Value Stream Mapping – A Tool for Engineering and Technology Education and Practice

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ABSTRACT

Value Stream Mapping (VSM) is a tool that is essential to both quality improvement initiatives and to implementation of lean manufacturing principles. This technique can be applied to manufacturing and processing environments, but also to business and management systems. This versatile, powerful method is used to visualize product flows through various processing steps, with the added benefit of illustrating the information flows that result from these operations, as well as the information used to control the product flows. As quality and lean concepts continue to gain importance in manufacturing and business settings, it is increasingly important for engineering and technology graduates to be knowledgeable regarding practices and procedures that are vital to achieving these objectives. Thus the goal of this paper is to introduce engineering and technology educators to the use of VSM. Toward that end, common nomenclature and symbols will be introduced, techniques for mapping an industrial process will be discussed, and an example application will be presented.

Keywords
Flow, lean manufacturing, process improvement, pull, push, value stream.

INTRODUCTION

The current pressures of global competition have forced companies to look at how they are organized and how they perform daily operations. What is often found in most manufacturing settings is that there are substantial costs occurring due to non-value-added actions. Many companies are now facing very determined competitors, and thus need to streamline processes and remove any actions that do not produce value. In order for companies to survive, they must be able to maximize outputs using minimal inputs. Companies that can deliver the highest quality goods at the lowest prices will stand a better chance of thriving in the current business climate. Lean manufacturing techniques are helping companies to become competitive, especially by reducing waste in their operations. Lean manufacturing has been defined as the reduction of waste in all forms by maximizing value-added activities (Forrester, 1995).

Lean manufacturing is an approach that can be used to maximize the use of resources while keeping processes simple. It achieves this by using less of everything. This includes human effort, manufacturing space, tooling investment, and engineering hours spent in designing new products, to name just a few. Also a reduction in inventory and number of defects can also be achieved (Lathin 2001).

Manufacturing plants that change their business philosophy from a batch system to a lean system often do so in a cautious manner. This is understandable, and appropriate, since changes can be expensive, often fail if not implemented correctly, and can have the potential to be prolonged endeavors. Moreover, lean initiatives, such as those that are aimed at Just-in-Time (JIT) manufacturing, can sometimes entail painstaking processes, not only for the business as a whole, but also for individual employees. Because of the many potential benefits of lean manufacturing, much attention has been focused on advancing its tools, techniques, and implementation strategies in recent years. Further discussions can be found in Bozzone (2002), Edwards (1996), Feld (2001), Kovach et al. (2005), Rother and Shook (2003), and Storch and Lim (1999).

Lean manufacturing must begin with a full understanding of the business in great detail, not only production processes and material flows, but also information flows. One powerful yet simple tool that is often used to capture this information when beginning a lean initiative is Value Stream Mapping (VSM). This technique is used to identify all of the value-adding as well as non-value-adding processes that materials are subjected to within the plant, from raw material coming into the plant through delivery to the customer. With this map, identification of wasteful processes and flows can be made, so that they can be modified or eliminated, and thus the manufacturing system can be enhanced (Lovelle 2001). VSM is used to outline both the present and future (i.e., improved) states of production. Because it is becoming ubiquitous in industry, it is imperative that engineering and technology students know how to use this tool effectively.

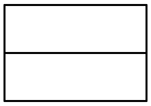
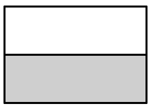
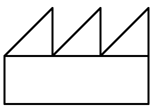
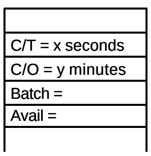
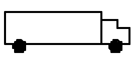
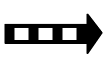
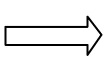
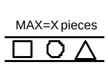
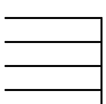
Therefore, the goal of this paper is to introduce engineering and technology educators to the use of VSM. Toward that end, common nomenclature and symbols will be introduced, techniques for mapping an industrial process will be discussed, and an example application will be presented. Additionally, incorporation into engineering and technology curricula will be discussed.

VSM NOMENCLATURE

A value stream encapsulates all of the material and information processes and flows that are required to produce a specific product. This includes all of the value-added as well as non-value-added actions that occur as raw material enters the plant gate until the finished product leaves the facility.

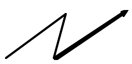
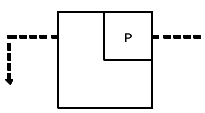
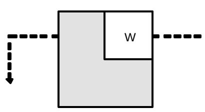
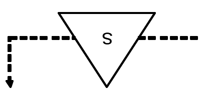
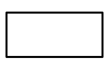
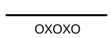
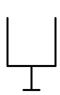
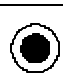
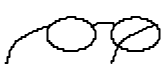
In order to use VSM to effectively "map" the production of a specific product, it is essential to understand all of the symbols that can be used to represent products, processes, and information flows. Table 1 below provides common material flow symbols. Table 2 below provides common information flow symbols. Table 3 below provides common general symbols. Each table also provides a brief description of each of the symbols.

Table 1. Material flow symbols (adapted, in part, from Rother and Shook, 2003).

Symbol	Title	Definition
	Dedicated Process	This symbol denotes a process, machine, or department through which materials flows.
	Shared Process	This symbol denotes a process, machine, or department that multiple value stream products share.
	Customer or Supplier	This symbol denotes either a customer of the product, or a raw material supplier.
	Data Box	This symbol is used to summarize essential information for a process, machine, or department, especially demand, batch sizes, and frequency.
	Inventory	This symbol denotes raw material levels, the inventory build-up between process steps, and finished product levels.
	External Shipment (Receiving or Shipping)	This symbol denotes shipment of incoming raw materials, and shipment of finished goods out of the plant.
	Push Arrow	This symbol denotes movement of material that is produced and then sent (pushed) to the next process step.
	Shipment (Receiving or Shipping)	This symbol denotes movement of incoming raw materials, and movement of finished goods out of the plant.
	FIFO Lane	This symbol denotes a First-In-First-Out inventory that limits flow between processes.
	Supermarket	This symbol denotes an inventory of parts used to reduce overall inventory levels

		that are essential for downstream processing.
	Material Pull	This symbol denotes the withdrawal (pull) of materials from a supermarket inventory for downstream processing.

Table 2. Information flow symbols (adapted, in part, from Rother and Shook, 2003).

Symbol	**Title**	**Definition**
	Manual Information	This symbol denotes manual flow of information (hardcopies, memos, notes).
	Electronic Information	This symbol denotes electronic flow of information (email, fax, phone, computerized data transmission).
	Production Kanban	This symbol denotes the production of a specific number of parts.
	Withdrawal Kanban	This symbol denotes the transfer of parts out of a supermarket inventory to a specific process.
	Signal Kanban	This symbol denotes a material pull, but when inventory levels have dropped to a minimum level.
	Production Control Information	This symbol denotes production scheduling information.
	Load Leveling	This symbol denotes the adjusting of kanbans to level production of parts over time.
	Kanban Post	This symbol denotes the location where kanban cards are collected.
	Sequenced Pull	This symbol denotes the production of a specific number of parts without using a supermarket inventory.
	Go See Scheduling	This symbol denotes scheduling production based on visually inspecting

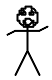
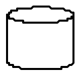
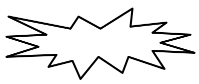
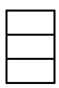
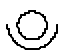
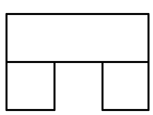
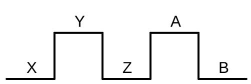
		inventory levels.
	Verbal Information	This symbol denotes the flow of verbal information.
	MRP/ERP	This symbol denotes the use of central production scheduling, such as MRP or ERP.

Table 3. General symbols (adapted, in part, from Rother and Shook, 2003).

Symbol	Title	Definition
	Kaizen Burst	This symbol denotes a potential process change that can be used to improve the Current State.
	Safety Stock	This symbol an inventory that is used in case of downtime to protect the production system from disruption.
	Human Operator	This symbol denotes a human operator at a specific workstation. The number of operators should be noted.
	Workcell	This symbol denotes a workcell where several processes are integrated.
	Timeline	This symbol denotes value-added times (lower) and non-value-added times (upper) for each stage in the production process.

VSM METHODOLOGY

Using the symbols discussed above, the methodology associated with VSM construction is relatively straightforward, and consists of three basic steps:

1) Draw a Current-State Map of the production system
2) Decide how best to improve the current system
3) Draw a Future-State Map for the production system incorporating these changes

The real goal of VSM is to produce the future-state map, which essentially plots an optimized production system. This is ultimately realized when lean is implemented on the actual factory floor. To achieve the future state, however, the current state must first be understood. A system's current state can only be defined after thoroughly examining the production floor, and analyzing the complete path a product takes through the plant, not necessarily according to the physical plant layout, but by major processing steps, wherever material or information flows occur. For each process, it is important to note the Cycle Time (CT), and Changeover (i.e., Setup) Time required. Other pertinent information includes production (batch) size, number of operators required, effective working time, and scrap rate. Product flows must be defined as either push or pull, depending on the production process. After all processes and material flows are delineated, it is imperative that all information flows, both electronic as well as manual, be placed on the map as well, especially scheduling information. Finally, a timeline must be added, so that the production process can be analyzed quantitatively. The lead time for each process should be denoted on the top position of the timeline, while the processing time should be provided on the bottom position. This allows a total Production Lead Time, as well as a total Processing Time, to be calculated for the entire production line.

After the current state has been mapped, the production process must be examined and analyzed so that it can be improved, and thus the future state map can be drawn. One of the primary reasons to examine the current state map is to quantify overproduction of items and wasted time, where inventory sits idle, waiting to be used by the next process. The map should be examined for areas where the concepts of lean manufacturing can be utilized to reduce or eliminate wasted time, and by so doing minimize lead times, and thus streamline each process. Eliminating processing steps, adjusting specific processes, incorporating continuous flow or pull systems, and leveling production are some of the techniques that can be used. More information regarding lean techniques and strategies can be found in the literature, including Dailey (2003), Liker (2003), and Womack and Jones (2003).

After proposing options to improve the production process, the final step of VSM is to draw the new scenario which incorporates these changes, which is known as the Future State Map, using the symbols provided in Tables 1 through 3. This map can then be used as a guide for implementing a lean strategy to improve the current production state.

It is suggested that pencil and paper be used when constructing a VSM. These maps can, however, be easily constructed using standard office software or graphics packages, such as CAD systems. Additionally, dedicated VSM software is available for purchase, including Stratego (http://www.strategosinc.com) and Systems2win (http://Systems2win.com).

Note that this synopsis of VSM is only intended to serve as a brief introduction for educators. In-depth information regarding VSM can be found in literature, including Keyte and Locher (2004), Rother and Shook (2003), Tapping et al. (2002), and Tapping and Shuker (2002).

VSM EXAMPLE – BOLT MANUFACTURING

A simple example will illustrate the techniques that can be used when implementing VSM. Figure 1 depicts a bolt manufacturing operation that ships 7500 bolts per week. This Current State Map provides cycle time and setup time information for each of the 15 processes that are used, and it provides inventory levels at each location. Additionally, information flow is depicted between the steel supplier, the bolt customer, and management vis-à-vis production scheduling. The total value-added time, denoted as Processing Time, is obtained by summing all of the individual value-added contributions at each processing step on the timeline. For this example, it equals 28.88 seconds. At each inventory location, Lead Time is calculated by dividing inventory level by daily production demand, which is 1500 bolts. Summing all of the lead times produces an overall Production Lead Time of 66.1 days, which is the entire time it takes an individual bolt to make its way through the plant.

To optimize the current production scenario, several possibilities exist. Figure 2 provides a few of these, shown as Kaizen bursts, including eliminating several processing steps, modifying some of the existing processes, and reducing travel distances between processes. Figure 3, the Future State Map, illustrates the incorporation of these modifications. As shown, the changes reduce Production Lead Time to 50.89 days, which is a 23% reduction. This production scenario could be enhanced even more if pull systems were incorporated at various locations, but that is left as a future exercise.

CURRICULA INFUSION

As quality and lean concepts continue to gain importance in manufacturing and business settings, it is increasingly important for graduates from engineering and technology programs to be knowledgeable regarding practices and procedures that are used to achieve these objectives. VSM is one such tool that needs to be understood. Infusing technical curricula with VSM can be accomplished fairly easily, especially in various manufacturing classes, from basic up to advanced levels. Additionally, plant layout and material handling, quality control and improvement, and even workplace safety and ergonomics courses would benefit by incorporating VSM exercises. Although VSM has only been discussed within an engineering and technology context, business processes are also amendable for this methodology.

VSM training can be readily implemented in any of the aforementioned courses, either as a specific learning module dedicated to VSM methodology alone, or as a tool that can be used to analyze specific production scenarios. The latter approach can be used to examine specific case studies, and even as a technique to examine potential manufacturing options in capstone senior design courses. Ultimately, the inclusion of VSM concepts and methods in undergraduate engineering and technology education will be dependent upon individual faculty interest and implementation, and will be primarily influenced by the creativity of the instructor.

CONCLUSIONS

This paper has been intended to introduce educators to Value Stream Mapping (VSM), which is becoming an essential tool for realizing lean manufacturing in actual production settings. Essential concepts have been discussed, as have common symbols and nomenclature, methodologies, and curriculum infusion techniques. Educators should find this a useful resource base from which to work in order to augment their current curricula.

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BIOGRAPHICAL INFORMATION

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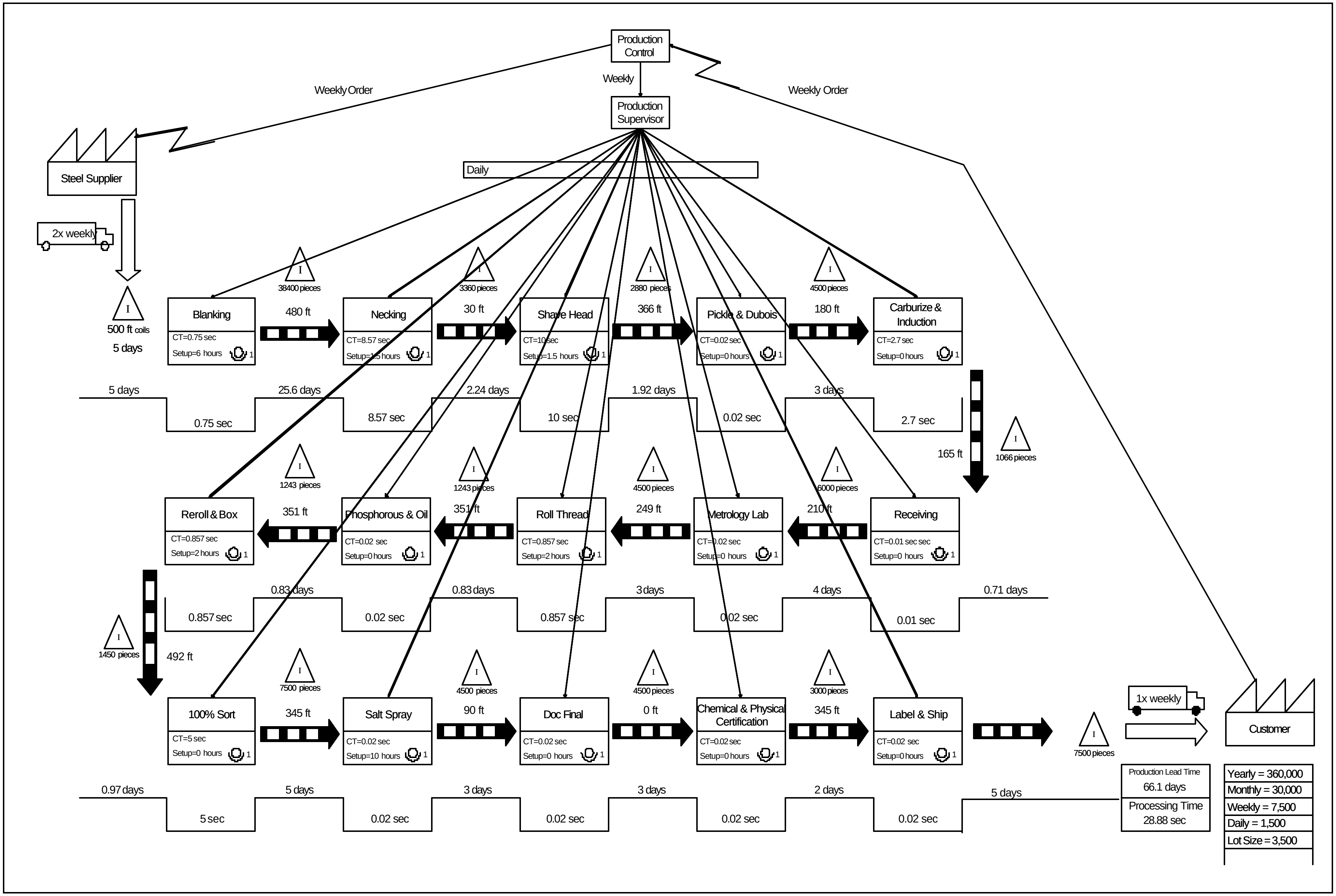

Figure 1. Current State Map for bolt manufacturing example.

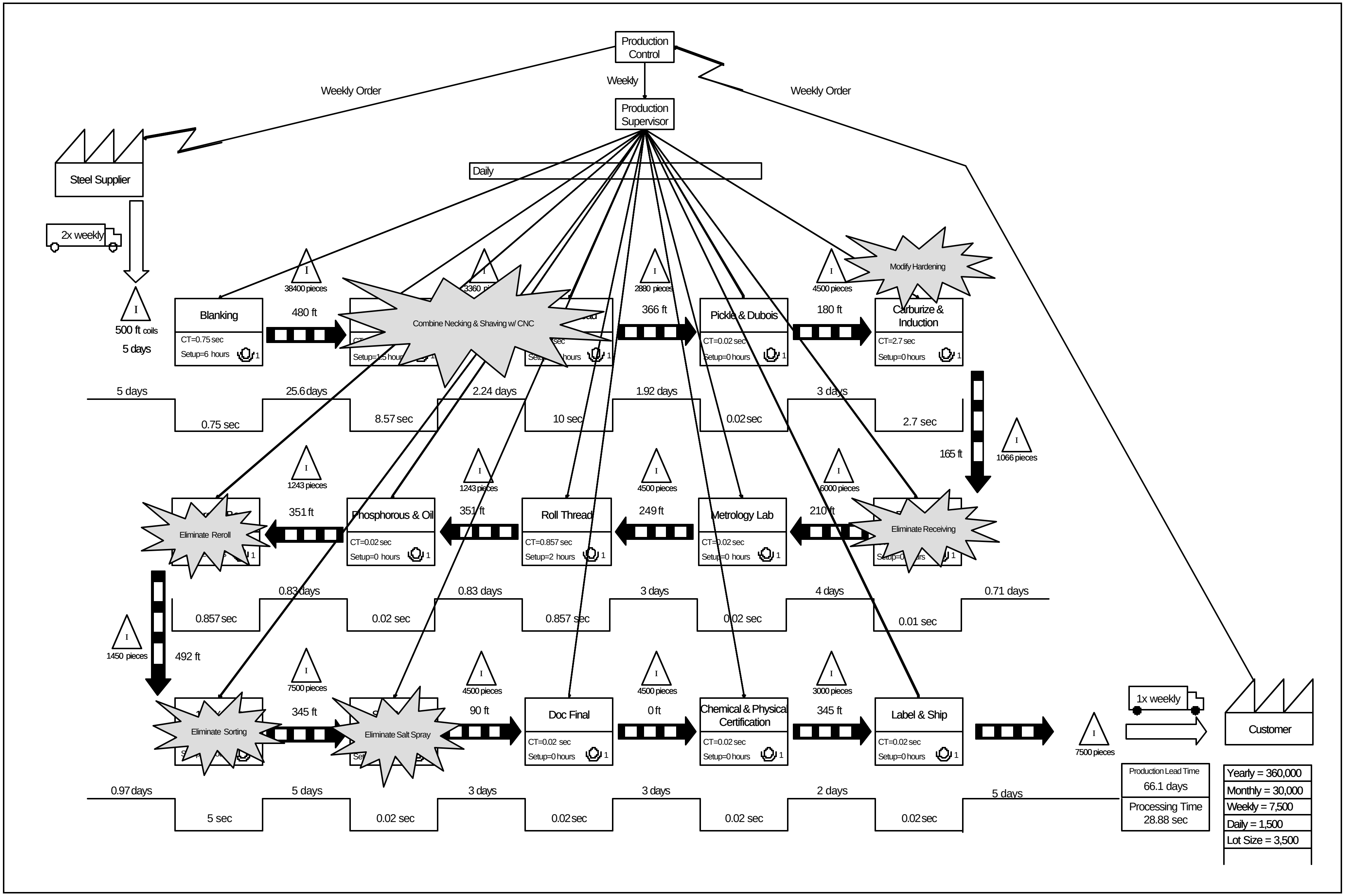

Figure 2. Potential process changes for bolt manufacturing example.

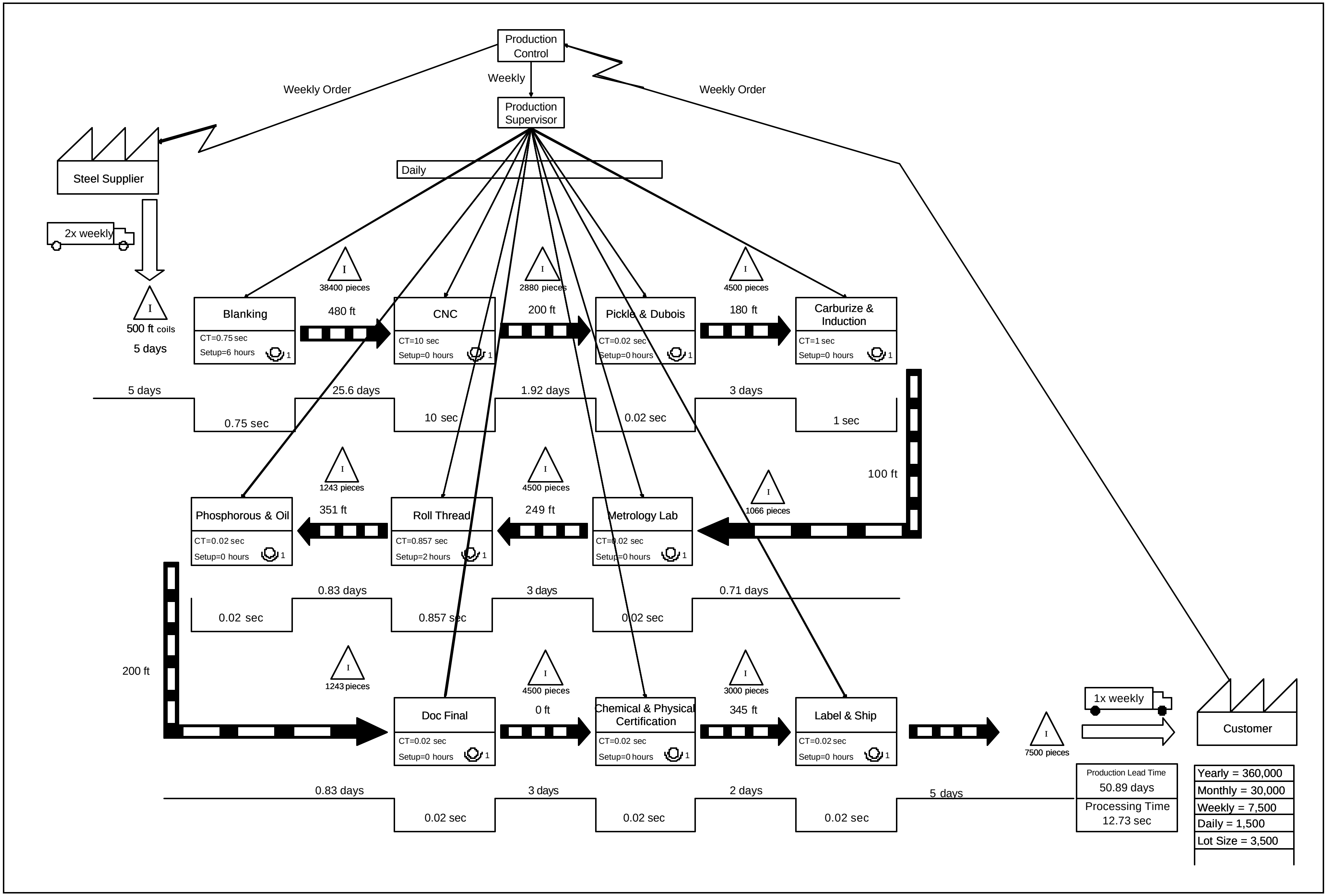

Figure 3. Future State Map for bolt manufacturing example.