Capacity Planning and Optimization for a National Painting Factory using Simulation Modeling and Lean Manufacturing Tools

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Abstract

This research paper presents capacity planning and optimization for a national painting company using customized time and motion study, simulation modeling and Lean manufacturing tools. The company currently facing large delay in their production line due to a set of non-value added activities. Therefore, simulation modeling has been used to identify the root causes of the problem in addition to time and motion study, value stream map, project charter, cause and effect diagram and other tools. Thorough investigations, the root causes of the problems have been identified and a new material handling method has been implemented in addition to two supermarkets (buffers) within the production line. The proposed solutions minimized the process time from 6.24 hrs to 5.34 hrs and the queue time from 2.5 hrs to zero.

Keywords
Lean Manufacturing; Simulation Modeling; Capacity Planning and Painting Factory

1. Introduction

The globalization of world markets has put today's organizations to venture into new strategic practices in order to sustain the level of competition in the market place. Today's competition is on product variety, innovation, cost and time. Therefore, an essential requirement to face these changes is through cutting production cost and increasing productivity without deteriorating quality and continually maintains quality standards. As a result, several studies have been adopted to improve production efficiency and effectiveness through different customized tools such as Total Quality Management (TQM) (Camison 1996; Hongen and Xianwel 1996), Quality Control (Pandey et al. 2011; Wang and Srinivasan 2009), Six Sigma (Cheng 2005; Habidin et al. 2015; and Mandahawi et al. 2010), lean (Cournoyer et al. 2010; Mandahawi et al. 2011) and Lean and Six Sigma (Adir 2019; Lizarelli and Alliprandini 2018).

Furthermore, Simulation is a powerful tool available to those responsible for design and operation processes. It is used to describe and analyze the behavior of a system, and to aid the design of a real system (Mandahawi et al. 2017). Discrete-event systems are dynamic systems that evolve in time by the occurrence of events at possibly irregular time intervals, which resembles the nature of real-world production and business system. As a result, simulation has been applied to a wide range of real-world applications including healthcare, manufacturing, banking, transportations, and distribution systems (Ahmed and Alkhamis 2009, Bond 2007, Chia, Lin 2016, El-Haik and Al-Aomar 2006; Gunal and Pidd 2006; Mandahawi et al. 2017; VanBerkel, and Blake 2007; Vos et al. 2007; and Werker et al. 2009).

2. Case Study

In this research paper simulation modeling combined with lean manufacturing tools have been customized to optimize the production line for a painting factory. The Liquid paint factory currently divided into six production departments which are the Lower Dyoko department, Enamel department, Emulsion department, Acrylic department, Upper Dyoko department, and the Grinding department. This study will focus on the Emulsion department, since it is the current bottleneck workstation and it has the highest percentage of the total daily production quantities. The study will also include in addition to the production department the raw material preparation and the quality control department. The following subsection illustrates how the DMAIC methodology is used to optimize the production capacity for the Emulsion department.

3. Define

At the define phase, a set of brainstorming sessions have been held in order to identify project scope, project team members, project time frame, project primary objectives, and project milestones dates. A Project charter has been used in this phase to prevent any conflict that may occur between the team members. Furthermore, to identify the most critical products that should be covered within the study, an ABC analysis is performed based upon company historical data and revealed that products Top-800 and SN-800 have the highest demand. The Emulsion department requires high integration and coordination between the production line, quality control and warehouse department as shown in Figure 1.

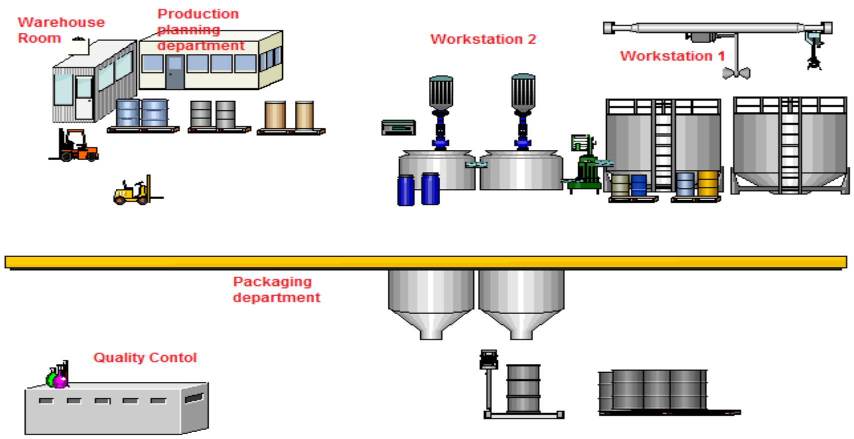

Figure 1: Top-800 and SN-800 production line

4. Measure

At the end of the first phase, the team is ready to move forward to the data collection phase using time and motion study. Time and motion study is an effective tool to minimize the gap between the estimated production capacity and the actual production capacity, which could be improved using Lean Manufacturing tool and Simulation modeling. A set of training sessions have been performed in order to minimize the personal errors during the data collection phase, sample from the collected data is shown below in Table 1.

Table 1: Data collection sample for three emulsion products

Processing Activity	Order 1	Order 2	Order 3
Prepare raw materials	20	19	25
Add S0025 2500 Kg	10	11.85	10
Transport raw material	0.6	1	1.5
Delay	0	76.2	0
Mixing Lot(1)	32.85	19	20
Transport raw material	0.6	0.8	0.6

Add PW004	31.68	37.48	30
Mixing PW004	33	20.85	25
Transport raw material	0.6	0.6	0.5
Add F0050	8.5	8.9	9.1
Delay	0	3.8	0
Transport raw material	0.6	0.5	0.8
Add F0047	16	16.4	17
Delay	4.1	0	0
sample of inspection	10	6	8
Delay	139	144	80
Pumping	20	154	26
Transport raw material	3	2.5	6
Add raw material	15	10	16.1
Mixing	20	17	21
sample of inspection	12	11	15
Setup for packaging	57	62	55
Packaging process	96	100	95

Time and motion study is carried out for four weeks to understand the process flow and the behavior of the production order through each workstation along the production line. Furthermore, a Simulation model has been developed using ARENA software to simulate the actual behavior of the production line over a long period of time. The process of constructing the baseline model involved a standard approach via a set of phases, at each phase a simple version from the model was built and verified with those involved in the process, adjustments were performed as required. The final model has been approved by the company top management team. Furthermore, the simulation model has been validated by comparing the outputs of the simulation to the actual data from the time and motion study. The model run for one hour for warm up before collecting the simulate data such that it copy the actual production line, after that the simulation model was run for 30 days, which is equivalent to 210 hours on Top-800 production line. Table 2 represents the simulation result for each production process. The results show that the average time from the simulation model for each process approximately equal to the actual data, it is clear that the simulation results are all within the range of the actual collected data.

Table 2: The Simulation Result for each production Phase

current model

Replications: 12 Time Units : Hours

Process

Time per Entity

Total Time Per Entity	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Adding raw materials 1	1.8555	0.01	1.8169	1.8990	1.6085	2.1848
Adding raw materials 2	0.2600	0.01	0.2366	0.2887	0.1333	0.3906
Delay 1	2.5886	0.15	2.2642	3.1191	0.7472	4.6150
Inspection 1	0.1170	0.00	0.1085	0.1259	0.04746312	0.1916
Inspection 2	0.2021	0.00	0.1896	0.2132	0.0939	0.3085
Mixing 1	1.0907	0.02	1.0336	1.1872	0.5526	1.5172
Mixing 2	0.2582	0.01	0.2147	0.2873	0.05839037	0.4891
Packaging process	1.6052	0.01	1.5844	1.6194	1.4646	1.7203
Prepare raw materials	0.3233	0.01	0.2990	0.3469	0.1147	0.4658
Pumping	1.2973	0.09	1.0366	1.5708	0.4195	2.8530
Setup befor packaging	0.9941	0.03	0.9221	1.0735	0.6577	1.3290
Transportation 1	0.08658555	0.00	0.08424633	0.08980873	0.04837460	0.1272
Transportation 2	0.1517	0.01	0.1363	0.1620	0.05873675	0.2467

5. Analysis

The lead time at the production process has been classified into value added (VA) time and non-value added (NVA) time within the Simulation model. All non-added value time should be analyzed and eliminate to improve the current production capacity, the NVA time has been classified into setup time, handling time, transportation time, and waiting time. The setup time occurs at the material preparation stage and before the packaging process, the transportation time appear between the warehouse department and the first workstation and the second transportation time occurs while transporting the material between the first workstation and the mixer machine. Value Stream Map (VSM) has been developed to show both the information flow and the material flow within the production line in addition to the added value and non-added value activities.

The average total lead time is 650.1 Minutes, which has been classified into raw material preparation time 19.8 Minutes, average production time at workstation 1 and workstations 2 are 344.9 Minutes and 129.1 Minutes respectively and finally the average packaging time 156.3 Minutes. Furthermore, the analysis shows that the material handling time and waiting time are the highest non-value added activities within the production line. Currently, raw material comes in small patches of 20, 25 or 50 Kg per package. Furthermore, during the production process the operator has to wait for the raw materials that are not ready yet to start the mixing process due to the improper communication between the production, warehouse and inspection departments.

6. Improve

The analysis show that there is a need to improve current material handling system, as discussed currently the raw material arrived in small patches of 20, 25 or 50 Kg per package. It has been approved by the top management and the raw material supplier to resize the raw materials into large quantities to minimize material handling time, afterward the material can be moved to the workstation using the current winch in front of the workstation. It is expected that by implementing the new material handling method the time can be reduced in average from 127.06 Minutes into 74.91 Minutes which represent around 41 % reduction.

Furthermore, to minimize the production waiting time due to the improper communication between the warehouse department and the production department especially in front of the mixing machine two supermarkets (buffers) have been added to the current production line, one in front of the warehouse department and another one in front of the production line as shown in Figure 2. The size of the supermarket has been measured and specified according to the quantity specified in the production order. The transportation of the raw materials from the primary warehouse to the secondary warehouse depend on the sequence of the production process as specified in the production order to avoid excessive processing time at the mixing machine.

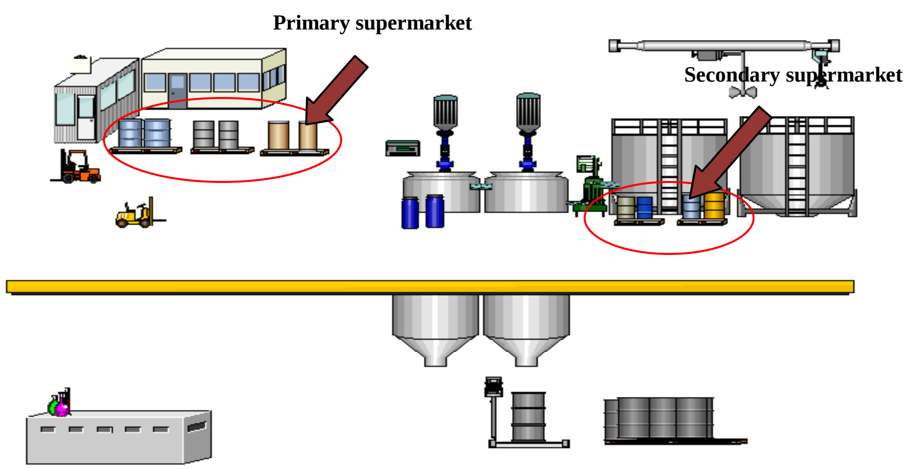

Figure 2: Primary and secondary supermarkets (buffers) along the production line

A new simulation model has been developed, evaluated and validated by adopting the supermarket concept in addition to the new material handling system. The future simulation model has been tested with the same number of replications and the same replication length. The results of the future simulation model indicate that implementing the lean concept within the production line could have enormous effect on reducing lead time as shown in Table 3.

Table 3: The expected KPI results after and before the implementation of the lean manufacturing tools

Key Performance Indication	Current Model	Future Model
Number of Output Orders	20	28
Queue Time (hr)	2.5	0
Processing time (hr)	6.24	5.34
Non Value added Time	1.5	0.65

7. Conclusion

The paper presents a simulation modeling using Arena software combined with lean manufacturing tools for the most two important products Top-800 and SN-800 which have the highest demand at the Emulsion department in a painting factory company. The current analysis shows that there is a need to improve current production line to increase the production capacity in order to meet customer demand. Through detailed time and motion study and simulation modeling analysis the team was able to identify the main non-value added activities that affect the production line capacity. Afterward, a set of lean manufacturing tools have been proposed to improve current production capacity such as improving material handling process and implementing two supermarkets to minimize the mixing time. A new simulation model has been developed, the analysis show that the lead time will reduce from 6.24 hr up to 5.34 hr, queue time from 2.5 hr to zero hour and non-value added time from 1.5 hr to 0.65 hr. All the proposed solutions have been approved by the company top management team and immediate actions have been taken to change current production process.

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