

The target given for this assembly line was 35 boxes/operator/hour. Due to the drawbacks associated with this method, the actual measured assembly output is observed to be 29.8 boxes/operator/hour. From the process study and the network diagram, it can be seen that the assembly line has large scope for improvement by careful analysis. The next step explores these opportunities and develops methods to perform the assembly better. The process / component list for a single package is as follows: c) Analysis and To-Be System The next step, operations analysis, helps to identify improvement opportunities by highlighting productive and non-productive operations. This step also facilitates effective ways of doing things by suggesting alternate methods to perform operations to reduce operator fatigue and unnecessary movements to improve the overall performance. The operations analysis step adapts certain principles of Lean manufacturing such as standardization, visual management, 5-S and ergonomics, making the assembly line Lean.

For the assembly line, the operations analysis is carried out and the assembly operations are standardized by reducing the non-value added activities and the corresponding standard times are established. The precedence network diagram for the standardized assembly is given in Fig. 8. Operations analysis step also results in selecting the most suitable assembly line layout, which further helps in planning a good material handling system. Taking into account the total assembly time required to produce one package (which is considerably small), the simplicity of the assembly operations, the feasibility to modify the existing layout without causing much effect on current production, the traditional straight line configuration is chosen. A straight line configuration is well suitable for assemblies involving operators perform a set of tasks continuously in a given sequence for all the products.

The two proposed assembly line configurations for the current assembly method are shown in Fig. 8. The next step to improve the assembly line productivity is to design and balance the assembly line accordingly to satisfy the cycle time and demand requirements.

Both the configurations take into consideration Lean manufacturing principles such as Standard Work, 5-S, Visual Controls, Kaizen (Continuous Improvement) and knowledge sharing, to improve productivity, reduce work-in-process inventory, floor space reduction, minimize operator unnecessary motion and reworks. A brief description of each configuration with the workstation specifications follows.

12 i. Single Stage Parallel Line Configuration

The entire set of assembly operations required to produce one package will be performed by single operator at one workstation. The number of operators is reduced from four to one operator per assembly table from the original method. The completed package will be placed in a master box and the finished master box with ten of these packages is moved through conveyor to an output buffer. The master box is then transferred to bar coding area by a material handler.

13 ii. Five-Stage Serial Line Configuration

The assembly table consists of five work stations and each stage is assigned with a defined set of work elements. The work elements are assigned to each station using Ranked Positional Weight (RPW) heuristic method. The balanced line with five assembly stages is shown in Fig. 9. After the completion of tasks at each stage, the components or sub-assemblies are pushed on to a conveyor located along the center of work table by using a material tray. The operator at the next stage pulls the tray from the conveyor and completes the assembly. Once the package reaches the end of assembly table it is placed in the master box and then the master box is moved to bar-coding area by a material handler.

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The conveyor at each assembly stage can hold only two material trays. This prevents excess work-inprocess inventory in terms of packages. The stopper acts as mistake proofing tool by avoiding accidental tray movement to the next stage.

15 d) System Evaluation

Under ideal conditions, experimenting with the real assembly line would be excellent, but is not feasible always. The costs associated with manipulating the system, parameters, operators and workstations may be quite large. These costs can be in terms of capital required to bring about the changes and the output lost during this process. Simulation proves to be an exceptional tool in such scenario and efficiently provides an estimation of all the performance parameters.

16 i. Objectives of the Simulation Analysis

Simulation was used to analyze the assembly line and the associated material handling and distribution system for the proposed assembly layouts. The objectives of the simulation analysis to determined are: ? The number of master boxes to be loaded per material delivery cart. ? The input and output buffer sizes of the assembly tables. ? The number of material handling carts required to deliver the master boxes from storage area to assembly tables.

? To determine number of material handlers required to deliver finished boxes from assembly tables to bar-coding area.

ii. Material Handling System -Proposed Operation

Manually operated push carts are used to deliver master boxes from the pallet storage locations to the assembly tables. Input and output buffers located at each table ensure a constant and controlled work-inprocess at the lines, and also appropriately protecting each station from possible material starvation. Labels and other documentation to be assembled with each product do not need frequent replenishment and will be stored at the point-of-use bins on the assembly table.

V.

17 Data Collection and Analysis

From the study of assembly line balancing it is found that the product is moved from one workstation to other through the line, and is complete when it leaves the last workstation.

18 a) Material Handling Cart Capacity

For single stage line it can be seen from Fig. 10 that at cart capacity as 6 boxes maximum utilization is achieved. The idle time for material carts increase when the capacity exceeds 6 units although utilization is 100%, which is not recommended. Similarly for fivestage line, maximum table utilization is observed at a capacity of 6 boxes. So, for both the configurations the material handling cart loads 6 boxes per trip. With the cart capacity fixed as 6 units, iterations are run by varying the cart quantities. For both the configurations, 2 carts are required to supply master boxes to input buffers.

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20 c) Input Buffer Size

The assembly tables yield maximum utilization when the input buffer size is 2 units. Fig. ??1

21 d) Output Buffer Size
The output buffer size is determined by performing iterations by varying the output buffer capacity for fixed input buffer sizes, cart capacity and quantity. The output buffer capacity is obtained for single stage line as 5 units and for five-stage line as 2 units per table.

22 e) Material Handlers Required -Bar Coding Side
The single stage line requires two operators to carry finished master boxes to bar coding area. The fivestage line requires three material handlers with carts to transfer master boxes to bar coding area. This is determined based on how the finished box removal from output buffer affects the assembly utilization. The material handling requirements based on the table utilization is shown in Fig. 12 Productivity Improvement through Process Analysis for Optimizing Assembly Line in Packaging Industries

23 f) Analysis of Results
The Table 1 consolidates and compares the results for the two assembly configurations tested. The consolidated results comparing the two assembly line configurations are as follows.

? Tables Served Per Material Handler: Number of tables served by each material handling unit is higher for five stage serial line configuration. ? Fig. 13 shows that the five stage serial line requires less material handlers than the single stage line. The number of tables to be served is lesser in five stage configuration compared to the single stage configuration. But it can be observed that the difference is not highly dominating. While solving an assembly line balancing problem, certain amount of imbalance in station times is inevitable. In this case, the level of imbalance shows a great impact on the assembly line utilization. The Table 2 shows the imbalances in station times for the five stage line. Hence, it is recommended to implement the single stage parallel line in order to achieve higher productivity and better overall assembly performance.

24 VI.

25 Discussion
In the light of collection of data, findings and analysis, the following inferences can be made:

? Experiments in line balancing show that optimal solutions for small and medium-sized problem are possible in acceptable time. ? A new improvement in priority rule is discussed which shows that production cost is the result of both production time and cost rates. ? For maximizing the production rate of the line robot assembly line balancing problems are solved for optimal assignment of robots to line stations and a balanced distribution of work between different stations. ? Three terms i.e. the lowest standard deviation of operation efficiency, the highest production line efficiency and the least total operation efficiency waste are studied to find out the optimal solution of operator allocation. ? Simulation tools such as Fact-Model, to modeling the production line and the works estimated are used to reduce the line unbalancing causes and relocate the workforce associated to idle time, eliminating the bottleneck and improving the productivity. ? New criterion of posture diversity is defined which assigned workers encounter the opportunities of changing their body postures regularly.

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27 Conclusion
From the analysis of data gathered from industry on assembly line balancing it is found that assembly lines are flow-line production systems, where a series of workstations, on which interchangeable parts are added to a product. The product is moved from o ne workstation to other through the line, and is complete when it leaves the last workstation. Ultimately, there is such workstation where the time study shows that the lines are not properly balanced. This is evident according to table 2 that item no 14, 18, 19, 28 and 29 have imbalance value of 2.73. So the priority of line balancing should start with these workstations in order to bring more improvement in productivity.

In the same way the second work stations of stage 3 needs attention for improvement.

In order to optimize line balancing from the results can be derived that ? A heuristic procedure for solving larger size of problems Paralleling of workstations and tasks may be studied to improve the line efficiency. ? To select a single equipment to perform each task from a specified equipment set. ? Bee and ant colony algorithm to be adopted for finding number of workstations. The industrial situation of each and every industry differs on type of product manufactured, nature of machineries available, category of worker involved, methodology adopted and the management principles and policies in force in the industries. Therefore a particular case study carried out at package industry can further be reinvestigated in other process industries like automotive products sector, batch production industries, bottling plants or such industries where products are manufactured in lots.

Therefore the topic on line balancing can equally be implemented in manual assembly line as well as automotive assembly line. The further research therefore can be carried out on the same pattern in other nature of industries producing metallic products or non metallic products. However there may be different no. of workstations and predecessor but the basic mathematical modeling equation for calculating the cycle time, balance delay and smoothness index will be same in all types of industries. [1] [2]

2

Figure 1: , Issue 2 ,

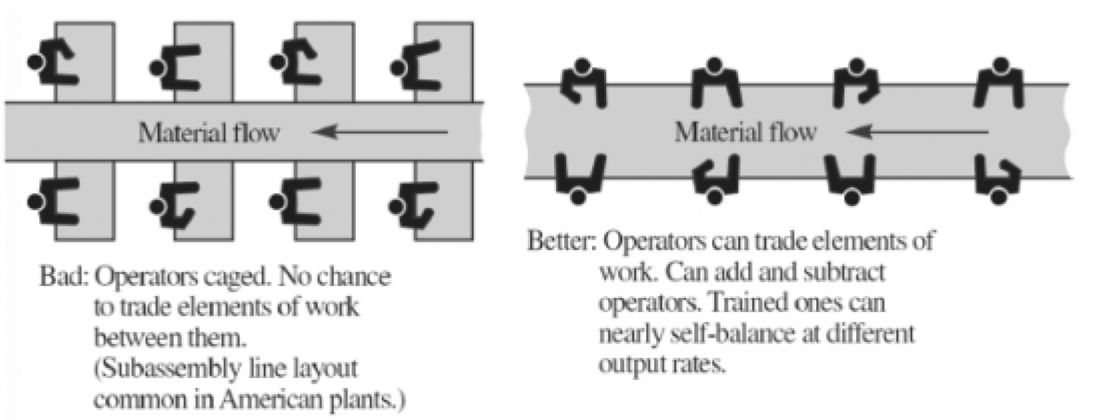

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Figure 2: Step 6 ?

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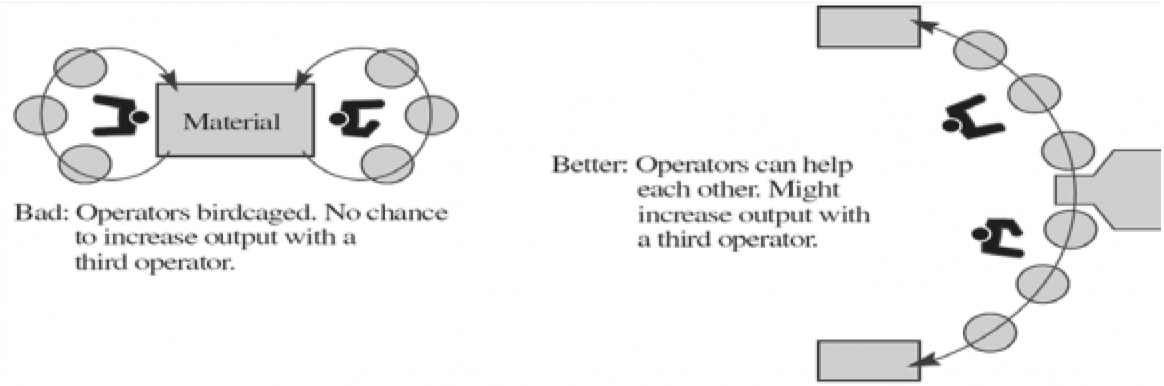

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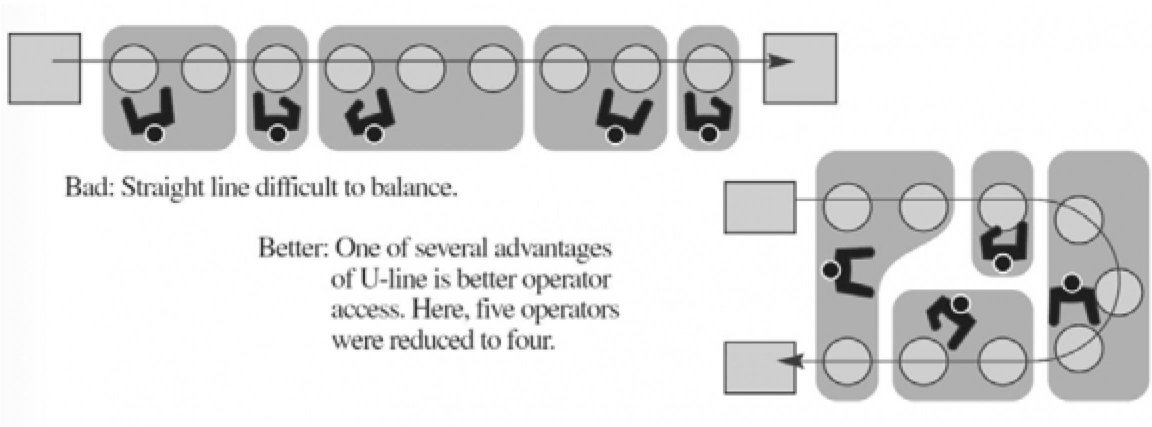

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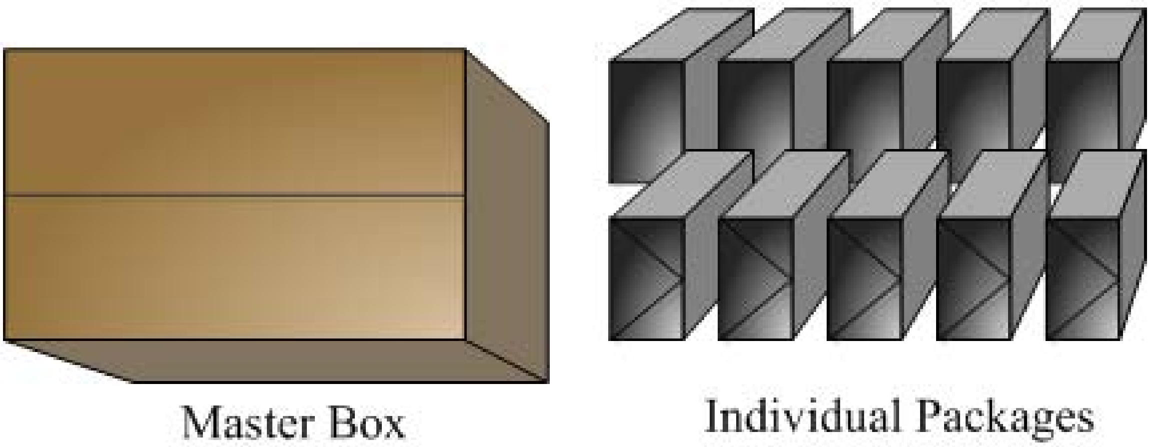

Figure 5: Figure 2 :Figure 3 :Figure 4 :

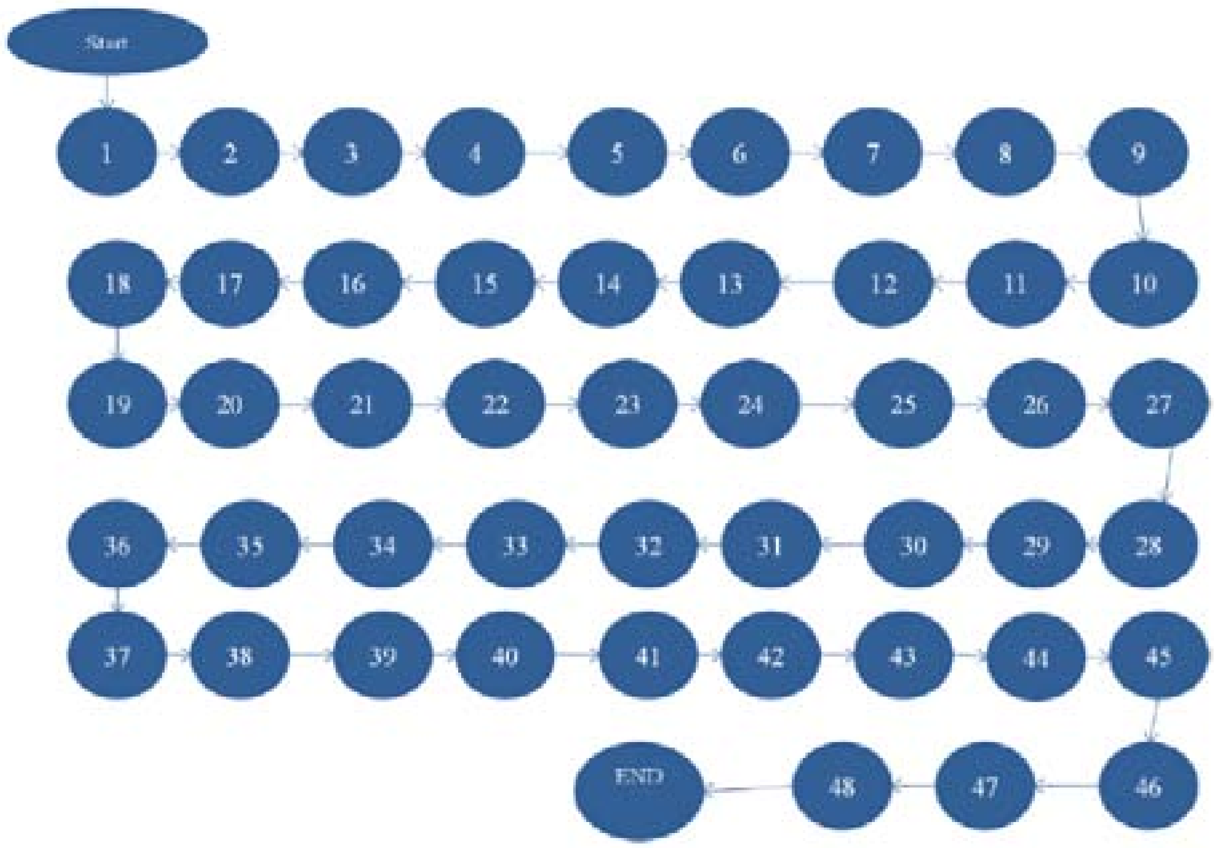

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Figure 6: Figure 5 ::

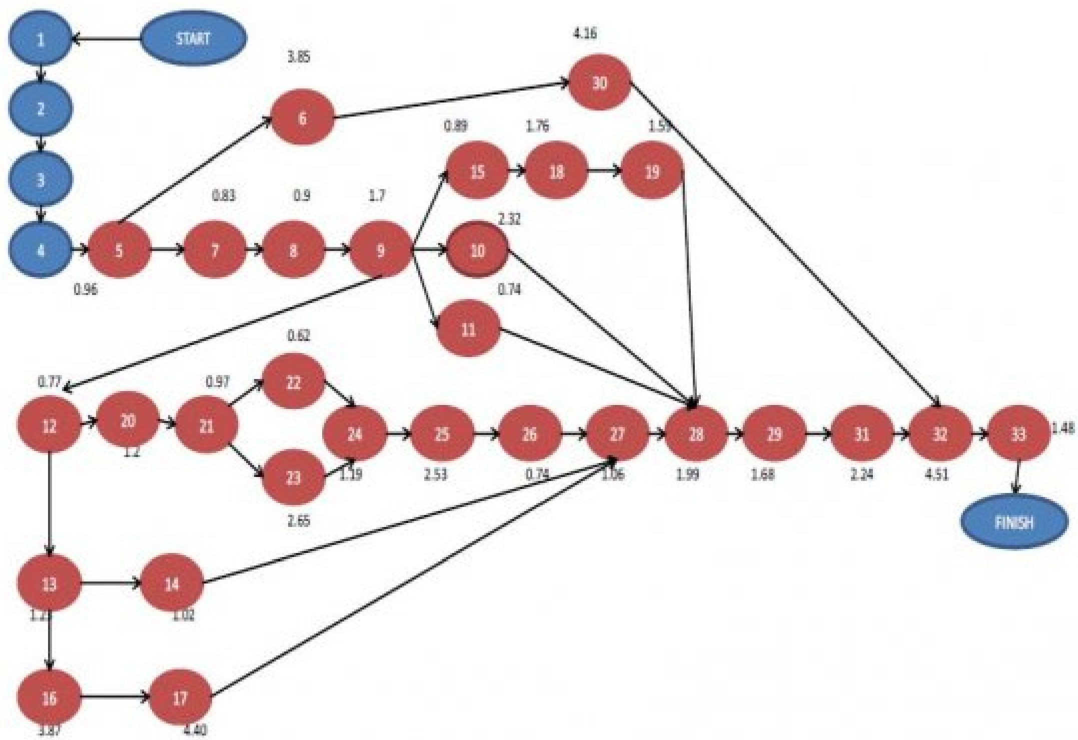

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Figure 7: Figure 7 :

8

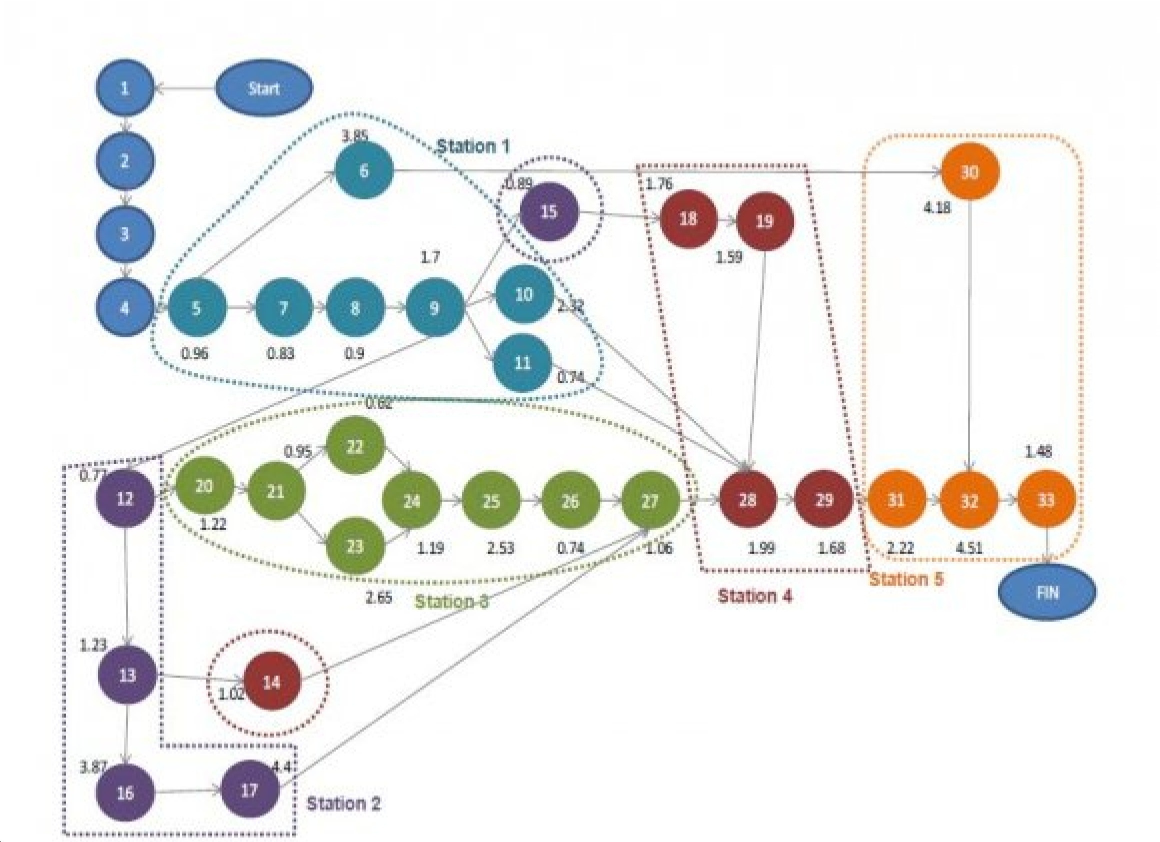

Figure 8: Figure 8 :

	120% 120%					
						99.70%
	80% 80% 100% 100%		73% 82.30% 86%	96%	100% 100%	
	60% 60%					Average Table Utilization
	40% 40%					
18 Year 2013	0% 20% 20% 0%	4	5 Buffer Size-1 6	7 8	Buffer Size-2	
XIII Issue v v III Version I Volume	87% 88% 87% 86%		82% 83% 84% 85% 86% 87% 88%	Single Stage Parallel Line		86.90%
D D D D) G	86%		81% 85.50%			D D D D)
Global Journal of Researches in Engineering (	4 83.40% 82.80% 86.80% 86.80% 86.80% 5 6 7 8 87% 87% 87% 87% 87% Five Stage Serial Line					

[Note: G© 2013 Global Journals Inc. (US)]

Figure 9:

1

Parameter	Single Stage Parallel Line	Five Stage Serial Line
No. of material handlers required - supply side	2 Carts with operators	2 Carts with operators
No. of material handlers required-Bar coding side	2 Operators	3 Carts with operators
Cart capacity	6 Boxes	6 Boxes
Input buffer size	2 Boxes	2 Boxes
Output buffer size	5 Boxes	2 Boxes

Figure 10: Table 1 :

4.50%

4.40%

4.40%

4.30%

4.20%

4.10%

4%

4.00%

3.90%

3.80%

Configuration-1: Single Stage Parallel Line

Configuration-2: Five Stage Serial Line

59.77%

59.50%

59.00%

58.50%

58.10%

58.00%

57.50%

57.00%

? Operator Utilization: Fig. 14 shows that the average operator utilization for single stage line is about 99% and for five stage line is 86.9%. It can be seen that for a five-stage line all the operators at different stages of assembly line are not uniformly utilized.

Figure 11:

2

S.No.	Operation	Average Time	Work Station	Station Time	Cycle Time	Imbalance
5	Take Individual Box	0.96				
6	Peel original Import label	3.85		11.31		
7	Breaking the seal of approval	0.83	Stage 1		10.77	- 0.54
8	Open individual box	0.90				
9	Remove pamphlets and disc from the box	1.70				

Figure 12: Table 2 :

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