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Design and Implementation of a JIT Scheduling System for Sheet Metal Industry

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***Abstract*— Lean manufacturing is a strategy and philosophy originated from Just-In-Time (JIT) production which aims to eliminate waste and maximize efficiency in the production process. While lean manufacturing is studied and applied in va¬rious scenarios, the approach encounters multiple challenges that are not yet solved in sheet metal production industry. This paper provides a novel scheduling approach specifically for sheet metal industries, and achieved the goal of reducing waste in the scheduling process in a real-life simulation through the use of value stream mapping simplification and intelligent order mixing.**

***Keywords*— Just-In-Time, VSM, Sheet Metal Manufacturing, Lean Manufacturing, Scheduling.**

I. INTRODUCTION

Lean manufacturing, also known as lean production, is a manufacturing philosophy and strategy that aims to eliminate waste and maximize efficiency in the production process. This approach focuses on delivering high-quality products on time and at the lowest possible cost, while also improving customer satisfaction.

The origins of lean manufacturing can be traced back to the Toyota Production System, which was developed in the 1950s by Taiichi Ohno and Eiji Toyoda. The Toyota Production System was built on the principles of just-in-time production and continuous improvement, and it emphasized the importance of waste reduction, standardization, and teamwork.

Lean manufacturing is based on five key principles, which are:

Value: Defining value from the customer's perspective and focusing on the processes that add value to the product or service.

Value Stream: Identifying the value stream, which is the sequence of processes required to produce the product or service, and eliminating any steps that do not add value.

Flow: Creating a smooth and continuous flow of products or services through the value stream by removing any barriers or bottlenecks.

Pull: Implementing a pull system, which means that products or services are produced based on customer demand rather than being pushed through the value stream based on production schedules.

Continuous Improvement: Encouraging a culture of continuous improvement through the use of tools, which is a method of continuous improvement that involves making small, incremental changes to the production process.

The benefits of lean manufacturing are numerous. By focusing on waste reduction and efficiency, lean manufacturing helps organizations to reduce costs, improve quality, and increase productivity. Lean manufacturing also promotes employee engagement and teamwork, which can lead to higher job satisfaction and better employee retention. Additionally, lean manufacturing can help organizations to become more flexible and responsive to changing market conditions, which is essential in today's fast-paced business environment.

However, implementing lean manufacturing can be challenging, particularly for organizations that are used to traditional production methods. To be successful, organizations must commit to a culture of continuous improvement and embrace change. They must also invest in employee training and development, as well as in the technology and equipment needed to support lean manufacturing processes.

II. RELATED WORKS

A. Lean Manufacturing

JIT and lean manufacturing have been researched and studied for years, the implementations in real-life scenarios has been experimented and optimized with the help of AI and other advanced ideologies and techniques.

The factors and ideas around lean manufacturing has been developed through the years it is researched. Usually it considers employee perceptions, value stream mapping, takt time, bottleneck, group technology and other concepts in the implementation of lean manufacturing [1]. At the same time, the study also showed that around 60% of industrial wastes are due to bad inventory. It has also been proved true that the lack of planning, lack of direction, lack of sequencing and interdependency factors of lean elements must be dealt with to achieve a successful scheduling system.

For real-life implementations, Bhamu et al has increased the production rate per day by 10.37%, decreased the production lead time by 10.51% and reduced non-value added time by 4% by identifying and eliminating non-value added activities through value stream mapping in a real-life case considering an automated production line in India [2]. The method has been proved successful by other researches as well, however it did not advance in other aspects in lean manufacturing or JIT which can certainly level the performance further. Xing et al has implemented lean construction techniques in Chinese projects , utilizing questionnaire and comparative analysis [3]. A JIT logistic is designed and applied with digital technologies including iot in order to improved continuously. The waiting time, defects of product, and underutilized people are greatly reduced as a result. However, the sheet metal industry provides different challenges compared to construction industry, which means it is able to take some aspects into account, but there are more barriers to be considered.

B. Sheet Metal Scheduling

Sheet metal scheduling in arranging the production process according to the orders. It is closely related and often referred as job shop scheduling problem [4], [5]. A well-arranged schedule is to map operations to resources, so both tardiness and material waste will be minimized [6]. There are several articles about sheet metal scheduling utilizing cloud functions [7-9], however there are downsides in cloud computation for sheet metal scheduling. There is an extra cost in using cloud functions from other enterprises, at the same time, cloud scheduling tools does not help employees at the work station as the information flow is not connected through different parts in the manufacturing process. At the same time, sheet metal manufacturing scheduling papers might not take different kinds of products into consideration [10], resulting in bad flexibility. As there are so many challenges from work stations, employers and employees, it is almost guaranteed that a well designed scheduling method can help greatly in reducing wastes, as Choomlucksana et al successfully reduced processing time by 62.5% and non-value added activities by 66.53% [11].

III. METHODOLOGY

From the related works and researches, certain challenges for sheet metal scheduling are revealed. As there can be hundreds of parts with completely different manufacture processes to assemble one machine from one order (shown in Figure1), the complexity raises exponentially when number of order increases. This paper focus on methods to simplify the process and manage resources in order to create a viable scheduling algorithm for sheet metal manufacturing. Methodologies applied in this paper include the simplification of VSM and order mixing.

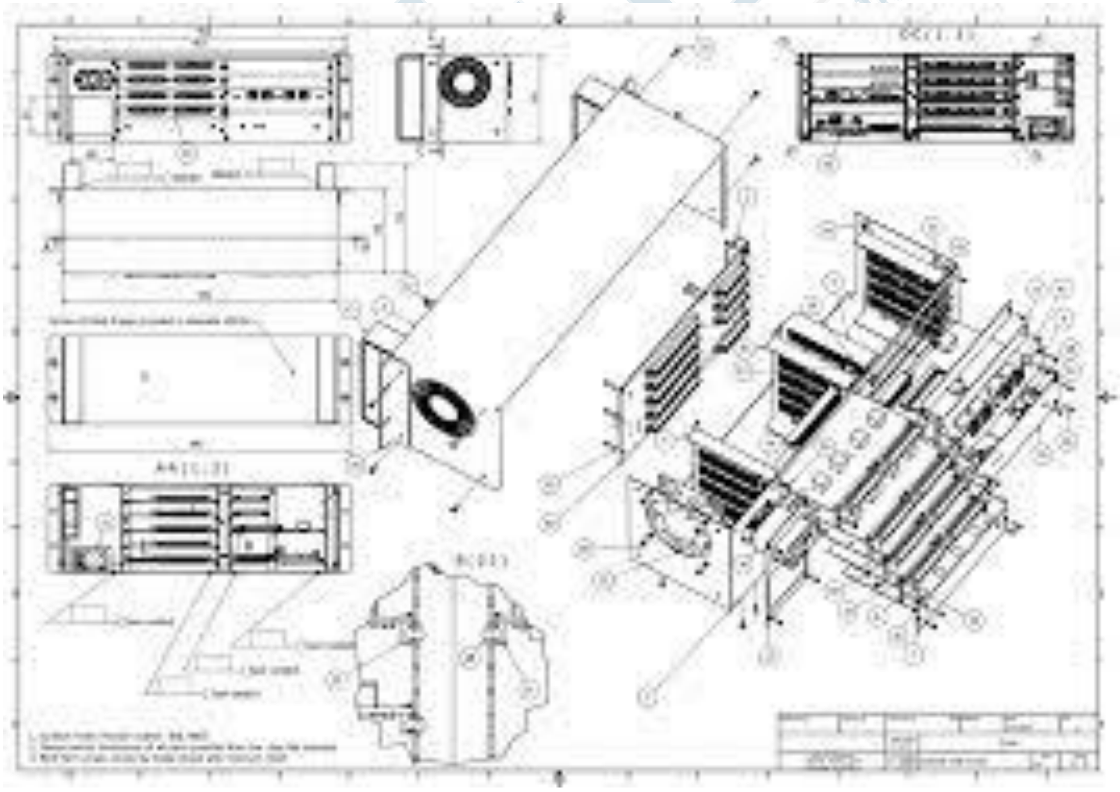

Figure 1. Example of Sheet Metal Components

A. Value Stream Map Simplification

A value stream map(VSM) is a visual representation of the material and information flow. It is a tool used to identify and eliminate waste, thereby improving efficiency, reduce lead times, and increase customer satisfaction as a way to increase value. A VSM usually includes information such as process steps, cycle times, inventory conditions, and material flow. As a gre at tool to identify potential wastes in the manufacturing process, constructing a VSM will be a necessary step to make the manufacturing process more efficient. However, the possible combinations of scheduling order raise the complexity and make the computation too costly in time. In order to successfully construct a VSM with an acceptable cost, this paper provides a novel method of simplifying the VSM. This paper simplifies the VSM both physically and virtually. According to the Toyota Production System, VSM should be a clear visual representation of the production process and should be easy to understand. Physically, it is often that a VSM simply includes all the production steps in order to make the map clear. However this make the map extremely complicated when considering sheet metal manufacturing, therefore this paper simplifies VSM physically by merging similar steps. For example, if there are 4 different components to be assembled, the processes would possibly be merged so there will be only one step in the VSM instead of four. It is required that the VSM shows the critical steps in the processes clearly while being simplified, therefore the VSM also need to be simplified virtually. This paper defines the critical steps in the production process in order to structure the VSM in the most efficient way.

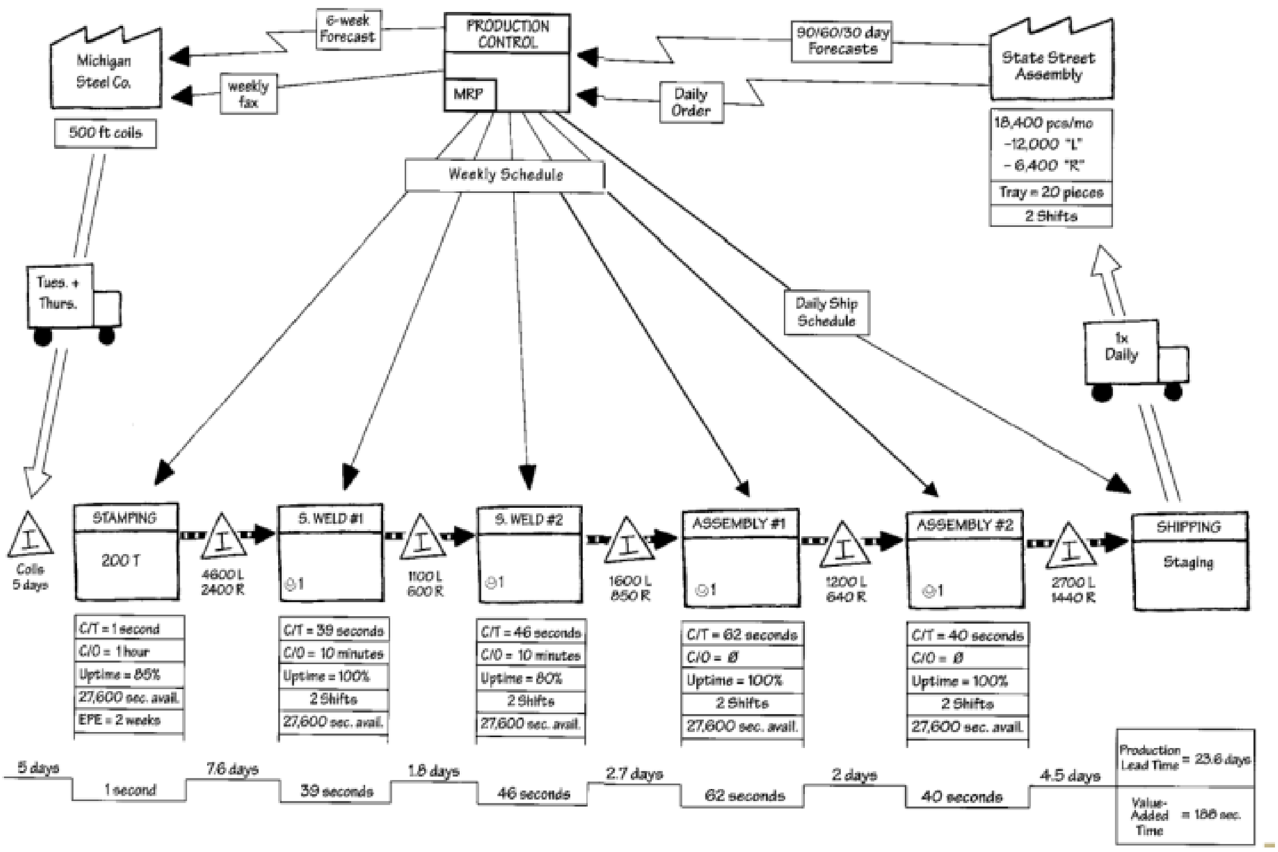

Figure 2. Example of VSM

B. Intelligent Order Mixing

It is common that a sheet metal manufacturing company is requested with different orders with widely ranged deadlines. Most companies nowadays utilize the push system, which is arranging the orders by deadline and push the materials accordingly. While the ordered components and final products are customizable, it is almost guaranteed that the schedule is not optimized and the waste will increase massively proportional to the increasing number of orders. This paper utilizes the pull system with order mixing in order to create an intelligent scheduling system with minimum waste. For pull system in lean manufacturing, the material and information flow is determined by the orders so that the manufacturing process saves inventory space and wait time which both cause wastes. The takt time is a key concept in lean manufacturing that refers to the pace at which products must be produced to meet customer demand. It is usually calculated by averaging the production time of different components of the product. It is used to synchronize the production process so that all production process are in the same pace with each other in order to avoid waste from differed producing speed. However, for sheet metal manufacturing, the components of a product may not go through the same processes, therefore challenges are encountered when the takt time for each station does not clearly represent the average producing speed for all components. Therefore, this paper divided the information flow to the bill of materials(BOM) and producing takt time.

With the divided information flow, the producing order and speed, as well as the whole scheduling process can be determined accordingly.

IV. SYSTEM IMPLEMENTATION

The performance of the proposed system is tested with sample data from a sheet metal manufacturing company. The exact content of the simulation is kept for privacy concerns. There are three main factors in the implementation of the system, which are the concatenation of the information flow in different processes, the integration of the material flow at different work stations, and a balance rule for machines with imbalanced efficiency. With focusing on these three factors, it is shown that the production process can be optimized and the waste can be reduced during the process.

A. Information Flow Concatenation

The information flow in this paper is referred to the information required during the manufacturing process. The proposed system involves with six different categories of information flow. The manufacturing process starts with the order, which includes information of the client, the product, the amount required, and the deadline. This information set the base of the product process which starts the pull system. Next, to manufacture the required products, the company needs to check its ability in producing the product. Different manufacturing companies may have different number of machines, human resources, and their own limitations. With a clear definition of the capacity, manufacturing companies can manage the resources more reasonably and efficiently. After the manufacturing process starts, it is vital to keep track on the production progress, this part includes the estimated time of completion and the latest progress of the whole process. With this information, companies can establish control over the process with a better understanding of what can be accomplished. During the process, it is also important to keep track of the condition of the material, waste often comes from unnecessary wait time and an overly stacked inventory or storage space. A clear grasp of the information can help avoid waste. While an order often involves with a lot of manufacturing processes, it is common to encounter different kinds of problems during it. It is vital to respond to the problems and resolve it or change the plan accordingly as soon as possible, which helps avoid unnecessary wastes that would exist if the problems are not solved timely. After the manufacturing is done, the data gathered during the process can be used for further analysis in order to identify and prevent the possible challenges as well as possible improvements that can level the efficiency or customer satisfaction. By combining the information flow, the manufacturing company can easily manage the manufacturing process, which helps greatly in reducing waste and raising the production efficiency and customer satisfaction.

B. Material Flow Integration

While information flow sets the standard for the manufacturing process conceptually, the material flow is what to be considered when the process is in progress. The integration of material flow involves management of the movement for materials. One of the key points of the proposed system is a integrated material flow as well as information flow. In real life scenarios, the employees at the stations may not understand the scheduling results, and may take actions those actually influence the manufacturing in whole negatively. The proposed system emphasizes on standard operations, that the material flow to each station will be clearly instructed to the employees at the station, therefore reducing waste from unclear instructions. At the same time, the transportation of the material will be done by specific personnel so that employees at the stations don't have to move the material on their own which cause unnecessary wait time for the machines. The route of the material transportation is also designed in the most efficient way so that employees don't have to wait for materials to come or leave the station, the traffic will be steady and immediate, and the time used in transporting will be managed as well. With an integrated material flow, the management of the materials is more flexible since the amount of materials to be manufactured, the estimated time, and the manufacture operations are already clearly instructed. In a word, every personnel is working on an already instructed operation, which ensures efficiency.

C. Balance Rules

On the other hand, for stations like welding, the production capacity of each machine is more influenced by the employee's experience than stations like bending or assembling. Therefore specific rules are defined to balance the pace of production of different machines in order to keep the work flow steady to avoid waste. Taking the laser cutting machine as an example. The proposed system utilizes algorithm to analyze new product layouts with data from the layouts those are manufactured previously to provide an estimated work time for the product. This helps make sure about the work time and capacity faster than layout software. Next, the total production time is averaged and divided between the machines with different production capacity. Finally, the employees and machines are distributed accordingly to the averaged time for the most steady pace. This solves a common problem when laser machines' work time are not certain and the schedule needs to be reworked after the machines start to work and find out the time is not compatible with other processes.

V. CONCLUSION

This paper provides a novel approach in the scheduling of sheet metal manufacturing utilizing value stream mapping simplification and order mixing. The VSM is simplified physically by merging similar steps in order to leave the critical processes in procedure and virtually by evaluating the information flow in order to ease the construction of VSM and hold the understandability of the original version. The orders are mixed in a pull system with the a defined takt time and BOM routing, which ensures a same-paced production process and helps reduce waste and increase customer responsiveness accordingly. The method is tested with real-life simulation of a series of sheet metal manufacturing orders and proved to be successful in reducing waste.

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