EVALUATION OF PRODUCTION PROCESS OF A FACTORY BY USE OF SIMULATION APPROACH[1]

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Abstract: It is very important to reduce costs and increase productivity because of increased competition in business life. In order to increase productivity, the process needs to be analyzed correctly. In this study, a company that produces solar energy systems is considered. Firstly, the process was analyzed using a work study. Process improvement studies were carried out on the basis of obtained results. There are two types of products namely "SEWHS (Solar Energy Water Heater Systems)" and "Boiler". The system works as pull-out. The main problem is that when the order comes, they don't know when to meet this demand. In order to overcome this problem, a simulation model has been developed. With the content of study, the work flow diagram and machine-equipment layouts have been developed. After that time studies have been carried out to obtain standard times for each process. Those are used in the ARENA 10.0 software and system is simulated. As a result of the simulation, the amount of products in the queue, waiting time and bottlenecks are determined. In addition, the company's ability to meet demands and the resource utilization rates of the machines have been determined. By using simulation software, company started to determine product delivery time.

Keywords: Process analysis, Process improvement, Work study, Simulation

Jel Codes: L1,L11

1. INTRODUCTION

Today, the importance of required energy is increasing every field. It is difficult to meet the required energy with the available resources. Therefore, solar energy which is one of the alternative energy sources has gained importance. Solar energy has become more attractive than other energy sources because of its potential, ease of use, cleanliness, renewability, eco-friendly, high efficiency and cost-effectiveness. For this reason, companies have concentrated on the production of solar energy systems.

It is necessary to optimize the capacity they have and reduce their production costs in order to protect the competitiveness of these businesses in the market. For these purposes,

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processes should be defined correctly and completely. It is necessary to analyze the processes of the product and to present the current situation by supporting the analyzes made with time studies. The data obtained from the studies are required to detect the bottlenecks and problems that have occurred. Also the processes that need improvement should be determined. Thus, production functions will work more comfortably because the time of the production can be determined in advance and managers will be able to make decisions more easily.

Process Analysis deals with the breakup of entire production cycle into phases or activities in a step-by-step manner from inputs, operations to outputs. This will make it easy for the management to take control of the overall process. This concept is the basic approach for designing the approach-development, identification, analysis-process (Deros et al., 2009).

It has been observed that many studies have been done when studies related to process analysis and improvement in the literature are examined: (Öztürk, 2008) land transportation exports sector, (Yamaç, 2006) defense industry sector, (Türker, 2001; Aydın, 2007) banking sector, (Çırkan, 2009; Öztürk, 2010; Yağız, 2010) automotive sector, (Şener and Kılıç, 2013) readymade sector, (Baddoo and Hall, 2003; Beecham et al., 2003; Niazi et al., 2005; Pino et al., 2008) software sector and (Freire and Alarcon, 2002) construction sector have been carried out work on process analysis and improvement.

In the second part of the work, the materials and methods for this study are explained. In the third part, the work study and simulation applications are given. In the fourth section, the results and discussion are given. In the last part, the findings were concluded.

2. MATERIAL AND METHODS

When we look at the studies on process analysis and improvement, it seems that many different methods are used. In this study, work study and simulation methods were used. In order to carry out simulation studies, the work study needs to be done. Therefore, after defining the work flow, the work study has been completed.

2.1. Work Study

Work study is the systematic examination of the methods of carrying on activities so as to improve the effective use of resources and to set up standards of performance for the activities being carried out. Work study then aims at examining the way an activity is being carried out, simplifying or modifying the method of operation to reduce unnecessary or excess work, or the wasteful use of resources, and setting up a time standard for performing that activity.

The main purpose of using work study in all production systems that produce goods or services is increasing productivity. In addition, work study is also used for the following purposes (Kuruüzüm, 1992): get rid of unnecessary activities, regulate the necessary activities in the most economical way possible, standardize appropriate working methods, determine the right time standards for work, increase the utilization rate of the factors used in production, improve current working conditions.

Work study is divided into time study and method study.

Time study is a work measurement technique for recording the times of performing a certain specific job or its elements carried out under specified conditions, and for analyzing the data so as to obtain the time necessary for an operator to carry it out at a defined rate of performance.

Method study is the systematic recording and critical examination of ways of doing things in order to make improvements.

2.2. Simulation

Some problems are too complex to solve with mathematical operations. They may include random elements or risk elements that make a practical mathematical solution impossible. In such cases, analysts sometimes form a model of the real life problem and follows a trial and error approach to provide a logical solution. A simulation is a way of modeling the basis of an activity or system. The aim of modeling is to make experiments possible to evaluate the behavior or response of the system over time (Monks, 1996).

The limitation of analytical solutions is one of the important factors in the development of simulation for solving complex problems. Another reason for the development of the simulation is that it can examine the dynamics of complex operating systems in detail (Turner et al., 2006). For simulation, there are number of softwares. In this study, ARENA 10.0 software is chosen to simulate the system.

3. PROCESS ANALYSIS AND IMPROVEMENT APPLICATION

3.1. Definition of the Problem

The company in which the work is carried out works in the solar energy systems sector. In this company, SEWHS and Boiler products are produced in general.

Capacity planning and demand forecasting are not used effectively in the company. Since it does not know the production capacity, it is difficult to meet increasing demands over time. Production processes are different due to its diversity products. These processes have not been adequately and effectively analyzed. Confusion arises because of this reasons.

The order delivery time cannot be determined because of the completion time of the final product is not known.

3.2. Aim of Application

The inability to deliver orders on time is one of the most important problems of the company. This problem is caused by deficiencies in production planning. Orders are not delivered on time causes customer dissatisfaction and loss of customers.

In order to eliminate these problems, the business processes are examined in detail and the production periods of the products are estimated. Thus, the customer's dissatisfaction was tried to be removed by determining the demand's due date. Production capacity has been determined with work study and time study. It is aimed to determine the bottlenecks and machines utilization rates by simulating the current system. Also at the end of the simulation, it is aimed to increase of efficiency of company by proposals.

3.3. Definition of Process and Work Study Application

Processes are defined separately for a total of 17 different models, including Boilers produced in 12 different models and SEWHS in 5 different models. These products are processed in 4 different sections and 16 different production units. These 4 different sections are “Preparation Section”, “Welding Section”, “Test-Acid-Enamel Section” and “Polyurethane Section”. “Preparation Section” consists of “Outer Sheath Preparation, Water Tank Preparation, Bending and Punctuation and Linear Welding”. “Welding Section” consists of “Grinding, Swelling, Punctuation and Marking, Circular Welding and Welding”. “Test-Acid-Enamel Section” consists of “Pressure Test (Quality), Chemical Process, Enamel Coating and Baking”. “Polyurethane Section” consists of “Polyurethane Preparation, Polyurethane Filling and Packing”. The production process and number of machines used in production of each product is different. The machine-equipment layout of the company was drawn using the Edraw Max Pro 7.9 software and the general flow diagram on the drawing is shown in Fig.1.

Processes defined for 17 different products were handled and a "Time Study" has done for each product separately. The obtained results are used as input for the simulation software. The results of the time study of SWEHS with 5 different models, which are part of the work done, are given in Table 1.

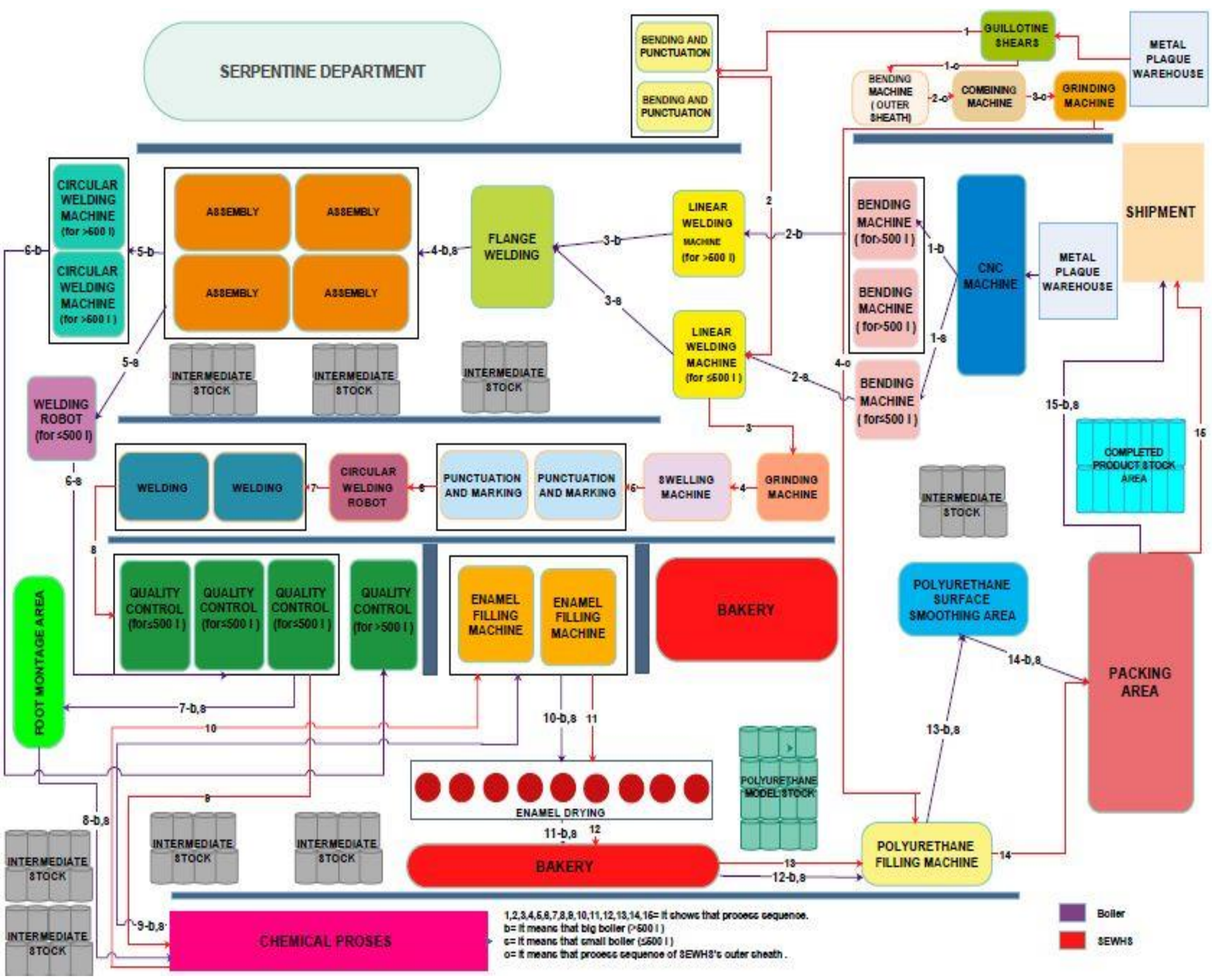
Tempo values required for time study and allowance factor for personal time were determined according to the standards by selecting appropriate values from the table. In addition observation proficiency test has been carried out 95% confidence level and it was concluded that the numbers of the observations were sufficient.

Table 1. Standard Times for SEWHS.

Name of Process	**Standard Time for Different Models (second)**				
	120 liters	**170 liters**	**200 liters**	**300 liters**	**500 liters**
Outer Sheath	**484,9**	**510,0**	**529,6**	**589,1**	**609,9**
Water Tank	**48,2**	**58,2**	**68,2**	**78,2**	**88,2**
Bending and	**484,7**	**491,6**	**475,8**	**646,0**	**701,6**
Linear Welding	**368,4**	**488,5**	**581,6**	**591,4**	**650,0**
Grinding	**391,7**	**460,5**	**535,1**	**887,1**	**834,5**
Swelling	**276,4**	**280,9**	**247,9**	**301,1**	**None**

Punctuation and	**760,3**	**728,1**	**743,1**	**834,7**	**1381,**
Circular Welding	**517,5**	**499,2**	**535,2**	**653,4**	**866,1**
Welding	**1230**	**1068,**	**1214,**	**1310,**	**1351,**
Pressure Test	**1490,**	**1549,**	**1451,**	**1713,**	**2236,**
Chemical Process	**4852,**	**4867,**	**5055,**	**5537,**	**6093,**
Enamel Coating	**3778,**	**3810,**	**6985,**	**7013,**	**9263,**
Baking	**1685,**	**1693,**	**1698,**	**1711,**	**1743,**
Polyurethane	**1024,**	**999,4**	**1133,**	**1226,**	**1985,**
Polyurethane	**1257,**	**1245,**	**1290,**	**1353,**	**1366,**
Packing	**1237,**	**1226,**	**1284,**	**1314,**	**1374,**

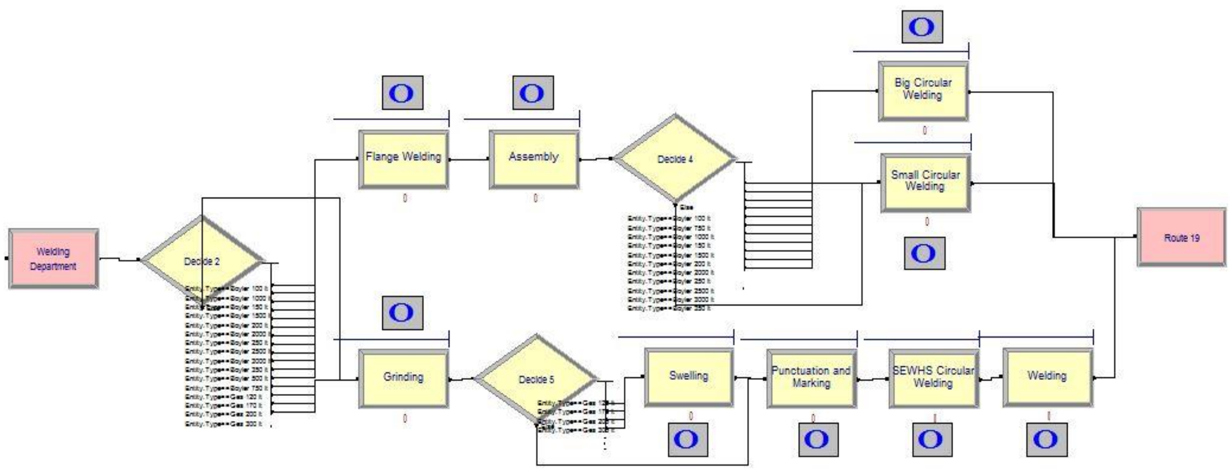
Figure 1. Machine-Equipment Layout of Company.



3.4. Simulation of System

The simulation of the inspected system was carried out using the Arena 10.0 software. The times used as input for each process in the software are the standard times obtained by the time study. A simulation model was developed for 12 types of Boilers and 5 types of SEWHS. It is aimed to determine the bottlenecks that may occur in the system when the demand is high. The number of product on line of the each production step and waiting time have been determined. In addition, capacity utilization rates for each process have been obtained. Simulation model also provide that the demand is met or not on the given time period. A part of the simulation model of the system is given in Fig.2. The simulation was run as 5.5 days a week and 8 hours a day to show its performance.

Figure 2. A Part Of System Simulation.



4. RESULTS AND DISCUSSION

The weekly demand of the products is obtained using the previous sale data. The production quantities and demand quantities obtained as a result of the system simulation are given in Table 2 for the Boiler products and in Table 3 for the SEWHS products.

Through the simulation, it is desired to obtain information about whether or not the system is capable of meeting the demand. For a week, the number of products entering the system is equal to number of products arriving system was found.

While producing the requested amount of products in which sections the queues are formed and waiting times in the queue are shown in Table 4.

Table 2. Demand And Production Quantities For Boiler Products.

BOILER		
Model of Product	**Weekly Average Demand (Quantity)**	**Weekly Amount of Produced Products (Quantity)**
100B	**14**	**14**
150B	**8**	**8**
200B	**11**	**11**
250B	**4**	**4**
350B	**3**	**3**
500B	**5**	**5**
750B	**1**	**1**
1000B	**5**	**5**
1500B	**1**	**1**
2000B	**1**	**1**
2500B	**1**	**1**
3000B	**1**	**1**

Table 3: Demand And Production Quantities For SEWHS Products.

SEWHS		
Model of Product	**Weekly Average Demand (Quantity)**	**Weekly Amount of Produced Products (Quantity)**
120S	**15**	**15**
170S	**21**	**21**
200S	**6**	**6**
300S	**5**	**5**

500S	**2**	**2**

Table 4. Number Of Products Waiting İn Queue And Waiting Times.

Process Name	Number Waiting (Average)	Waiting Time (Average)
Acid Process.Queue	0,31290	475,74
Camber Punctuation.Queue	0,00011	0,37
Bending and Puntuation.Queue	0,00005	0,08
Big Boiler Polyurethane Process.Queue	0,02493	567,24
Big Circular Welding Process.Queue	0,02114	254,49
Big Linear Welding Process.Queue	0,00041	6,38
CNC Cutting Process.Queue	0,07891	212,75
Outer Sheath Preparation Process.Queue	0,01104	35,42
Enamel Coating Process.Queue	0,00212	3,22
Enamel Drying Process.Queue	0,17900	270,74
Enamel Cleaning Process.Queue	0,04491	66,56
Baking Process.Queue	0,11060	167,74
Flange Welding Process.Queue	0,03068	85,63
SEWHS Circular Welding Process.Queue	0,00799	26,09
SEWHS Polyurethane Filling Process.Queue	0,00000	0,00
Welding Process.Queue	0,00173	5,69
Grinding Process.Queue	0,00581	18,95
Small Boiler Polyurethane Process.Queue	0,46030	1425,94
Small Circular Welding Process.Queue	0,01358	47,92
Small Linear Welding Process.Queue	0,02845	47,66
Assembly Process.Queue	0,00000	0,00
Packing Process.Queue	0,00000	0,00
Polyurethane Preparation Process.Queue	0,01036	33,92
Polyurethane Cleaning Process.Queue	0,02316	66,17
Metal Plaque Cutting Process.Queue	0,00030	0,02
Swelling Process.Queue	0,00000	0,00
Soda Process.Queue	0,00737	11,25
Test Process.Queue	0,00129	1,92
Oil Cleaning Process.Queue	0,28990	400,00

When we look at the results in Table 4, it can be seen that the process that is the most waiting process is the small boiler polyurethane process and there is no or little waiting in some processes. Generally, there is very little waiting in the processes. This shows that the present situation can easily meet the demand.

The capacity utilization rates of the machines are also given in Table 5.

Table 5. Source utilization rates of machines.

Instantaneous Utilization	Average	Half Width	Minimum Average	Maximum Average
Acid Pool	0,40890	0,01	0,38660	0,44890
Camber Punctuation 1	0,20810	0,01	0,18550	0,22080
Camber Punctuation 2	0,02937	0,01	0,01371	0,05254
Bending 1	0,23670	0,01	0,21620	0,25080
Bending 2	0,04321	0,01	0,02992	0,05648
Bending 3	0,00483	0,00	0,00000	0,00979
Big Circular Welding	0,12920	0,01	0,11090	0,16850
Big Linear Welding	0,04365	0,01	0,03607	0,05717
Big Polyurethane Area	0,22100	0,03	0,14670	0,28340
CNC	0,13200	0,01	0,11370	0,16170
Outer Sheath Preparation Area	0,15840	0,00	0,15490	0,16660
Enamel Mixing Machine1	0,39600	0,01	0,37120	0,42890
Enamel Mixing Machine2	0,21640	0,02	0,18110	0,24630
Enamel Mixing Machine3	0,10740	0,01	0,09320	0,11940
Enamel Mixing Machine4	0,05058	0,01	0,02888	0,06838
Enamel Drying Bakery 1	0,38450	0,03	0,32860	0,42460
Enamel Drying Bakery 2	0,24680	0,02	0,20380	0,27930
Enamel Cleaning Area	0,20610	0,00	0,20080	0,21280
Bakery	0,25830	0,01	0,23930	0,27630
Flange	0,22670	0,01	0,21850	0,24890
SEWHS Circular Welding	0,16480	0,00	0,16130	0,16890
SEWHS Polyurethane Filling Area 1	0,27340	0,02	0,22710	0,29060
SEWHS Polyurethane Filling Area 2	0,09270	0,01	0,06616	0,13800
SEWHS Polyurethane Filling Area 3	0,02017	0,01	0,00771	0,03880
SEWHS Polyurethane Filling Area 4	0,00237	0,00	0,00000	0,00811
Guillotine Shears	0,01478	0,00	0,01443	0,15076
Welding 1	0,29330	0,01	0,27510	0,31760
Welding 2	0,06680	0,01	0,04273	0,09050
Grinding	0,15480	0,00	0,15210	0,16100
Small Circular Welding	0,20950	0,00	0,20250	0,22120
Small Linear Welding	0,23620	0,00	0,23090	0,24990
Small Polyurethane Area	0,53140	0,02	0,50550	0,57970
Assembly 2	0,10530	0,01	0,56383	0,13120
Assembly 3	0,01623	0,01	0,00000	0,04020
Assembly 4	0,00143	0,00	0,00000	0,01427
Assembly 1	0,33150	0,02	0,29600	0,36880
Packing 1	0,49870	0,03	0,41960	0,54970
Packing 2	0,29940	0,01	0,26730	0,32810
Packing 3	0,15360	0,02	0,11450	0,19080
Packing 4	0,04376	0,01	0,00835	0,09080
Packing 5	0,01073	0,01	0,00000	0,02432

When we look at the results in Table 5, it is seen that the highest resource utilization rate is in Packing 1 and 49% of the capacity is used. This shows that it has the capacity to meet increasing demands.

5. CONCLUSION

The study aims to protect the competitiveness of the company in market conditions, to meet customer orders on time and thus to increase its productivity. The workflow and machine-equipment layout has been created in detail. For each of the defined work processes, a time study has done, standard time has calculated and process analysis has carried out. Using the measured standard times for all the liters of the examined SEWHS and Boiler products, a simulation study was carried out with the help of the Arena 10.0 package programme. All the examined products are shown on a single system. Product quantities and waiting times in the queue were determined from the beginning to the final product of each product. Examining past years' demands, it is determined that the amount of weekly demand and the demand will be met or not. It is reached through the simulation study to know when the products to be demanded can be delivered. Thanks to the simulation, knowledge that the capacity utilization ratio is low and the number of products waiting in the queue is very small have been achieved. This indicates that the company has the capacity to meet more demands.

As a result of all these studies; it is required to removed waiting and unnecessary transportation in order to remove the problem of not being able to deliver on time. It is necessary to start with the processes that have the greatest length of queue and the longest waiting times while improving company. If the data are recorded on a regular basis and the importance is given to the process improvement work, the increase in the production quantity and efficiency will occur.

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