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Technical Paper

Lean production system design for fishing net manufacturing using lean principles and simulation optimization

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ABSTRACT

Value stream mapping (VSM) is a useful tool for describing the manufacturing state, especially for distinguishing between those activities that add value and those that do not. It can help in eliminating non-value activities and reducing the work in process (WIP) and thereby increase the service level. This research follows the guidelines for designing future state VSM. These guidelines consist of five factors which can be changed simply, without any investment. These five factors are (1) production unit; (2) pacemaker process; (3) number of batches; (4) production sequence; and (5) supermarket size. The five factors are applied to a fishing net manufacturing system. Using experimental design and a simulation optimizing tool, the five factors are optimized. The results show that the future state maps can increase service level and reduce WIP by at least 29.41% and 33.92% respectively. For the present study, the lean principles are innovatively adopted in solving a fishing net manufacturing system which is not a well-addressed problem in literature. In light of the promising empirical results, the proposed methodologies are also readily applicable to similar industries.

1. Introduction

The common challenges that companies face are market competition, increased pressure on inventory, increased service levels, and reduced work in process (WIP). Lean manufacturing is one of the approaches that can help companies respond appropriately to these challenges [11,18]. The focus of the approach is on cost reduction, by eliminating activities that do not add value by linking and balancing work stages, so that products from one stage are consumed directly by the next stage, until the end of the production line is reached [4,5,7,18].

Applications of lean manufacturing have spanned many sectors, including the automotive industry, electronics, white goods and consumer goods [1,21]. However, there is no evidence of work applying lean manufacturing principles to fishing net production. Fishing net manufacturing is a high make-to-order (MTO) environment, because net size and type change according to the ocean environment, fish kinds and ship size.

MTO manufacturing need not be a pull production system—a lean design principle. Usually, there are many (or some) simultaneous orders in the manufacturing process. These orders may be different in size and specifications. Thus, there is no guarantee that the system will follow a first-in-first-out rule. In fact, it is often quite messy when production is loaded with work-in-process. Thus, it may be effective to adopt lean principles to regulate the flow and to control the work-in-process level.

Higher WIP and longer cycle times always result in a lower service level and produce lower customer satisfaction in MTO environments. Moreover the fishing net manufacturing system is distinctive. Through the production procedure the production units become bigger and bigger and the processing time in most steps are quite long (between 3 and 10 days). This provides the motivation for this research, to design a lean manufacturing system for this industry.

Value stream mapping (VSM) is a visual tool that facilitates the process of lean production by helping to identify the value-adding steps and eliminating the non-value adding waste [22]. In recent years, VSM has emerged as the superior method to implement lean production in factories, and has been used to identify where waste occurs [3,12,14,15,17,24,25,28]. VSM creates a pictorial representation and common language for the production process, enabling

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more purposeful decisions to improve processes. Numerous applications can be found in the literature. For example, Seth and Gupta [22] applied VSM to establish lean production in an Indian two-wheeler motor company. Lummus et al. [16] report on a VSM project in a small medical clinic. The new system can increase patient throughput and reduce patient waiting time. Abdulmalek and Rajgopal [1] describe a steel mill case, and apply VSM to identify the opportunities for improvement. Lian and Landeghem [14] propose a generator which automatically yields a simulation model for VSM. The current and future state VSM of a poultry and pig rearing equipment manufacturing system is introduced to demonstrate the proposed generator. Barber and Tietje [2] demonstrate the use of VSM to achieve both greater efficiency and value creation in a sales process. Seth et al. [23] identify and address various sources of waste in the supply chain of an edible cottonseed oil industrial process and use a VSM approach to improve productivity and capacity utilization in an Indian context. Lasa et al. [12,13] redesigned six production systems with the VSM technique, and then analyze the causes for the limited adoption of lean manufacturing concepts. The six production systems are manufacturing systems for kit furniture, water heaters, forging, detonator systems, mechanized and stamped parts, and thermoplastic parts.

Rother and Shook [20] proposed seven guidelines based on the concept of lean manufacturing to construct the future VSM which can be implemented in a reasonably short time period without any major investment. According to the seven guidelines, there are several factors that should be considered. Different combinations of the factors would result in different production performance. However, the implementation of the recommendations is likely to be risky. Simulation is a useful tool for evaluating the performance of a new design but it cannot provide the optimal design. Combining simulation with experimental design or intelligent search has been successfully adopted for simulation optimization. Yang et al. [27] use a commercial tool called OptQuest for optimizing an integrated-circuit (IC) packaging system. OptQuest embeds scatter search (SS) in a simulation tool Arena to optimize the simulation models. Yang et al. [26] combine simulation with genetic algorithm for optimizing dispatching rules in a flow shop with multiple processors. Kuo et al. [9] integrate simulation and the Taguchi method to optimize an integrated-circuit (IC) packaging system.

The objective of the present study is to model a non-typical production system – a fishing-net manufacturing system – and to propose a lean production system design which is optimized by simulation optimization.

The remaining sections of this paper are organized as follows. In Section 2 the lean principles are introduced, and a number of decision factors are highlighted. Then, the fishing-net production system is introduced and the current state VSM is provided in Section 3. Finally, a hybrid experimental design and intelligent search approach is adopted for optimizing the decision factors and then the future state VSM is constructed in Section 4. A summary of results and concluding remarks are presented in Section 5.

2. The lean principles

Rother and Shook [20] propose a five phase implementation of VSM. The phases are (1) selection of product family; (2) current state mapping; (3) future state mapping; (4) definition of working plan; and (5) achievement of working plan. The lean techniques to be used are defined in the third phase which contains seven guidelines to define the future state map [12]. The seven guidelines are summarized below:

2.1. Guideline #1: produce to your takt time

"Takt time" is used to synchronize the pace of production with the pace of sales. In general, it can be calculated by Eq. (1)

$$\text{Takt time} = \frac{\text{available working time per day}}{\text{customer demand rate per day}} \tag{1}$$

However, when the process times of different products are quite different, the takt time calculated by Eq. (1) is not reasonable. For example, suppose there are two types of product, A and B, and the unit process time and demand rate of product A are 120 min and 4 units per day, respectively and the process time and demand rate of product B are 60 min and 8 unit per day. If the available working time is 18 h per day, then the takt time is 90 min ($18 \times 60/(4+8)$). This means that one unit should be produced every 90 min, but this is impossible for product A. The present research uses Eqs. (2)–(4) for calculating the takt time.

$$KS_i = \frac{\text{The lowest common multiple of processing time for all products}}{P_i} \tag{2}$$

$$NK_i = \frac{D_i}{KS_i} \tag{3}$$

$$\text{Takt time} = \frac{\text{Available working time per day}}{\sum_{i=1}^{N} NK_i} \tag{4}$$

In Eq. (2) KS_i indicates the kanban size of product i ($i = 1, 2, \ldots, N$), and P_i indicate the processing time of product i. In Eq. (3) NK_i indicates the number of kanbans of product i, and D_i indicates the demand for product i per day. Thus, for the same example, the kanban size for product A and B are 1 and 2 units respectively, and the number of kanbans for product A and B are both 4. The takt time is 2.25 h. This means that one unit of product A or two units of product B should be completed every 2.25 h. Each kanban indicates one unit of product A or two units of product B and four kanbans are required per day for both product A and B.

It should be noted that the lowest common multiple of processing time for all products in Eq. (2) is an approximate value and should be as small as possible. Managers can increase the process time of some product types to tune it. For example, if there are three product types and their corresponding processing times are 12, 11 and 25 min, then the processing time of the first two product types can be increased to 12.5 min, so that the lowest common multiple of processing time will be 25 min.

Corollary 1. The takt time is dependent on the size of a production unit.

Corollary 1a. A kanban represent the same required production time regardless of the different product types.

2.2. Guideline #2: develop continuous flow where possible

Continuous flow refers to producing one piece at a time to reduce the inventory of WIP and production CT. However continuous flow requires a great deal of creativity to achieve and sometimes it requires plant layout redistribution [12]. In this research, this guideline is not applicable and is not taken into consideration in the case study.

2.3. Guideline #3: use a supermarket to control production where continuous flow does not extend upstream

A "supermarket" is nothing more than a buffer or storage area located at the end of the production process for products that are ready to be shipped [1]. When continuous flow is not possible and batching is necessary, a supermarket can smooth the whole manufacturing process. Supermarkets use a kanban system to fix the