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ENHANCEMENT OF PRODUCTIVITY IN WHITE GOODS APPLIANCE PRODUCTION LINE THROUGH SIMULATION MODEL: A CASE STUDY

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ABSTRACT

Understudy manufacturing organization is the pioneer in the manufacturing of deep freezer in Pakistan established since 1960. The organization is also involved in the manufacturing of other white goods appliances. "Assembly Line" of the deep freezer manufacturing division was focused in present study. Different methods were studied to improve the quality and productivity of the assembly line. There are a lot of stages in deep freezer production from sheet cutting to packaging. This study was focused on some critical stages that include cabinet foaming, electrical parts assembly, vacuuming and testing because these stages consume more resources than other stages. Closely observe all the steps involved in this assembly line and identified those factors which were contributing towards low quality and ultimately less productivity. Visual SLAM simulation model was used to investigate quality and productivity issues in the manufacturing of deep freezers. It also observed that system time, waiting time in queues and idle time of servers decreased and utilization of resources and production rate increased. Simulation study outcome was considered by decision makers plus recommendations were executed.

KEYWORDS: *Assembly line, simulation, optimization, white goods, appliances*

INTRODUCTION

The assembly concept has certainly been changed a lot in these days. Innovation of assembly line is significant revolution in industrial sector. Henry Ford is the first who completely change the assembly concept in 1913 by the virtue of presenting assembly lines within automobile manufacturing. He introduced in factory a moving belt where the workers were in a position to build single piece at one time rather than one car simultaneously. From that time, assembly line concept is reformed and products were made along with cutting down cost of production. Since then, effective assembly lines design drew great consideration from both academicians and companies. [8]

Assembly line balancing is a distinguished assembly design procedure that is used to optimize the given objective function, by allocation of tasks among the workstations. Assembly line is an industrial method comprising of several tasks wherein identical parts are added in chronological order to the product on a station to yield a complete product. Usually it requires large capital investments due to long term decision of an assembly line installation. It is significant that assembly line should be planned and well-adjusted in order to work in possible efficient manner. In any organization (manufacturing or service), the highest priority is of both the superior quality and enhanced productivity. Enhanced quality goods results in enhanced productivity due to fewer revise and rejection rate.

RATIONAL OF STUDY

A simulation study was chosen for "manufacturing process reengineering". To increase the overall productivity of the company's current manufacturing operations by evaluating a set of changes, it was the key study goal. This research study carried out for one middle size deep freezers manufacturer who needed a detailed study of its manufacturing processes. To analyze the limitations and problems of current manufacturing system, a simulation model was developed. Some adjustments were proposed to actual existing system of manufacturing and related operational performance measures were evaluated in order to strengthen conclusion process related to the execution of proposed alterations. Simulation study results were conversed with management while number of accurate adjustments to manufacturing system were decided. Taking into consideration the consequent results attained mostly modifications welcomed and then being applied. Furthermore, to help the company in redesigning manufacturing system, this study will assist small medium size enterprises (SME's) to fine-tune their manufacturing processes. In order to resolve productivity and quality issues by using diverse quality tools, a lot of researchers conducted studies in manufacturing organizations and they applied mostly the case study technique. Till now there was no research carried out in deep freezer manufacturing organization for enhancing quality and productivity using line balancing simulation technique, which was the main aim of this study.

AIMS AND OBJECTIVES

This study aim is to align all resources properly and reduce workload for assembly line along with achieving requisite output.

Aims and objectives are to:

- Identify bottlenecks and eliminate them
- Improve productivity and production rate
- Regulate machinery and equipment as per assembly mechanism
- Determine optimal number of workstations and equally distribute the workload among workstations
- Shorten total amount of idle time to reduce number of workers for given amount of work
- Improve production functions with building mix form of manual assembly and automation assembly

STEPS INVOLVED IN THE MANUFACTURING PROCESS

The company under consideration uses certain parts to assemble a deep freezer include facilities; internal case, external case, lid, baskets, grids plus control panel.

Focal operations in manufacturing are:

- Pressing, cutting, bending sheets of metal
- Internal case assembly: side panels assembly and bottom, attachment of the copper tube and capillary
- Finishing of Internal case : thermostat tube attachment along with inspection of insulation
- Lid (door) assembly: diverse parts attachment which form the lid of freezer
- Cabinet assembly: internal and external cases attachment
- Drying: in dryer lid and cabinet are placed (before foam filling)
- Foam filling: lid and cabinet foam filling
- Lid finishing: additional parts fixing i.e. hinges and lighting
- Condenser assembly
- Parts assembly: brackets assembly, fan and thermostat
- Handle and lid assembly
- Electrical assembly: compressor, control panel along with soldering of different parts
- Gas filling and vacuum

- Inspection with number of standard tests carried out
- Scrubbing and packaging

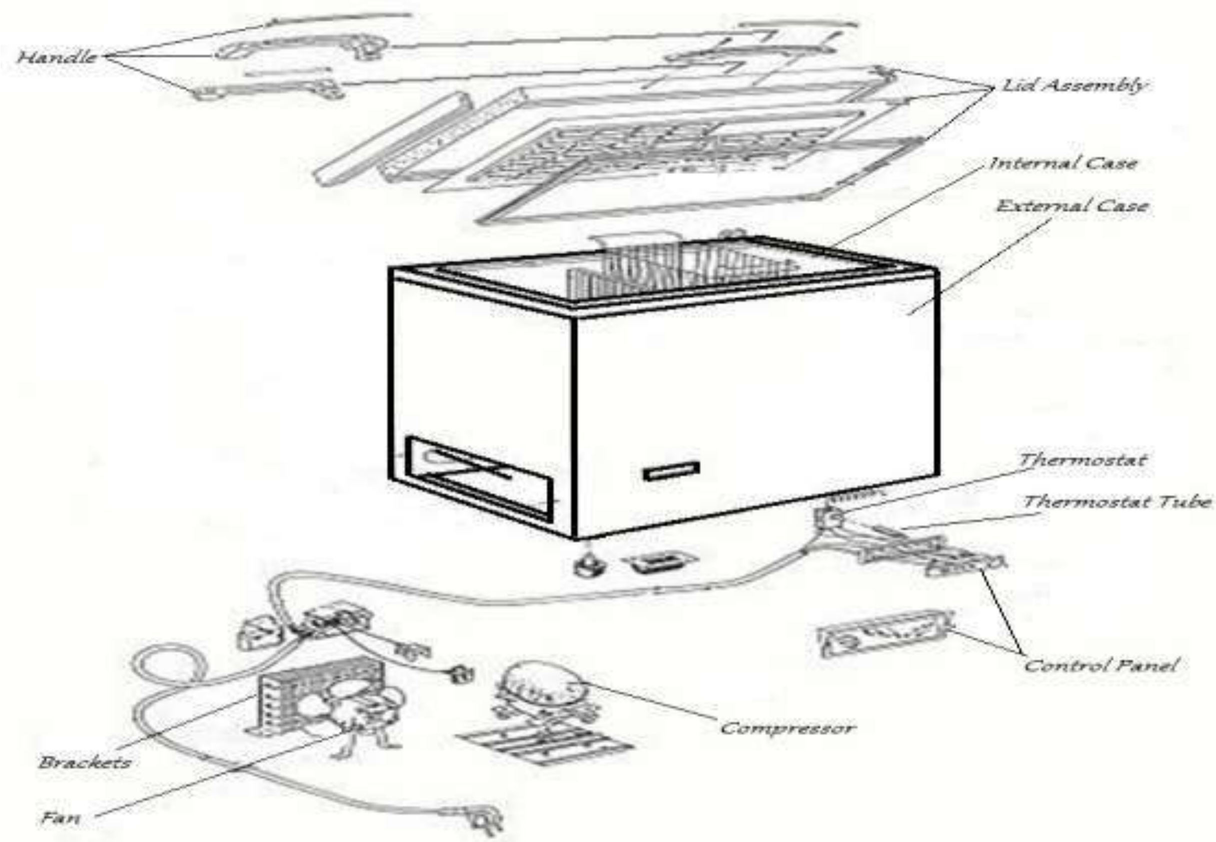

Fig-1: Deep Freezer with Parts

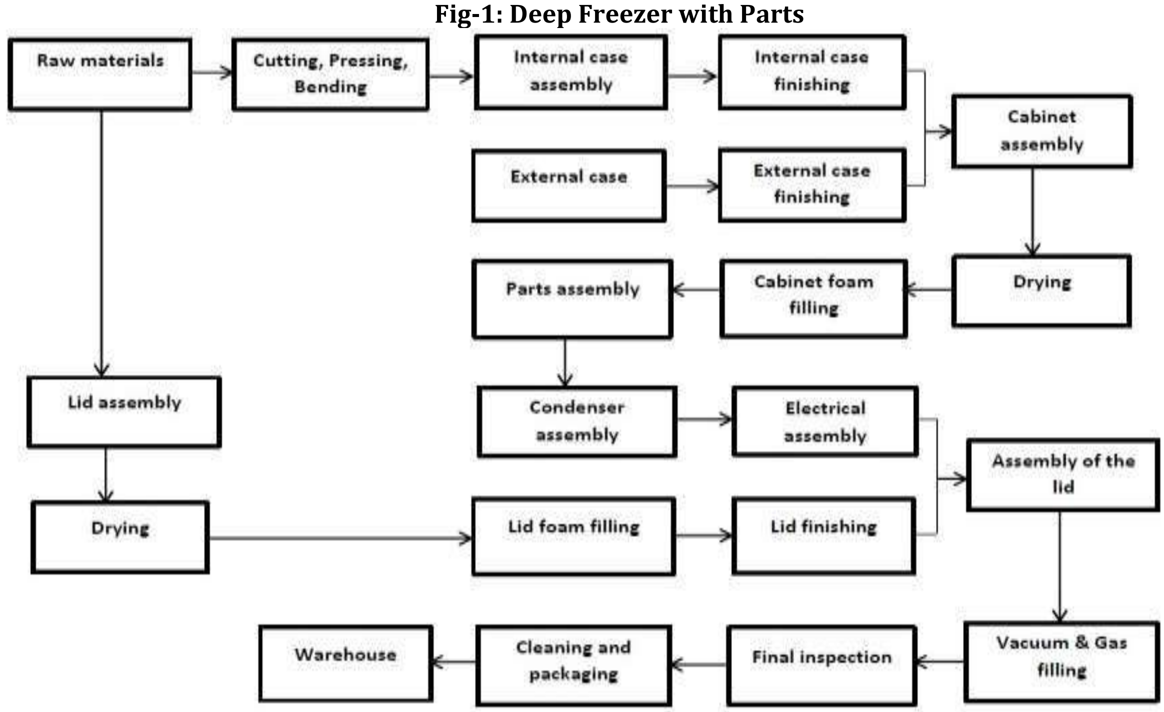

Fig-2: Process Flow Deep Freezer Assembly Line

METHODOLOGY

To optimize the existing system, data was collected by stop watch; time of each activity was noted and tested it for goodness of fit (distribution fit) by using Minitab software. With the help of gathered data simulation model was developed using visual SLAM software then verified and validated with actual system. It was expected that, there was no significant difference between existing model and actual system. Existing model was working in batch form, it was transformed into unit production with the help of lean manufacturing concept and optimized it using what-if analysis. At the end results of existing and proposed models were compared and outcomes of performance measures were discussed.

Primary Data (Time Study)

Comprehensive time study was performed in order to determine durations for tasks so as to balance the production line on top of increasing efficiency of the line. Required time for completing one task depends upon different factors like task, quality level of products, materials properties, working environment, shift time, operator and psychology of operator etc. Fifty measurements were taken into account for every task to estimate the near factual process time of one task along with working on line operator. This study accomplished by stop watch along the line. Every process was measured and noted in minutes. Gathered figures were tested primarily for independency, because it is important that job floor gathered data needed as independent and afterwards collected data was verified while aiming at goodness of fit (distribution fit) by using Minitab software.

Secondary Data (model inputs)

Values based upon calculations such as number of servers for each work station (a server can be a machine or a counter), distribution of gathered data for each activity. The goodness of fit test includes Anderson Darling (AD), conforming p-values (P) plus likelihood ratio test p-values to assess whether a distribution fits the collected data, queue capacity etc. These values were used as inputs to this system.

Typical inputs to this model are:

- Distribution Fit and Goodness of Fit
- No of servers or workers
- Queue capacity of each work station

SETTING UP SIMULATION MODEL

Simulation can be applied for analyzing system behavior because it is a technique to demonstrate an actual or proposed situation on a computer. Forecasts can be done on system behavior by shifting variables. It gives forecasts on existing system performance. Furthermore, alternative solutions can be compared by proposing possible scenarios on system. Which make it reasonably useful analysis for suggesting investment strategies to companies for a specific design problem in allocating tasks to workstations.

It's a discrete-event simulation, operations which are provided in system are centered on consecutive sequence of the events. In the present study production line contains a series of diverse stages of the assembly operations, which illustrates discrete-event simulation. Visual SLAM and AweSim (student version) from Pritsker Corporation was used for discrete-event simulation.

BASICS OF MODEL BUILDING

There are seven basic network elements in Visual SLAM. These network elements are: CREATE node, QUEUE node, TERMINATE node, ASSIGN node, ACTIVITY branches, GOON node and COLCT node. With these basic network elements, many diverse network models can be built.

The method CREATE node is used for making entities for insertion within network. The QUEUE node is utilized for modeling complex decision processes which take part when an entity reaches to service operation where disposition of entity rely on server status with number entities in a queue at same time waiting for server. TERMINATE node is utilized for removing entities from the network. The ACTIVITY branches denote obvious time delays for entities navigating within network. The Service activities denote operators, machines and the like which can process limited number of entities simultaneously. Prior service activity, a buffer or waiting area must be prescribed which is achieved through QUEUE node usage. Activities are referred to as regular activities which model clear delays but do not have a limit on the number of parallel entities. GOON nodes utilized for separating activities and after the completion of an activity can model branching logic to route entities. COLCT node is used for collecting statistical information on entities and Visual SLAM variables.

During creation of model, decision of exact node at accurate place is a dire issue. A node can be a counter, queue, machine or a product etc. For creating our production line model, various nodes forms were utilized as presented in figure-3.

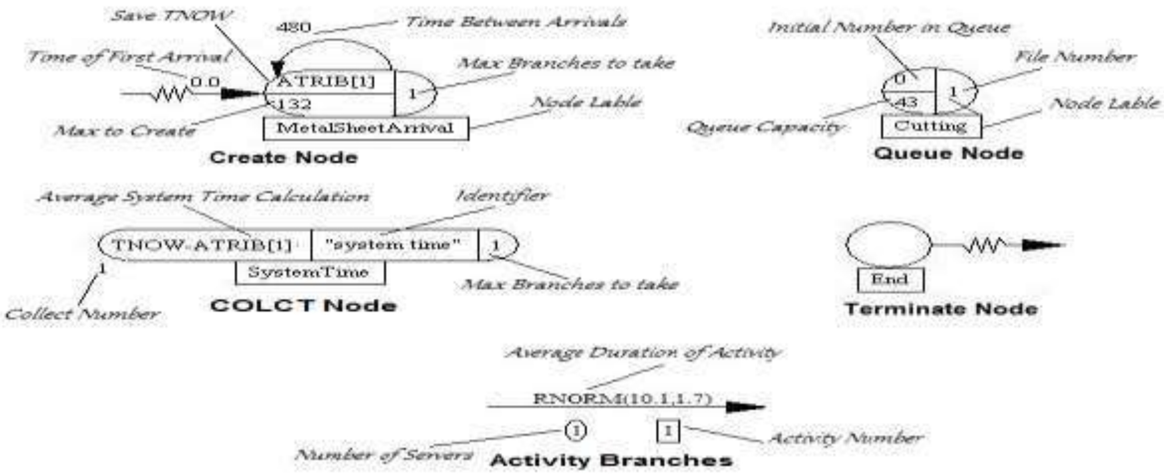

Fig-3: Types of nodes used in this simulation model

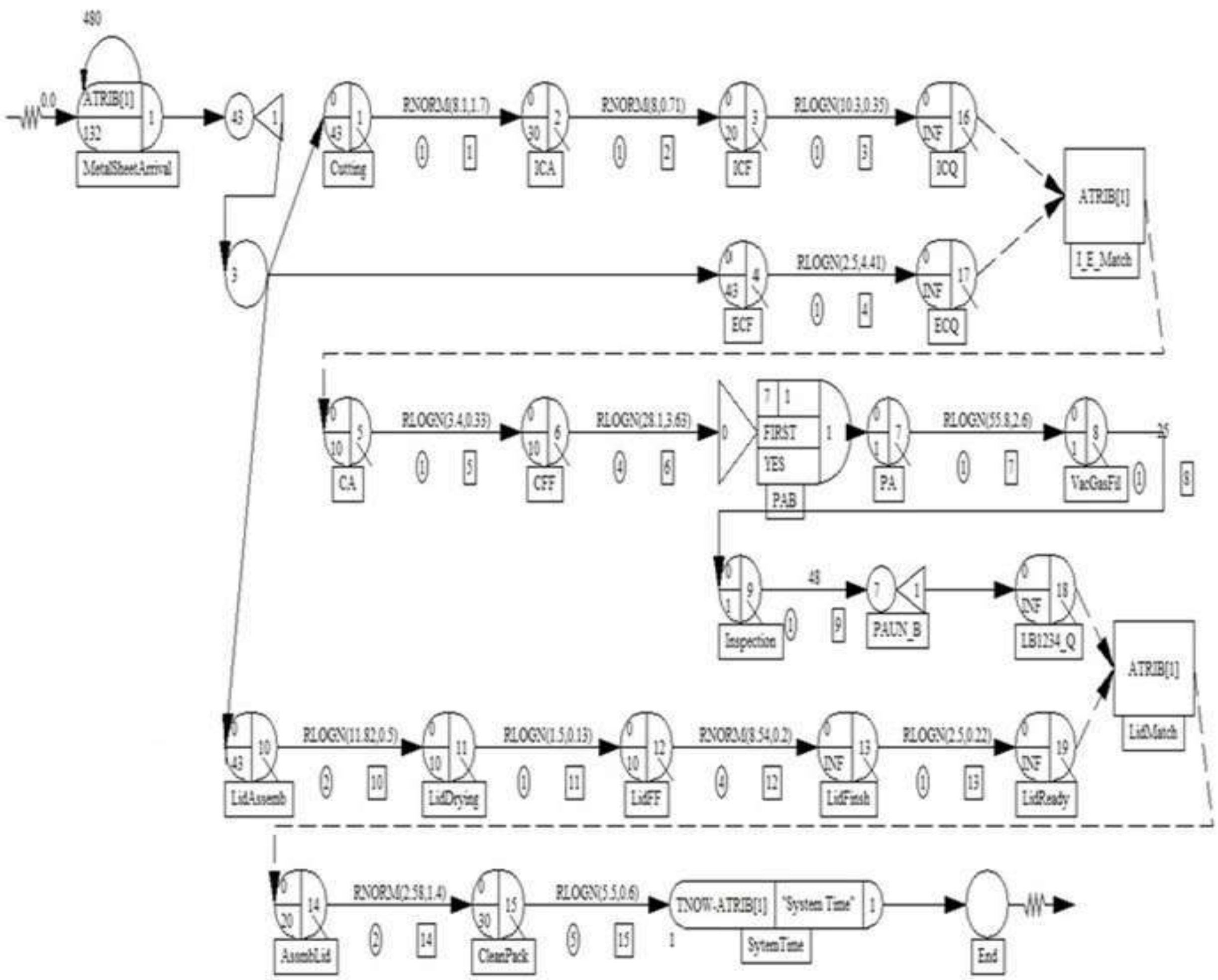

Fig-4: Existing Simulation Model (Real System)

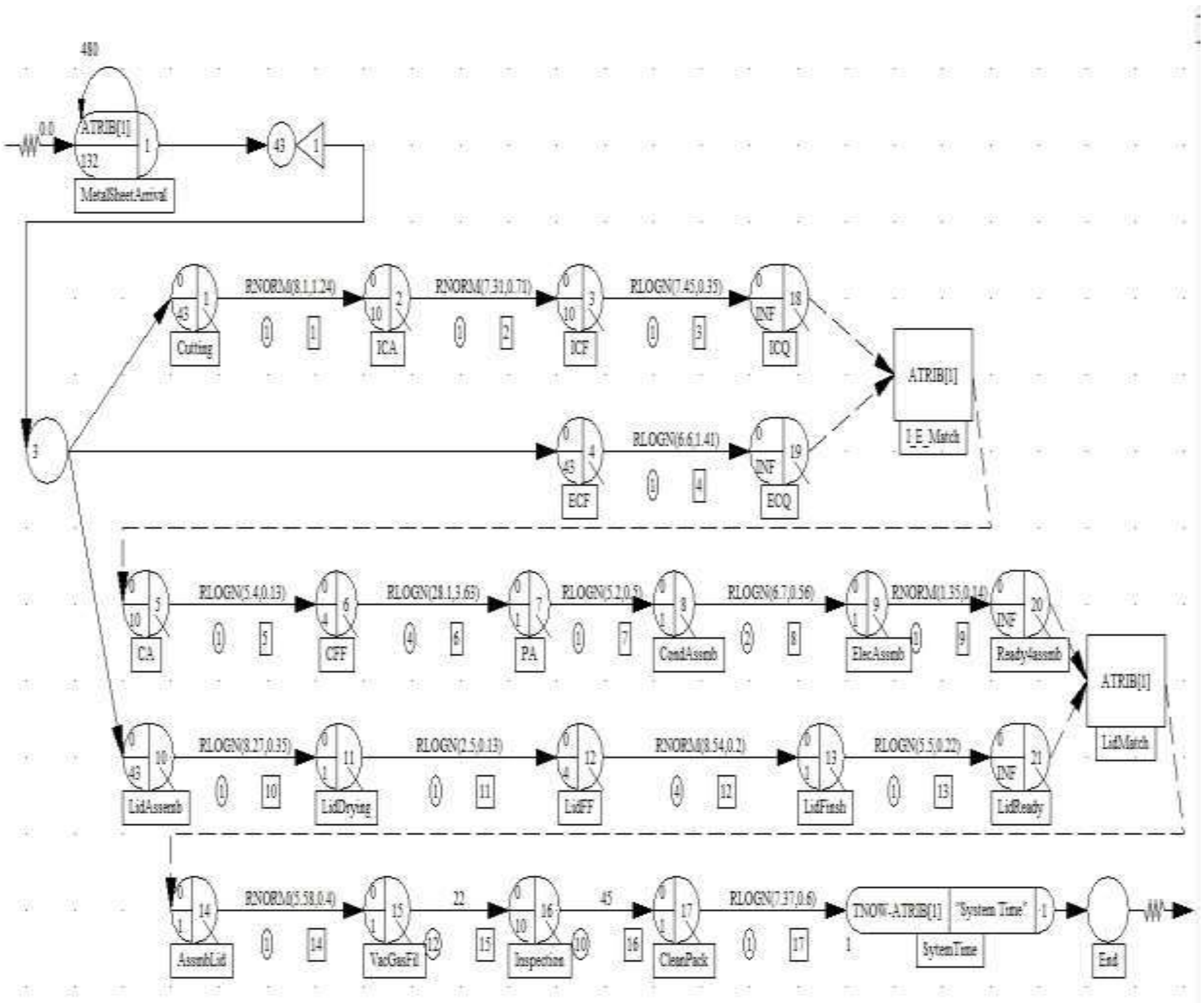

Fig-5: Proposed Simulation Model

In the figure-4,5 the connections between the nodes is showed with arrow sign. Before and after the server node and the assembly node job always waits in lines like real system to be processed. Data for model was entered while bearing in mind preference checks. As described in the previous section, gathered data was converted into simulation model for every operation separately as well as the arrival time interval of raw material directly transformed into the model.

MODEL VERIFICATION AND VALIDATION

Verification of model was done in steps. Model statistics: present and average job number in nodes in the system, average system time, interval between jobs, percentage of server utilization, average output, productive performance of nodes, etc. were matched with existing system and no differences were found in all cases between the model and the existing system.

RESULTS

Following performance measures considered in order to analyze the results of the system:

- Average System Time
- Waiting Time in Queue
- Average Daily Output
- Server Idle Time
- Resource Utilization

Results based on existing model

Existing model results are presented in Table-1 as per performance measures. It can be observed in Table-1 that during the whole 8 hours shift average 28 units were produced, the average idle time is 99.32 and the average resource utilization is 35.82 when figures from actual system and these results were compared, it was revealed that the actual system and the existing model results were similar.

Performance Measures	Average	St. Deviation	Min	Max
System Time	366.99	76.12	264.72	470.88
Server Idle Time	99.32	116.39	-	-
Resource Utilization	35.82	27.25	-	-
Average Daily Output	28	-	-	-

Table-1: Performance Measures of Existing Model

It was also observed that 366.9 minutes is average system time for a unit and the average waiting time of queues 1, 4 and 10 does not have much impact on the manufacturing system because processes are initiated from these queues but we must reduce the waiting time of queues 2, 3 and 14 to enhance the system performance.

In order to increase efficiency of production line, primarily bottlenecks were identified and afterwards what-if analysis applied to try possible combinations.

It was observed that batch production line created bottlenecks and due to these bottlenecks other servers entered in idle states and the waiting time of the system increased. Parts Assembly, Vacuum and Gas filling and Inspection were running in batch form. Each batch contains 7 units and at this state 33.17 minutes average waiting time was observed. In existing system most servers contain large idle time due to unbalances and un-aligned activities. Resources are not utilized properly and company is paying extra cost due to excessive man power. It was decided to implement lean manufacturing concept for productivity enhancement which will help the organization to align all activities properly and the resource utilization efficiency will also be increased.

Results based on proposed model

The optimal simulation model that increased productivity by using all existing resources properly. As Table-2 shows that the average system time has decreased from 366.99 to 316.36 minutes and the waiting time of queues 2, 3 and 14 is minimized to the least. Production average increased from 28 to 42 units that can be increased further but adding some resources. Vacuum and Gas filling station is working on 17% resource utilization, there are 12 servers and each unit vacuumed with fix time of 20 minutes.

Performance Measures	Average	St. Deviation	Min	Max
Average System Time	316.36	95.58	150.37	476.45
Server Idle Time	85.68	59.88	-	-
Average Resource Utilization	46.94	20.33	-	-
Average Daily Output	42	-	-	-

Table-2: Performance Measures of Proposed Model

For identification bottlenecks in proposed simulation model, number of current and average job in nodes in the system, average system time, waiting time of jobs, server utilization percentage, average output, productive performance of nodes etc. were taken into consideration. It was detected that in activity Vacuum and Gas filling with greater processing time blocks system. Therefore, in proposed simulation model, activity Vacuum and Gas filling is identified as bottleneck.

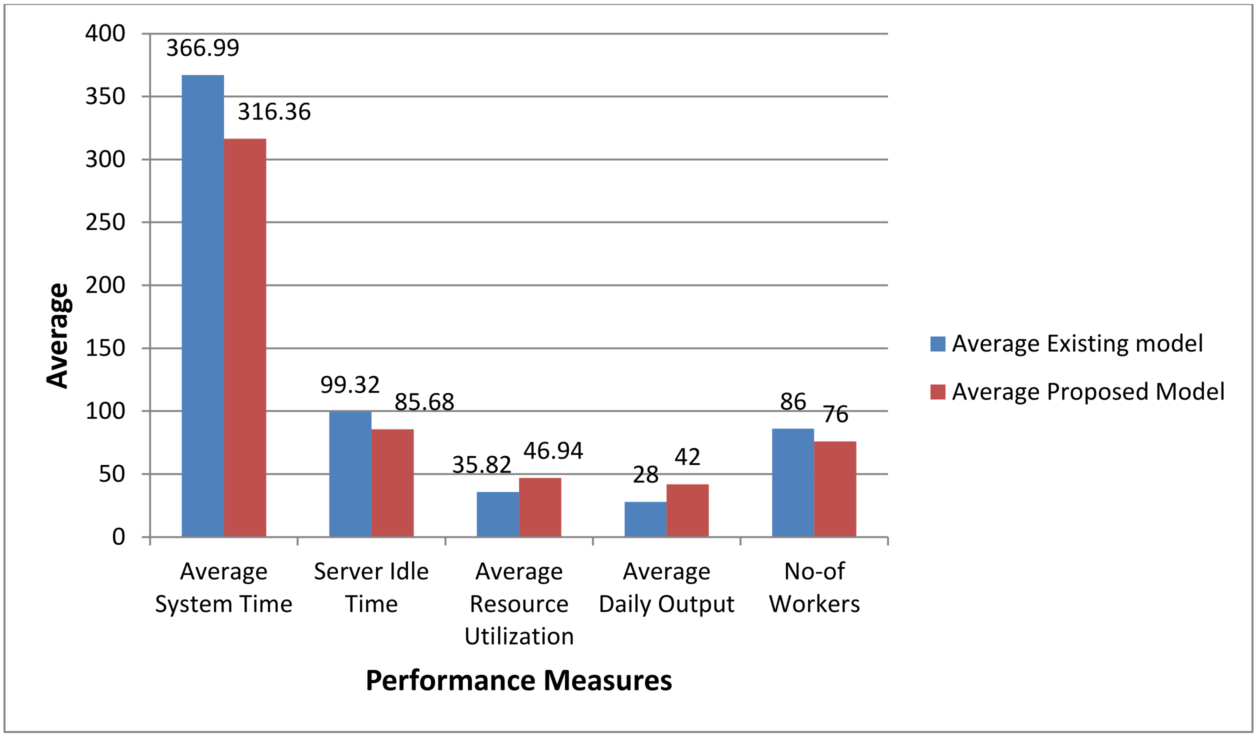

Fig-5: Performance Measures of Existing and Proposed Model

In existing system resources were not properly utilized. Due to excessive man power the utilization was reduced, but at this instant by reducing man power the utilization increased and saved 22% labor cost. Figure-5 shows number of average finalized deep freezers per day increased by 50% with proposed model; average system time is decreased by 14%; average resource utilization is increased by 31%; whereas the idle time is decreased by 14%.

CONCLUSION

The structure is analyzed by simulation of white goods appliance production line. A deep freezer assembly line was considered for simulation model. In this study it can be concluded that existing system was running with batch production and batch production line created bottlenecks. Due to the bottlenecks and unbalanced activities, some servers were in idle state and waiting time of the system was increased. It is also observed that due to excessive man power company was paying extra cost. Lean manufacturing concept is being implemented to properly align all the activities and resources by using visual SLAM simulation software. Unit production is proposed instead of batch production to enhance the productivity and overall system performance. Proposed changes are accepted and being implemented. All objectives like identification and elimination of bottlenecks, improve productivity and production rate, equally distribute the workload among workstations and minimize the idle time to reduce the number of workers for a given amount of work are achieved successfully and so as to present more comprehensive decision, alternative study can be made by carrying out cost investigation of the potential scenarios.

Finally, this research study has demonstrated successful use of Visual SLAM simulation software to solve assembly line balancing problem in a white goods appliance production system.

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