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INTEGRATING VALUE STREAM MAPPING
AND SIMULATION

By

Michelle Eileen Scullin

A thesis submitted to the faculty of

Brigham Young University

in partial fulfillment of the requirements for the degree of

Master of Science

School of Technology

Brigham Young University

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BRIGHAM YOUNG UNIVERSITY

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FINAL READING APPROVAL

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ABSTRACT

INTEGRATING VALUE STREAM MAPPING AND SIMULATION

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An important principle in Lean manufacturing, value stream mapping (VSM) can be helpful in understanding how process flow and information flow affect each other. A VSM is a static picture of a process that allows the user to see where value is added into the value stream.

Simulation is used to evaluate the behavioral issues of processes. In a manufacturing realm this means simulation shows how each operation affects other operations so determinations can be made about where bottlenecks or other problems exist in the process. Theoretically, the integration of VSM and Simulation can aide in process improvement by showing both the static and behavioral characteristics of a process. Determining the feasibility of such an integration is the basis for this thesis.

Using research performed by Jack McClellan at BullFrog Spa, a comparative study was conducted by two test groups. One used the traditional simulation approach and the other the integrated simulation approach. The test groups were formed from nine students taking the Manufacturing Systems course fall semester 2004.

The traditional simulation approach used the ProModel simulation software to perform a test using a paper form of a VSM. The integrated simulation approach used Process Simulator simulation software, which created a simulation from a VSM created in Microsoft Visio. After completion of the tests, the students filled out surveys comparing their results with McClellan's results for verification of their simulations.

The results from the study indicated that the students were able to create a working simulation using both approaches and there was no significant difference between times that it took to create the simulations. It was also discovered that a VSM helps increase understanding of a process, but cannot be the sole source of information to create a simulation. More behavioral information about the process is needed.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Value stream mapping and simulation are tools that aide in change management decisions within a manufacturing environment. Separately they look at the intricate details of the manufacturing facility to determine areas where improvements can be made. Together they can determine both the static and behavioral issues of the system and, if done successfully, can show where improvements may exist.

Many different factors within the facility's value stream add to the ambiguity of the system. Factors such as time, material flow, inventory, personnel, lead times, and information flow affect each other during production. The effects that these factors have on each other are difficult to define without analysis along the value stream. A value stream map (VSM) was designed to analyze these factors. However, a VSM has limitations in that it is a static picture of the system's value stream and does not show the behavioral aspects about the system. For behavioral issues, the concept of simulation is used. "Simulation reproduc[es] the operational behavior of a system [by] imitat[ing]...a dynamic system using a computer model in order to evaluate and improve system performance." (Harrell, Ghosh, & Bowden, 2004). In order to generate a simulated model of a manufacturing process the system has to be broken down into its intricate parts. This includes material flow, information flow, takt times, down times, production activities, personnel, lead times, etc. The process of acquiring all the information that is needed

for a simulation is tedious; however, the more information that a person has about the system the closer to real life the simulation should react.

1.1.1 Traditional approach vs integrated approach

This study addresses two approaches that can be used to create a simulation of a system. The traditional simulation approach takes the information on a VSM and inputs the information into a simulation program. A VSM contains most of the information that a simulation program would need and can be used as a source of data input for the simulation program. Some of the shared information includes Takt times, down times, number of operators at a location, etc. The traditional simulation approach is performed by creating a current state VSM on paper, analyzing possible places for improvement, creating a future state VSM on paper and then transferring the information from both VSMs to a simulation program for comparison of the improvements. Depending on how much detail is needed for the simulation, the traditional simulation approach can take a lot of time. Often when a VSM is used in the traditional simulation process data transfer to the simulation software is required. This re-inputting of data most often occurs when the VSM is produced separately from the simulation software. A value stream map requires the individual to think statically in terms of a location's time, how many operators are at a particular location, what obvious changes can be made, etc. Building a simulation model forces the individual to look at the behavioral details of a system. For example, what resources are used where, are they used in another place? And what time is associated with that resource? This information as well as the VSM information; are also part of a simulation model. The differences between the static picture and behavioral issues, can cause difficulties for individuals that are forced to think statically and behaviorally. This also can cause a slowing of the traditional

approach as the individual creates the VSM and simulation separately. Errors are also more likely to be introduced as data re-entry is necessary.

The integrated simulation approach is defined as the combination of VSM and simulation, thus trying to eliminate the step for data re-entry. Process Simulator is an added stencil/process tool made specifically for the Microsoft Visio program. The basic steps for the integrated simulation approach flow as follows: a value stream map is generated in Microsoft Visio using the Process Simulator stencil of icons. Using the Process Simulator icons, a simulation program is generated from the information on the value stream map. The integrated approach tries to eliminate the data re-entry step of the traditional simulation approach. This research will help determine the effectiveness of the integrated simulation approach as compared to the traditional simulation approach and whether or not a VSM is a good resource for all the information needed to create a simulation.

1.2 OBJECTIVE

The purpose of this research is to test the feasibility of a simulation created by the integrated simulation approach as compared to the traditional simulation approach. After the test has been completed, the results will evaluate the usefulness and validity of such an integration and whether or not VSM can be used as the only source of information for creating a simulation.

1.3 PROBLEM STATEMENT

Many different models have been created to aide manufacturing facilities in change management decisions. Lean manufacturing is one of those models. Lean practices are a topic of

great interest for saving a company money and resources. Deciding whether or not these practices should be implemented can be difficult. Simulation was created in order to understand how behavior within a manufacturing facility affects the production flow. Through this tool, predictions can be made concerning the effectiveness of Lean manufacturing changes before time and money are spent on the change implementation. Profozich stated, “By using simulation to manage change, you should ultimately realize the most significant benefits that any information technology can deliver—dramatic improvements in business performance and profitability.”(1998)

Simulation has been a great benefit to the change process. Improving the system usually involves making changes to the system. Simulation allows for predictable outcome rather than trial and error. “Simulation avoids the expensive, time-consuming, and disruptive nature of traditional trial-and-error techniques.”(Harrell et. al, 2004) The Lean tool called a value stream map, allows the user to manipulate the flow of value through a system, it does not allow the user to manipulate the behavioral responses to the changes. The VSM gives a static picture of what is going on within a system and where exactly value is being added to the product. A limitation of a VSM is that it does not give predictable outcome from the changes made along the value stream.

For both simulation approaches, before a simulation can be built the more detailed behavioral parts of a system have to be defined. Profozich stated, “You cannot use a static tool to study a dynamic problem. A static tool gives an optimistic performance assessment. The greater the variability in the system, the greater the error in static analysis.”(1998) A VSM is a static picture of a system that breaks the system down into time values (like cycle times, lead times, Takt times, etc.). The time values indicated within a VSM are all necessary bits of information that a simulation requires. Determining whether or not the static picture created from the VSM is

enough information to create a simulation, as well as how both the integrated and traditional approaches differ is the purpose for this research.

1.4 HYPOTHESIS AND JUSTIFICATION

The hypothesis of this thesis is that, the development of a method that integrates value stream mapping and simulation is feasible and a VSM contains all the information needed to create a simulation of a system. Value stream mapping causes individuals to think more systematically with regard to process and information flow. A VSM is a static picture of the process and information flow within a system. This information is necessary for a simulation but also requires behavioral information that flows through a system.

1.5 METHODOLOGY

Testing of the differences between the two simulation approaches was conducted through the administration of a case study based on the thesis research of Jack McClellan at BullFrog Spa. The reason for using McClellan's thesis was to have a basis for comparison against actual data. McClellan was able to successfully create a simulation of BullFrog Spa that reflected real-life production at BullFrog. McClellan was limited in the information that he was able to discuss about the BullFrog process due to proprietary issues at BullFrog. However, evaluation of the current state VSM included in McClellan's thesis, and by creating a simulation program of the process myself, it was determined that there was enough information given within his research that a case study could be created from his information.

The comparison was completed by a group of students that were instructed in the use of value stream mapping and simulation during Fall semester 2004. This group consisted of nine students enrolled in the Manufacturing Systems course. Four of these nine students were also enrolled in the Simulation course during the same semester. During the semester the students were instructed on how to use various Lean manufacturing techniques, more particularly VSM. All of the students created future state VSMS and simulations for the case study based on the information from Jack McClellan's thesis project.

All nine students were given the case study and current state map for BullFrog Spa. From this information the students created a future state value stream map of BullFrog Spa. Five members of the Manufacturing Systems class only learned Process Simulator's approach (integrated simulation approach) of the simulation process. The remaining four members used ProModel (traditional simulation approach) to simulate the information from the value stream map. These four members were the students enrolled in the Simulation course. The class was split thus to allow for maximum support for answering questions about their particular simulation program that they were using and to lessen confusion between computer software packages. The results from the students' programs were compared with the results from McClellan's research as a determinant of their simulation validity. If the students were able to obtain the same ratio results from level loading the BullFrog process, their simulation was determined to be correct. The students also kept track of the time that they spent creating their simulations and also the number of questions they asked.

At the completion of each step for the case study and simulation models the students were asked to fill out surveys about their abilities before simulating and after simulating. These surveys indicated the number of questions asked during the case study, time to completion,

assumptions made, ease of use for the programs, and also asked for their simulation results (which were compared to McClellan's results). From these surveys some of the problems associated with the computer programs were determined and also gave the qualitative results from the opinions of the students for the ability to simulate using only a VSM.

1.6 ASSUMPTIONS

It is always difficult to use human subjects for a research project and variations between the opinions of the students were expected. It was assumed that each of the students had never used an integrated program for simulation and value stream mapping. The term value stream mapping was also somewhat of a new term for many of the students as well. The students enrolled in the class were either first year graduate students who completed their undergraduate work at Brigham Young University, or were still undergraduate students. Having completed my undergraduate studies at Brigham Young University, I knew that the most exposure many of these students had to Lean manufacturing and its respective tools were limited to awareness rather than study of them. The Manufacturing Systems course was the first real introduction to Lean manufacturing and its respective tools that most of these students had ever had and for that reason I made my assumption of their knowledge of VSM. This was also the basis for my assumptions concerning their knowledge and exposure to simulation software. The study did not, therefore, mimic real life situations for rapid learning of a program; however, it gave good results for evaluation of the time that it took for the students to adequately program a simulation and gave adequate results for opinions on the completion of both simulation approaches.

1.7 DELIMITATIONS

Evaluating the use of either simulation approach in industry would be difficult for a study of this nature. This research was limited to the use of students taking the Manufacturing Systems and Simulation classes. Only nine students were enrolled in the courses and hence nine students comprised the population group that was evaluated for this study. A disadvantage of such a limitation was that the results might not have reflected true opinions of the manufacturing industry. A study of a larger population would be a future project and was beyond the scope of this research. A study of all the aspects of value stream mapping was beyond the scope of this study as well. A case study based on Jack McClellan's simulation study of BullFrog Spa is used as an isolated basic value stream map because the icons used within value stream mapping (e.g.: supermarket, FIFO lines) were used within his research. Even though McClellan's research was used as an isolated VSM it contained most of the common icons and processes used for most manufacturing facilities and was easily used with the capabilities of either computer software package. Some suggestions for software improvements were indicated from the qualitative results of the study, but generating a perfect fit software program was not the focus of this particular research project.

1.8 GLOSSARY

- Arrivals: define the time, quantity, frequency, and location of entities entering the system.(Harrell, 2004)
- Assumptions: Determinations made about a process that help define characteristics or behaviors about the process.

- Attributes: variables that are associated with an object such as its size, condition, time in the system, and so on. (Harrell, 2004)
- Batch Processing: The movement of products through the manufacturing process in large numbers of identical units at once. Entire batches, or lots, are sent to each operation in the production process at the same time.
- Capacity: The ability of a machine and its operator(s) to complete the work required.
- Constraint Operation: An operation that is long in duration or is critical to completing a manufacturing process.
- Customer Value: An aspect of a product or service for which a customer is willing to pay.
- Cycle Time: The time it takes to successfully complete the tasks required for a work process.
- Entities: the objects processed in the model that represent the inputs and outputs of the system.(Harrell, 2004)
- FIFO (first-in, first-out): A production method in which the oldest remaining items in a batch are the first to move forward in the production process.
- 5S's (sort, shine, set in order, standardize, and sustain): A method of creating a clean and orderly workplace that exposes waste and errors.
- Internal Processes: Activities that an equipment operator must perform while the production line is idle.
- Inventory: And part of product that is not immediately required for a customer order, such as excess raw materials, WIP, and finished goods.

- JIT (just in time): A method of inventory management in which small shipments of stock are delivered as soon as they are needed.
- Kanban System: A production-control system that uses cards or tickets as visual signals to trigger or control the flow of materials or parts during the manufacturing process.
- Lead Time: the time it takes to complete an activity from start to finish; it includes batch and process delays.
- Load Balancing: Finding a balance between the volume of work that your organization needs to do and your capacity.
- Load Leveling: Adjusting a production schedule to meet unexpected changes in customer demand.
- Locations: places where entities are processed or held.(Harrell, 2004)
- Material Flow: the physical movement of materials from receiving, through production, to the shipment or delivery of finished goods or services.
- Production Activities: the physical tasks employees must perform to produce a product or deliver a service.
- Pull System: where the materials are moved from one operation to the next based on a request from the next operation.
- Push System: where materials are automatically moved from one operation to the next, whether or not they are needed.
- Resources: agents used in the processing of entities.(Harrell, 2004)
- Routing arrows (paths): the course of travel for entities and resources in the system.(Harrell, 2004)

- Simulation: “the imitation of a dynamic system using a computer model in order to evaluate and improve system performance.”(Harrell, 2004)
- Supermarket System: A stocking system in which materials are stored by the operation that produces them until they are retrieved by the operation that needs them. When a store is full, production stops.
- Takt Time: the total available work time per day (or shift) divided by customer-demand requirements per day (or shift). It sets the pace of production to match the rate of customer demand.
- Value Stream: all the activities your company must do to design, order, produce, and deliver its products or services to customers.
- Value stream map: uses simple graphics or icons to show the sequence and movement of information, materials, and actions in your company’s value stream.
- Variables: statements that tell the computer how the system elements affect each other and overall performance objectives.(Harrell, 2004)
- Waste: Any activity that takes time, resources, or space, but does not add value to a product or service.
- Work Flow: The steps and motions employees take to perform their work tasks.
(all paraphrased, unless otherwise indicated, MacInnes, 2002)

CHAPTER 2

REVIEW OF LITERATURE

2.1 INTRODUCTION

Value stream mapping and simulation are tools that can be used to determine improvement applications within a manufacturing system. Value stream mapping is a static picture of a system and simulation maps the behavior of a system. There are two approaches for simulation: the traditional approach and the integrated approach. By studying these two approaches the effectiveness of a simulation built from the use of a VSM can be evaluated.

This chapter is a compilation of the information obtained about simulation and value stream mapping not only in general, but in reference to decision making and the purpose for having an integrated simulation approach. The research includes some of the different motivation and training tools for change decision making. The information obtained through this research indicates the different areas of motivation and training that are established in industry in terms of Lean manufacturing and basic business practices. It also includes background information for both simulation and value stream mapping as information tools and their common uses in industry. A study performed by the University of Alabama (Donatelli & Harris 2004) suggests that an integration of value stream mapping and simulation can be performed, but the validity of the simulation outputs from just the value stream map remains in question.

After completion of this chapter the reader should adequately understand the guidelines behind value stream mapping and simulation and what areas of industry they can influence in

terms of process improvement. The reader should also understand the role of technology in change management as a use for communicating the vision and as an influence in process improvement.

2.2 STEPS FOR LEAN MANUFACTURING AND VALUE STREAM MAPPING

2.2.1 lean basics

The main focus of lean manufacturing is to eliminate waste. Waste is anything that does not add value to the product being made or is not needed to produce the product. D. Nave (2004) gives five essential steps for lean. They include:

1. Identify which features create value.
2. Identify the sequence of values called the value stream.
3. Make the activities flow.
4. Let the customer pull product or service through the process.
5. Perfect the process.

The focus of this thesis study addresses Nave's second step for lean manufacturing or "identify the sequence of values called the value stream." This step is sometimes accomplished through the application of a value stream map. The VSM has different symbols, which represent value adding or value decreasing activities. Some of the symbols represent actual times and values for each machine or activity in the process. The design of this study is to generate a simulation from a value stream map that shows all the applications of value and non-value. The results from this study will show the usefulness of a VSM as a source of information for generating a simulation model. And show whether or not a dynamic system can be modeled using a static picture of a process.

With the traditional simulation approach there are added steps to create a simulation model. First the value stream map is generated, usually by paper or a simple computer program. After the current state map is created, it is given to a simulation team, which then takes the information and tries to create a simulation from the paper map. After that is created, various tests are taken for validation and experimentation. Once a decision is made for the changes to the current state map, a future state VSM is generated and the process is started over again. With the integrated simulation approach the value stream map becomes the backbone for the simulation and while the user is creating the VSM, the program is creating the simulation.

A lean production system is created for the flow of information and material and is involved with every product in a family in a facility. Many manufacturing facilities and some service-based facilities are evolving into a lean system. The benefits from Lean include the reduction of waste, reduction of costs, less time to delivery, less WIP, and increase in throughput of the system.

[Lean] concepts have grown to challenge fundamental manufacturing concepts. Instead of mass producing one item for less, [Jim Womack] says, lean has pushed manufacturers to produce more high-quality product variations at the request of customers.(Newsome, 2003).

There are five primary elements to Lean that help organizations function according to customer demand. These five elements include: Manufacturing flow, Organization, Process Control, Metrics, and Logistics (Feld, 2001). The goal of VSM is to show a static picture of all of this information, in an attempt to understand how all of these elements affect one another within the organization. A VSM does not take into account the behavioral effects of the dynamic system, but simplifies the system into its basic components. The basic components include material suppliers, operations, resources, etc.

By breaking the system down into its basic components, the evaluator should be able to see where the seven deadly wastes lie within the system. As was mentioned previously, Lean was created in an attempt to eliminate waste. The seven deadly wastes include: “overproduction, waiting, transport, inappropriate processing, unnecessary inventory, unnecessary motion, and defects” (Taylor & Brunt, 2001). By eliminating these wastes it is assumed that production will increase and better product will be reaching the customer. Each of these wastes are shown as non-value adding activities on a VSM. Through the process of creating a current state VSM and converting it to a future state VSM the company is able to eliminate or decrease the effects of these elements of waste.

As was mentioned previously, a VSM is a static picture of a system, it does not depict how different operations effect one another. For this purpose simulation was created to show the behavioral effects from one step in the system to the next. This study will evaluate how effectively a VSM can communicate the information needed for a simulation model by evaluating the two different simulation approaches.

2.2.2 Applications for lean and managing lean

The premise behind Lean is to help a system work toward supplying customer demand. “Lean manufacturers, lean enterprises, lean supply chains and lean extended value streams are in various stages of construction by companies looking for competitive advantages in tough markets”(Howardell, 2004). Applications for Lean manufacturing are involved or can be involved in almost everything that we do. Womack (2004), President and Founder of Lean Enterprise Institute, discussed the more common problems involving Lean. Because Lean is such a broad application, many different organizations have had problems implementing Lean

principles because of differing opinions between Lean experts. The real problem, according to Womack, is that once a lean principle is applied, it is rarely written down as to the specific steps that they took to implement that principle. Then when another application needs to be introduced, there is no standard system of operation for lean principles as of late. Womack suggested that an organization should ask themselves the following questions before moving to implement Lean. They are:

- Do we have a standard, lean way to conduct plant operations that everyone understands?
- Do we have a standard, lean way to interact with our suppliers on an operational level that everyone understands?
- Do we have a standard, lean way to interact with our customers on an operational level that everyone understands?
- Would a new manager just arriving at a facility or in a new area of responsibility immediately know what to do, as prescribed by our operating system, and do it the standard way? (Womack, 2004)

Having top managers involved in lean transitions is vital for the method's success.

When you transition a company in the direction of lean, you've got to have the full support of upper management—after all, it is a radical change in manufacturing philosophy...lean is a different way of looking at things. And in order for us to truly maximize our efforts, we wanted to give everybody a good, solid foundation, as to what we were trying to do. It is important to mention that everyone from the CEO down was on board with the change(Traylor, 2004).

The real challenge is to make sure that everyone is involved and committed to the changes. One of the best ways to make sure that this happens is to educate everyone at the facility in the reasons why going lean can help. Once the real meaning behind the effort is realized the people are more committed. "Companies are a collection of people voluntarily banding together to produce a product or service. In order to have a lean enterprise, you have to

have *lean people*. And the people have to get lean before the company can get lean. Lean people make a lean enterprise!”(Howardell, 2004).

The decision should be made whether or not the company just needs lean manufacturing, or if it needs a lean enterprise. A Lean enterprise encompasses the entire system, including all personnel and programs. Lean manufacturing refers to the information flow and production flow of the system. Value stream mapping can be implemented for either of these processes.

By following the team building steps of forming, storming, norming, performing, and adjourning, the lean enterprise thinking can be implemented easier. Within these phases the proper innovation and creativity will be present within the team to introduce and lead the program successfully. Generally people like to avoid change, but with more evidence of the good that will come, people will more likely be advocates of the change program for lean implementation.

Through the team building steps Howardell’s (2004) seven skills can be developed to their productive capabilities: 1. Customer consciousness, 2. Enterprise thinking. 3. Adaptation, 4. Taking initiative, 5. Innovation, 6. Collaboration, and 7. Influence. What is essentially developed is a bigger view of the system as a whole, which allows for the flow of information and knowledge that is necessary not only for making proper decisions, but also for seeing the process on a systematic level. All aspects of which are needed to develop a value stream map and the information for a simulation.

2.2.3 What are some of the barriers to implementing lean

The behaviors of people involving change can be broken down into three groups. According to Boyer and Sovilla (2003), about 95% of the people within the organization would

accept the need for change and would be willing to perform that change but would need strong leadership. Three to 5% of the employees would not only accept the change but could potentially be strong advocates for the change. The remaining group of about 5% would be completely opposed to the change.

Seven rules of change were defined as follows:

1. People do what is perceived in their best interest, thinking as rationally as circumstances allow them to.
2. People are not inherently against change. Most will embrace initiatives, provided that the change has positive meaning for them.
3. People thrive under creative challenge but wilt under negative stress.
4. People are different. No single elegant solution will address the entire breadth of these differences.
5. People believe what they see. Actions do speak louder than words, and a history of previous deception multiplies present suspicion.
6. The way to manage effective long-term change is to first visualize what you want to accomplish and then inhabit this vision until it becomes true.
7. Change is an act of imagination. Until the imagination is engaged, no important change can occur.(Boyer & Sovilla, 2003)

Traditionally Lean changes flow downward from management. Individuals in leadership positions are the key players when lean changes are to be made. As Boyer and Sovilla's (2003) fifth rule stated, "people believe what they see". Value stream mapping and simulation are some of the tools that leaders can use to show actual results of lean changes. "True leadership will provide clarity of executive purpose even through times of fear and threat" with less "fire fighting"(Boyer & Sovilla, 2003).

Lean implementations take time: a lot of thinking, researching, and deep analysis of the current system before any implementations can be made. Often times individuals look for the quick fix or waste time "fighting fires" rather than do the work that is required. These quick fixes are enticing but do not take into account the real issues that are at hand.

2.2.4 What is value stream mapping and how it is used

A value stream map is defined as, “[The use of] simple graphics or icons to show the sequence and movement of information, materials, and actions in your company’s value stream” (MacInnes, 2002) Value stream mapping is a tool that allows the analyst to see the entire manufacturing system from information flow to production flow. Usually the information flow is depicted on the top half of the value stream map and the production flow is depicted on the bottom half of the value stream map. Within the value stream map (VSM) such information as Takt times, down times, production activities, personnel and lead times are listed. With this information the analyst can see the entire production as a static picture. From the current state static picture, a future state value stream map can be generated that will indicate the possible areas of improvement for the system. After the benefits of the future state map have been evaluated, then generally, the new improvements are implemented in the process. A sample of a value stream map is indicated in *Figure 1*.

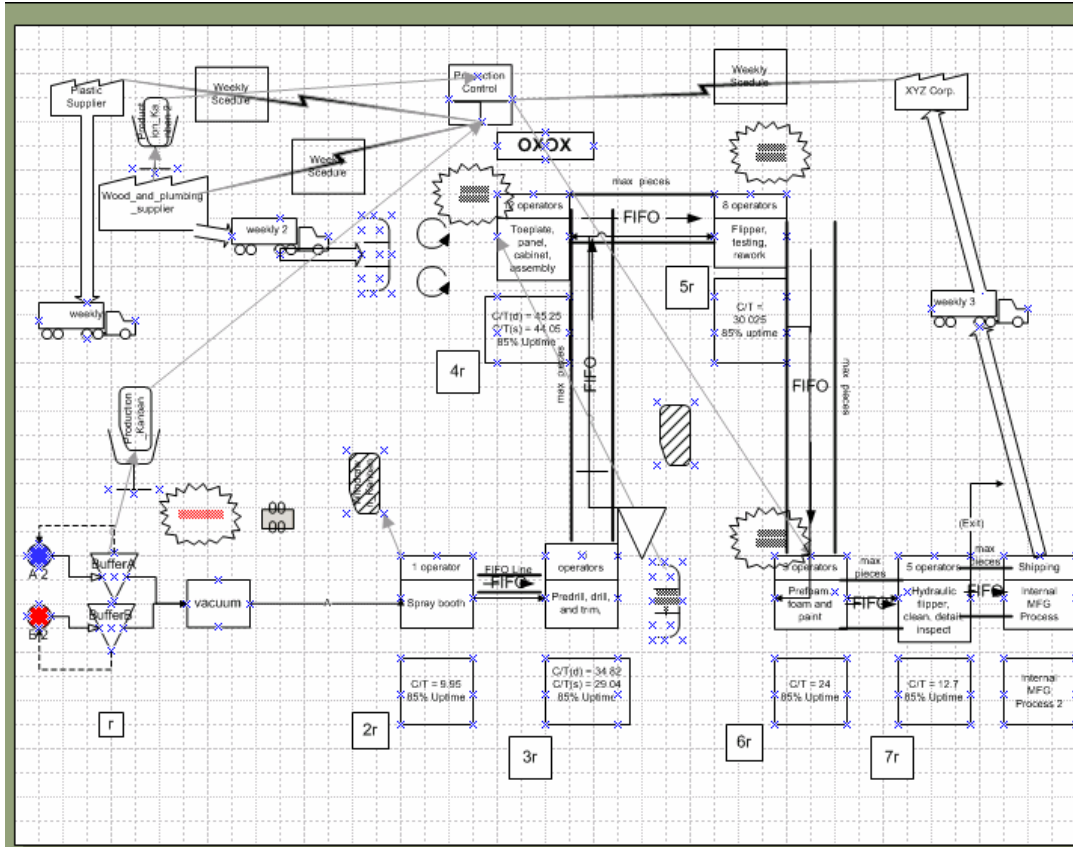


Figure 1: VSM of BullFrog Spa, courtesy of Student A, Appendix B

Waste is the adversary of lean manufacturing. Waste is considered anything that does not add value to the product produced within a facility. WMEP's *Value Stream Mapping* (2004) stated that as much as 60% of the operations performed within a manufacturing facility are considered to be non-value added or waste. "Value Stream Mapping gives you the tools to stand back and identify the waste in your business and to streamline processes to get rid of waste." (WMEP, 2004) A value stream map is a map that consists of the different operations or processes within the company's value stream. It shows all the information flow and production flow of a product throughout a process. Some of the information within the value stream is the information flow, lead times for the product as well as the time and failures throughout the system. "The basic idea is to first map your process and then above it map the information flow that enables the process to occur" (Ron, 2004). The value stream map is to improve a system by

“reduc[ing] lead time; improv[ing] product quality and space utilization; reduc[ing] rework, scrap, and inventory levels; and reduc[ing] indirect labor costs.”(WMEP, 2004)

The most common icons for use in a value stream map are indicated in *Figure 2*.

NAME	SYMBOL	DESCRIPTION
Push movement of production materials		Shows the movement of raw materials or components that are "pushed" by the production process rather than being requested by the customer
Pull movement of production materials		Shows the movement of raw materials or components that are requested by the customer (i.e. they are not pushed)
FIFO		Indicates that products need to be pulled and delivered on a first-in, first-out (FIFO) basis: the oldest remaining items in a batch are the first to move forward in the production process
Truck Shipment		Shows the movement of materials by truck. Be sure to show the frequency of shipments on your map.
Inventory		Indicates the inventory count and time.
Storage (Supermarket)		Shows all products contained in a storage area. You can note the minimum and maximum levels within each bin or row location.
Manual Information Flow		Shows information that is transferred by hand.
Electronic Information Flow		Shows information that is transferred via computer.
Information Type		Indicates the type of information being communicated.
Production Kanban		A card used to initiate the production of a certain item. (used for Kanban systems only)
Withdrawal Kanban		A card used to obtain an item from a storage area. (used for Kanban systems only)
Signal Kanban		A card used to initiate a batch operation. (used for Kanban systems only)
Kanban Card Post		This indicates the use of physical mailbox location for kanbans. It is used for kanban systems only.
Load Leveling Box		Used for kanban systems to indicate load leveling.
Department or Manufacturing Process		The top of the icon shows the name of the department of the process being mapped. The bottom of the icon shows resources, information, or a relevant lean-enterprise technique.
Outside Sources		These include customers and suppliers.
Data Box		This is a place for key data such as machine availability; number of product variations; product changeover times; whether or not parts are run daily, weekly, or monthly; cycle time, process capacity; equipment efficiency; whether or not it is a constraining operation.
People		Shows the number of employees required to perform an operation.

Figure 2: VSM icons, paraphrased MacInnes, 2002; Appendix F

The value stream is the flow of information and material from receipt of raw material to shipment of the final product. The value stream map is a static snapshot of all that information. It allows management or those making changes within the company to readily see the flow of value

through the system and able to clearly see the waste or non-value added time. As mentioned in the WMEP (2004) article, if over 60% of value is non-added value on average, there are numerous changes that can be made within the system. VSM allows an individual the opportunity to decide whether or not a lean operation is feasible. A. Traylor (2004) stated of his operation at Sunrise Medical:

We utilized a simple tool called a Value Stream Map in all of our facilities, in all fabrication and assembly areas. It allows you to look at your current state of operation, and develop your future state of operation, to see where your waste lies, and how you can drive it down. It identifies which activities create value for the customer, and which ones add costs but no value.

As stated in *Value Stream Mapping, A Lean Manufacturing Tool*, “Value Stream Mapping can be a communication tool, a business planning tool, and a tool to manage your change process.”(Williams et al., 2004) Value stream mapping forces individuals to focus on the future state of the process. It causes them to think about what areas to improve in order to accomplish future goals. This forward thinking occurs because they are beginning to notice where the seven wastes are located within their process and how to eliminate those wastes for future improvement.

The process includes physically mapping your “current state” while also focusing on where you want to be, or your “future state” map...VSM can serve as a starting point to help management, engineers, production associates, schedulers, suppliers, and customers recognize waste and identify its causes.(Williams et al., 2004)

Often improvement is focused on one particular operation or product. The benefit of value stream mapping is that the focus is brought to the plant level. This added awareness causes the change decision makers to focus on the big picture. VSM also puts all the information in one place where changes can be discussed before implementing. By knowing exactly how the operation works currently (current state map) and looking toward the future (future state map) a

company is able to see where waste lies and how improvements could be made. Womack (2004) stated, about the success of various companies that he visited,

There was a clear knowledge of the current state of each operation and a vision of a better state to be achieved quickly through kaizen. Nothing seemed to happen by chance and continuous improvement was easier because the base condition was visible to everyone.

Making the condition of the system visible to everyone involved is one of the keys to successful change. The addition of simulation if proven feasible will give leadership and or management more validity to their change decisions as more individuals can actually see what would happen with the future state implementation.

There are other ways to map the process flow of a system, one of the more common ways is to do a process map like those done for Six Sigma. Some of the fundamental differences between value stream mapping and traditional ways, like flow diagrams, of mapping processes include:

1. [VSM] gathers and displays a far broader range of information than a typical process map.
2. [VSM] tends to be at a higher level (5-10 boxes) than many process maps.
3. [VSM] tends to be used at a broader level, i.e. from receiving of raw material to delivery of finished goods.
4. [VSM] tends to be used to identify where to focus future projects, subprojects, and/or kaizen events.(iSixSigma LLC, 2003)

Value stream mapping is an innovative approach for solving process change problems.

Value stream mapping creates the simplified information and allows for easy changes to be seen.

Simulation of the process generates solid values that are measurable. Value stream mapping

alone is a powerful tool, with the addition of simulation the tool's validity as well as

performance could be expounded upon.

2.3 THE STEPS FOR SIMULATION

2.3.1 Guidelines for simulation use

The Simulation process is an involved process that takes into account not only physical movement of objects and material, it also takes into account the not commonly noticed aspects of a flow process. One unique feature for simulation is the fact that it can be used in almost any operational application. These other applications for simulation can be seen in service providers and small businesses not just for manufacturing purposes.

In order to begin a simulation process, deep involvement in the system needs to occur.

According to B. Manar (1997),

Manufacturing assembly within the factory will not be the only field to see a significant increase in the use of simulation. Areas like information management, communications, training, and even public relations will benefit from what this technology has to offer. Companies who realize this and align the talents of their workforce to utilize this technology will gain immensely from their efforts.

Simulation is “the imitation of a dynamic system using a computer model in order to evaluate and improve system performance” (Harrell et. al, 2004). Simulation requires deep understanding of the behavior of a system. In order to define how the system actually works in real time; how different operations, resources, material, and information effect each other has to be known. It is wise to know the system or problem intimately to be involved in the simulation process.

The first step for building simulation models is necessary to ensure that the system reflects actual system operations. First the problem needs to be defined. Defining the problem is an in-depth research study of all the elements in the system, often times the scientific method is implemented in this portion of the process. Once all the background statistics and information is acquired the model can be built. In order to define the model an experimental design should be

considered for validation of the model. Constant validation should be implemented to ensure that the information that the model is outputting is real to actual performance. Once the model has been validated it can be improved.

The complexity of the model determines how difficult it is to simulate. [O]ne must weigh the complexity of the model with the degree of difficulty involved in its solution. It is necessary to consider (a) the “order” of the model, i.e., the number of independent functions required to describe the process, (b) the number of parameters involved in the model, and (c) the number of independent variables to be included in the model. The simpler the model, the easier it is to solve analytically or numerically; the more complicated the model, the less likely it is that a simple solution can be found (Bischoff & Himmelblau, 1967).

There are two simulation approaches, the traditional approach and the integrated approach. This study helps determine the complexity of creating a simulation model from information given from a VSM. This complexity determination will help discover whether or not a VSM has enough information to create a simulation model of a system. Profozich (1998) stated, “You cannot use a static tool to study a dynamic problem. A static tool gives an optimistic performance assessment. The greater the variability in the system, the greater the error in static analysis.” VSM is a static picture of an operation, but contains most of the dynamic information that a simulation would require, this research will determine whether or not the information provided will be enough to create a simulation model. Also from this research it will be determined whether or not there is a significant difference between the two simulation approaches in terms of time saved or simulation performance.

2.4 CONCEPT OF CHANGE AND MANAGEMENT GOALS

2.4.1 Managing change as a leader

Managing change has been a stumbling block for many organizations. Usually a management team meets together and determines where the organization needs to change. After some deliberation and often complications, a change operation is implemented into the overall system. Unfortunately, too often the change program is then rejected. In the article “Leading Change: Why Transformation Efforts Fail,” J. P. Kotter (1995) explains why these change efforts often fail during implementation and what should be done during the change process. Kotter’s eight specific steps to transformation show how to avoid change program problems before implementation.

The first step is “Establishing a sense of urgency,”(Kotter, 1995). If those in organization see no real need to change, why should they change it? This step dictates the need to examine sales forecasts, customer demand, etc. Examining these closely helps determine where the real needs lie. This step generates topics of discussion and pinpoints crisis centers for change. It also is part of gathering the information needed for a value stream map. A VSM is a static picture that shows the information flow and production flow through a system. Customer demand and sales forecasts are all items for information flow which effect production flow.

The change program could be the defining characteristic of the organization’s future, but if there is no strong guiding force, it will likely fail. The second step is “Forming a powerful guiding coalition,” is the establishment of a strong guiding force they need to “create a vision”. Without vision the change effort has no direction. “A useful rule of thumb: if you can’t communicate the vision to someone in five minutes or less and get a reaction that signifies both understanding and interest, you are not yet done with this phase of the transformation process.”

Value-stream mapping and simulation are tools that can be used to help communicate the vision for change. How effectively they can be integrated and how the integration effects the two different simulation approaches may or may not affect the change decision (Kotter, 1995).

The fourth and fifth stages in the change process “communicating the vision” and “empowering others to act on the vision,”(Kotter, 1995) involve the importance of communication. As mentioned previously, if the vision is not directly understood by all members involved in the change process, it will likely fail. These two steps involve making the vision happen by ensuring all parties understand it. It discusses removing the obstacles to change and teaching new behaviors to the individuals involved. In other words, everyone is and should be involved in the change process and implementation of the change program. By being involved they understand the system’s inner workings, how the information flows and how the production should flow. These understandings also help when building a simulation program as a simulation is the behavioral aspect of a system. Some of the ways that changes can be communicated is through actual output from a simulation or from the changes made from a current-state to a future-state VSM.

“Planning for and creating short-term wins,”(Kotter, 1995) helps generate employee involvement and loyalty that a change program needs. Successful improvements should be rewarded and recognized. People like to see the fruits of their labor and need visual confirmation that what they have done is good and was a valiant effort. A simulation model of their improvements is one way that a visual confirmation can be justified.

The last two steps “consolidating improvements and producing still more change” and “institutionalizing new approaches,”(Kotter, 1995) defend the need for continuous change. No system is perfect. One successful change to the system is going to keep it progressing forward.

Constant improvement and recognition of the need for change is what makes a good organization great.

Mistakes are still going to happen. But Kotter's (1995) suggestions make the change process a little easier to see as a step progression from mediocrity to greatness. By following these eight steps the promise is made, "a vision of the change process can reduce the error rate. And fewer errors can spell the difference between success and failure."

VSM and simulation are steps in communicating change programs effectively. Each give the vital information that management needs to make change decisions. Study of the two simulation approaches may indicate how to make these changes more efficiently by saving time or eliminating unnecessary steps. By completion of this research I hope to discover how a static picture of an operation affects the behavior of that operation and whether or not an integration of these two characteristics can be accomplished.

2.4.2 Effective leadership in reengineering and change management

"Empowerment is the process by which ownership is bestowed upon those individuals, or groups of individuals, actually doing the work."(Brown, 1996) It generates a sense of responsibility and dictates the consequences of decisions. There are a few ways that this ownership can be given to individuals, job title, promotions, formation of teams to work on a particular thing, etc.

Cross-functional teams allow for information flow and communication between members. "Cross-Functional Teams can provide the necessary communication from each discipline required for effective decision making."(Brown, 1996) This not only generates better accessibility to the knowledge needed for change programs and decision making, it also aides in

expressing the real concerns of individuals within the organization. These communication skills improve their ability to see the changes that need to be made and the areas of management. From this information they are able to generate a current-state VSM and see where improvements can be made for the future-state VSM. They are also able to understand the behavioral issues that are involved between personnel and other resources within the system which is all information needed to create a simulation.

According to S. C. Brown's (1996) thesis "An Analysis of Elements Critical to Effective Leadership in Business Process Reengineering and Change Management", each team workgroup grows a little differently but they all go through similar development steps. "The five stages are as follows: forming, storming, norming, performing, and adjourning." Forming starts with initial impressions of group members and the generation of trust. Storming is the most important stage of the group process. It is where titles are made and defined for each person in the group. It is also where some of the most important change ideas are discovered. Often this step is cut short out of sheer discomfort or because of time limits. The norming stage is where the group finally finds itself, meaning they are finally agreeing on decisions and changes. More than likely the influence of simulation and value-stream mapping will be used during this stage of the group's development. And add to the support and debate for the changes in the establishment. The performing stage is characterized by the dependence of the group members on each other and their ability to be productive instead of resolving personal problems amongst group members. Adjourning is the stage that is often not realized simply because it is a natural feeling. But this is the stage where the leader needs to be most present. Naturally a person is resistant to change and often fears it. The leader needs to step into this phase explaining the need for change and aide members of the group that may have problems with the degeneration of the work team.

The leader is a critical member of the change effort. “Leadership is not possessing a prescribed set of personal characteristics, but is defined by the actions of an individual.”(Brown, 1996) Not only do they need to be the motivator, they need to take into account the feelings that may be generated during the entire change process and be able to handle the differences and guide effectively. Value stream mapping and simulation are communication tools that the leader can use to help a team make effective decisions. The differences in the two simulation approaches may also make a difference in the time that the change effort is communicated to the other members of the teams. If the integrated approach is successful it eliminates steps in the traditional approach and may suggest the shortening of time to results from the simulation program.

2.5 COMUNICATION AND IMPLEMENTATION OF CHANGE PROCESSES

What makes change so difficult are issues with implementation and acceptance by the workforce. “[W]ith change, the task is to manage the dynamic, not the pieces. The challenge is to innovate mental work, not to replicate physical work. The goal is to teach thousands of people how to think strategically, recognize patterns, and anticipate problems and opportunities before they occur”(Duck, 1993).

The challenge that faces every organization is how to effectively implement changes needed to improve a process. Sometimes these changes are straight forward and organized. But often they are vague and undefined. Implementing change involves all aspects of an organization, a fact that is often overlooked. Value stream mapping is a tool that helps indicate the systematic flow of material and also information. The knowledge gained through this practice helps illuminate somewhat dark and often overlooked problems. “Value Stream Mapping can

help illustrate improvements and progress made...A value stream map is a tool to help sort all the product types into distinct families. It assists you in visualizing, identifying, and eliminating all forms of waste”(Conner, 2001).

Each element of change affects another element of change. The key to proper information is how that change program is communicated with all the individuals involved in the change effort. J. Duck (1993) explains in “Managing Change: The Art of Balancing,” what usually happens with a corporate change effort. The CEO realizes that change needs to happen in one particular area and then delegates this concern to his subordinates. The CEO then pushes for quick results and if those results are not met then the change team is blamed for the failure of the change program. The result is the creative/ brainstorming phase gets cut short to meet management demands for timely results. This stifles the creative process, which takes away from the strategic thinking necessary to successful change.

Duck (1993) stated, “Until managers have listened, watched, and talked enough to know that the answer to all [their questions] is yes, they haven’t communicated at all.” Communication is the key to all successful change programs. If communication is lacking the entire program will lack substance and likely fail. Sometimes effective communication generates feelings and loyalties that would not have been represented otherwise.

Change and trust are often viewed as opposites. People are comfortable in the positions that they are already in. The way that change program meetings occur usually are behind closed doors discussing the needs of what is going on outside that closed door. The key is that that door is closed. By opening the door the lines of communication are opened and information can freely flow between parties rather than fear, rumors and non-accepting efforts.

“Setting the context for change means preparing the players, understanding what they do and don’t know, working with them, watching their performance, giving them feedback, creating an ongoing dialogue with them”(Duck, 1993). If there is no communication, no leadership and no thinking; there will be no trust, no loyalty, and no change.

2.6 WHAT IS TECHNOLOGY’S ROLE IN THE CHANGE PROCESS?

Technological change is at the heart of engineering and manufacturing processes. According to K. Venkataraman in the article, “Management of Technological Change,” he states that technological change can be grouped into three categories. First, how technological improvements are internal to a company. Second, how these changes are aimed at energy conservation or reduction of energy requirements. And third, how the technological changes enhance advances in the other two categories for change.

Management and management style are always key focuses for implementation of change. How that change and knowledge is handled can either make or break the change’s success. “Major technological shifts can indeed be classified as ‘competence destroying’ or ‘competence enhancing’ because they either destroy or enhance the competence of existing firms in an industry”(Venkataraman). Management has to pay attention to three important factors when dealing with technology enhancement for improvement procedures. They have to know which technology to pursue and when to pursue it, managing the technology changeover to the new technology, and how to prepare the enterprise for the technology transition. All of these change aspects are difficult and finding the right balance is what management needs to accomplish.

The greatest way that an organization can generate ideas and acceptance of a change program is to not only focus on the “top down” as Vankataraman described, but to encourage the “bubble up”. The “top down” and “bubble up” approaches refer to the atmosphere in which the organization operates. “Top down” is more of a dictatorship approach where upper management dictates what is to be done about the change effort. The “bubble up” approach indicates an atmosphere of creativity. It is where “ideas flow freely from employees to managers at any level.” Which approach, he states, is “crucial to the generation of minor innovations that often have short cycles and can quickly enhance the competitiveness and success of a company” (Vankataraman).

Based on the three main categories of technological change, a manager should be able to generate the proper implementation for a particular project. Using the “bubble up” approach a lasting impression can be made through their change efforts. The more that people are involved with generating ideas, the greater the acceptance is of the change effort.

2.6.1 Managing change efforts using simulation

Some of the different change management tools have been mentioned in previous sections for understanding and applying change decisions. In terms of VSM and simulation change decisions can be seen on paper or on the computer screen. VSM is a static picture of the process and does not describe the changes in behavior of the system. Simulation was created for this purpose to communicate the behavioral aspects of a system’s functions. In the book *Managing Change with Business Process Simulation* by D. Profozich it reads,

Simulation is a tool that we use to predict performance and to understand the impact of change. It offers many important and well recognized benefits. It allows us to test out system designs before they are built, and it reduces the risk and time associated with implementing new systems or changing existing ones. To those

familiar with the technology, it is inconceivable that any significant new system would be designed and built, or any existing system significantly modified, without the benefit of simulation (1998).

Simulation has many good benefits like Profozich stated. It is an improvement tool that many organizations use to evaluate the significance of their change improvement plans. It is used as a communication tool to see the profitability of the change before time and money are spent on implementing the changes.

A simulation model of your business will allow you to eliminate—or at least mitigate—much of the uncertainty that you repeatedly experience when facilitating changes. Gaining a high degree of confidence that your business decisions will succeed is an invaluable benefit of utilizing simulation (Profozich, 1998).

Seeing the benefits of simulation, the question could be asked why simulation is not used in all cases. One reason for this is that the software itself is expensive, a lot of time is required to build the simulation model, and in many cases the complexity of the system makes it difficult to simulate. Simulation works because it is a computer model of the variation that can happen within a system. This variation is difficult to match real time perfectly and requires a lot of time and research to obtain proper data for time distributions and other dynamic characteristics of a real time system.

Once a current-state simulation is built it is often compared to the real time system to ensure that the results obtained from the simulation are a good reflection of how the real system works in real time. Once the steady state results are obtained the improvement changes can be made to the system and evaluated. The manufacturing sector was an early acceptor of simulation for this purpose of seeing improvements before time and money are included. But also, according to Profozich (1998), simulation was accepted because of...

The frequency of change in products and processes within manufacturing and the continual need to redesign facility layouts,...manufacturing systems in the 1960s and 1970s were better suited for simulation technology...because they were more clearly defined and formalized in terms of their procedures,...[and]nearly all the success stories [using simulation] came out of manufacturing.

The well defined manufacturing facilities allowed for simulation to be accepted earlier than service industries. Having well defined locations for operations and process flow are factors with the success of simulation as well. VSM also utilizes this aspect of manufacturing as it is a static picture depicting the information and process flow through the system. Profozich (1998) explains how a static tool like VSM could effect simulation as he stated, “You cannot use a static tool to study a dynamic problem. A static tool gives an optimistic performance assessment. The greater the variability in the system, the greater the error in static analysis.”(Profozich, 1998) This statement directly relates to the purpose of this research. A VSM contains most of the necessary information that is needed to complete a simulation model. But the question lies in whether or not the simulation created will actually reflect real life occurrences. Through the application of a case study based on Jack McClellan’s research with BullFrog Spa, a group of students will perform the traditional and integrated simulation approaches. From the results of the surveys and simulations completed, the validity of Profozich’s statement can be determined.

2.7 VALUE STREAM MAPPING AND SIMULATION IN THE CHANGE PROCESS

2.7.1 Simulation and training

Simulation is not a new concept for teaching Lean principles. Usually, like with this research, it is used to show how lean principles can improve a system. Many simulation programs have also been made for the application for teaching or training. The Lean Sim

Machine is designed by the Donnelly Corporation to be a training tool in the fundamentals of lean for front line manufacturing workers.

Lean Simulation is an important teaching tool at Donnelly. Rather than lecture at people, the simulation allows participants to experience how their decisions impact the bottom line in a much more powerful and fun way (Ewing, 2004).

Teaching new principles is difficult in any situation and is heavily involved in making change management decisions. Learning new processes and improvement procedures are especially difficult when the staff has been accomplishing the same task the same way since they started work fifteen years ago. Lean manufacturing, as was stated in previous sections, requires that all levels of production are dedicated to the change effort. An example of simulation software that helps teach and train is Lean Sim Machine. A simulation model allows for verification of the changes made within the system. It gives tangible results that individuals can see and relate to. The concept of this research using Microsoft Visio and Process Simulator encourages this type of atmosphere for learning. If the results show that the simulation created by using a VSM is valid, and that a static picture can give all the information for a dynamic system, Process Simulator can also be used as a training application for Lean principles as well.

2.7.2 Applications that include simulation and value stream mapping

The integration of simulation with value-stream mapping is a relatively new concept. Lean simulator is the product name for the concept made by ProModel that takes a VSM made in Microsoft Visio and uses Process Simulator to simulate it. As described in the product's concept description, "A Lean Simulator would be a valuable tool to those familiar with Value Stream Mapping but unfamiliar with simulation. The idea is to provide an easy way to construct and simulate a Value Stream Map (VSM)" (2004). Proof that a VSM contains all the information that

a simulation needs is the basis for this research. As was stated by Profozich (1998), “You cannot use a static tool to study a dynamic problem.” This research will help illuminate the abilities of using a static picture (VSM) to create a dynamic system (simulation). It will also explain the differences between the two simulation approaches (traditional and integrated) and evaluate the capabilities of both.

As background for this research, a description of the Process Simulator program and its competitors are discussed in the following. Process Simulator is how the computer program will be referred to for the integrated approach for simulation, the computer program is also commercially called Lean Simulator. Many of the required icons for VSM have currently been designed for Process Simulator in the form of a special stencil. (Many of these icons were shown previously in *Figure 2* shown in section 2.2.4 of this chapter.) But the question lies in whether or not such an integration is feasible. The largest competitor for Lean Simulator (Process Simulator) is SimLean by OSGI. This application program has an output feature that works with Microsoft Excel. According to the article description of Lean Simulator, their competitor, SimLean’s applications include:

Product highlights:

With SimLean™, users can do the following:

- Improve and integrate lean processes and systems
- Streamline drawing, distribution, and updating of VSM diagrams
- Support mass-update of VSM process data directly from/to spreadsheets and ODBC compliant databases to value stream maps
- Seamlessly share VSM process data between Microsoft® Visio, Microsoft® Excel, Microsoft® Word, and Microsoft® Project
- Automatically calculate key VSM metrics
- Automatically produce comprehensive report spreadsheets and graphs
- Dynamically model VSM flow(Advanced Manufacturing, 2004)

In contrast, the applications that Lean Simulator hopes to accomplish include:

- Provides an easy computerized method for defining a VSM.
- Streamlines the drawing, distribution, and updating of VSM diagrams.
- Automatically calculate static VSM metrics.
- Provides hyperlinks to other diagrams, or to supporting files or Web pages for enterprise level views.
- Enables collaboration using Document Workspaces that reside on Windows SharePoint™ Services sites (requires Microsoft SharePoint Portal Server).
- Diagrams can be saved as Web pages complete with navigation controls, custom property viewer, reports and a search feature.
- Permits simulation of the VSM without the need to build a separate model.
- Simulation provides key VSM metrics that can only be dynamically determined such as cycle times, delay times, inventory levels, and resource utilizations.
- Can model individual cells (which is effectively a micro value stream) or entire value streams (Advanced Manufacturing, 2004).

SimLean and Lean Simulator (Process Simulator) are not the only computer software packages used for lean applications. Other applications for simulating lean principles have been developed including Simcad by Create a Soft, which is basically a simulation program that takes into account the usage of value-stream mapping and other lean principles. It has applications within the program that allow for the development of a value stream map but does not necessarily simulate that value stream map. It is the backward approach to the VSM/simulation problem. It takes a simulation and through the use of the Process Mapper Module, a value stream map can be generated along with reports of value time added or lost through the system. The program also allows for layers of operation. It allows the user to view different levels of operation. One example would be the more defined layout of a cell operation. This built-in cell technology is what gives Simcad strong benefits for their value-stream mapping product.

With the seamless integration of value stream mapping and process flow, Simcad is the ideal tool to store, manage and validate all value stream maps, and process flow diagram within your organization. Simcad's simulation capabilities provide a unique environment to validate your value streams under different conditions and constraints. Multiple value streams can be integrated and tested individually or as a group using the built-in Cell technology (Simcad brochure, 2004).

As the desire for more lean operations grow, a tool that combines value-stream mapping and simulation would be a valuable product to tell managers what their process is doing as well as what it could be doing. The following statement is from a study at the University of Alabama in Huntsville where they performed a similar application integrating value stream mapping and discrete event simulation.

Some obvious steps in VSM that can be helped by simulation are (1) analysis and evaluation of the current and future states, (2) documentation of areas to improve, and (3) assessment of the impact of proposed improvements. The data collected in the act of value stream mapping provides the information necessary to develop a computer simulation of the current process. The simulation can be used in analyzing and evaluating the current and future states. And once a suggestion to improve a targeted problem has been made, the simulation can be modified to include the suggestions and then run to measure the potential impact. This allows the team to make changes and observe the effects without disrupting the production process or causing unnecessary downtime and costs (Donatelli & Harris, 2004).

From this study it was determined that a combination of value-stream mapping and simulation would aide in Lean implementation. The following are the conclusions that the study performed at the University of Alabama (2004) arrived at from their study of a combination of discrete even simulation and value-stream mapping.

The following conclusions are made for the use of simulation with value stream mapping:

- VSM is an extremely valuable tool in lean manufacturing and the continuous improvement effort.
- Simulation adds the fourth dimension, time, to a value stream map. After being simulated, the VSM is no longer just a snap-shot; it is a moving picture which offers insights which may have been missed if VSM alone had been used.
- One tenet of lean manufacturing is to not get “paralysis by analysis,” – simulation of the VSM allows the lean team to more quickly “just do it,” and without causing interruption in the production process.
- Simulation makes not only testing ideas easier, cheaper, and quicker, but also gives immediate assessment of proposed changes to the system.
- The VSM process provides the model and the data, making simulation easier to do.
- VSM and Simulation are a natural combination and each enhances the other’s value in the lean manufacturing effort.

2.8 SUMMARY

As was shown in a study completed by the University of Alabama (2004) a powerful analysis tool that integrates value stream mapping and simulation could help change efforts be recognized more quickly than the traditional simulation approach. The traditional simulation approach often requires data re-entry, which can initiate mistakes. This approach can also be confusing as other differences in paradigms are recognized. The validity of a simulation that is produced by this integrated approach is the basis for this thesis study. The question of whether or not a value stream map contains all the information to generate a valid simulation model will be discussed. The application that will be used is a case study based on the thesis work performed by Jack McClellan at BullFrog Spa. The differences in paradigms between the traditional and integrated simulation approaches are discussed according to their steps.

The traditional approach for simulation using a value stream map is often a long and tedious process. The value stream map is usually created by pencil on paper or using a simple

computer software package. Then the information is transferred from the VSM into the simulation software. This transfer of information can often introduce errors from re-entry or confusion from switching between computer programs.

The integrated approach for simulation and value stream mapping tries to eliminate the middle step of re-entering data. By eliminating the middle step, time may be saved from the traditional approach. Simulation allows for dynamic analysis and predictable outcome. This information is valuable for making decisions within a manufacturing facility. Knowing how much a system can produce without making physical changes to the system saves money as well as time. Simulation then becomes a powerful tool for change management decisions because it can be used as an effective communication tool. People believe what they see. If a valid simulation can be built using the integrated approach, people would be able to see the static as well as behavioral influences that Lean manufacturing can have on a production system.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The purpose of this thesis study is to evaluate the feasibility of using a VSM as a source of information for the generation of a simulation program comparing both simulation approach methods, traditional versus integrated. A case study based on Jack McClellan's thesis research involving BullFrog Spa was created. Completion of a level-loading process through simulation and reducing changeover times was the focus of McClellan's research. McClellan's research was chosen because it took into account basic value stream mapping concepts. The study groups, traditional approach group and integrated approach group, for this thesis study were required to also complete a level loading process using value stream mapping and simulation. Determinations for this thesis study were qualitative in nature and many of the results and conclusions were based on opinion from surveys and personal observation of the two simulation approaches.

The students in the Lean Manufacturing and Simulation classes fall semester 2004 performed all the necessary steps as outlined within the case study as is described in the following. They were first given the current state map as well as some background information on BullFrog Spa. From the current state map they created a future state map of the process first on paper and then using Microsoft Visio. After the completion of the future state map the students were given the first survey which evaluated how well they understood value stream

mapping as well as the Microsoft Visio program, how much exposure the students had to VSM and simulation, and allowed for their personal comments.

After the future state VSM was created the students were then separated into their study groups, traditional and integrated. All of the students were enrolled in the Manufacturing Systems class offered fall 2004. The students were separated according to the following criteria. Students that were also taking the Simulation class (4 students) and the remainder of the Manufacturing Systems class (5 students). The traditional approach group performed their work by taking a paper form of a value stream map and simulating it using a traditional simulation package. The simulation package in this case was ProModel. At the end of a three-week period the students completed validating and level loading the BullFrog process, compared their results to McClellan's thesis study, and completed a survey about their experience.

The integrated approach group used Process Simulator for creating their simulations. They had two-weeks to complete and validate their future state maps generated from the Microsoft Visio program. They also validated their process using McClellan's thesis results and by completing a survey about their experience. If the simulation results from both study groups were correct, they were producing around 21.8 spas per 14 hour workday at BullFrog Spa for the current state and about a 60/40 level loading ratio for the future-state, as these are the simulation results determined by McClellan. The difference in time allowance for completion between the two groups (three-weeks vs. two-weeks) were determined by the difficulty of the computer software packages and were also given to allow the students access to ask questions of professors with expertise that were traveling during part of the time.

After the completion of all the surveys, a statistical review of the time that it took the students to perform their work was performed to see if the time differences between approaches

were significant or not. This was performed by t-tests of the student's hours and a comparison between the resulting confidence levels. Each of the survey questions were also reviewed. The responses to the survey were qualitative in nature. The opinions were evaluated and noted as they were the significant results for this study. I expected that there would be some resistance to performance as this case study was a side effort made by the students and was not required for a grade. As motivation for completion the professors of both classes allowed extra credit as compensation for the student work performed.

I performed a personal study using the BullFrog Spa case study to evaluate the validity of the case study. This validated the assumptions that I had to make concerning the BullFrog process. These assumptions were made because of the proprietary nature and the limiting information about resources within McClellan's research. My performance also indicated what problems may occur with the computer software. This chapter lists the important factors of the case study mentioned previously as well as including copies of the surveys, and limitations or things that I learned while performing my own study.

3.2 CASE STUDY

In order to perform a comparison test between two study groups a common basis for evaluation was needed. The simulation created by Jack McClellan in his thesis research was the common basis for evaluation. Each of the nine students were given the same current state VSM for BullFrog Spa with the same assignment to complete a level loading operation for the BullFrog process. From the results after completion of the simulations, the students should have come to similar results from Jack McClellan's thesis research in order to determine that their simulations were valid simulations. These similar results include approximately 21.8 spas per 14-

hour workday at BullFrog Spa for the current-state and a ratio of 60/40 for spa production in the future-state. The current state value stream map and the instructions for the case study are included in Appendix A.

A few modifications to the BullFrog case study were made during class for clarification. Some of these modifications include the assumption that all the machinery has an 85% uptime and the triangular distributions at the Rework and Hydraulic Flipper stations for generating the future state map, (shown on the current-state map located in Appendix A) were limited to the median value. There was a strict time constraint on the students to finish their assignments, which may have caused more questions asked or added confusion about the case study or simulation programs. The time constraint came from the limitations of the semester and the student's requirements to complete other assignments for their education. The case study was simplified from the original simulation study performed by McClellan to allow for ease of use for the students according to the time constraints presented. The simplifications made include the combination of cycle times to eliminate unnecessary locations and assumptions made concerning cycle times and down times for each process.

3.3 TESTING THE FEASIBILITY OF THE CASE STUDY

In order to simulate any process, an in-depth research of the processes, activities, and resources was needed. Process times and distributions are a large portion of what happens within a process. Without this information a simulation could not be performed. Before the students started their simulation process, I performed my own study on the process to determine the feasibility of the assumptions made for the BullFrog Spa case study. This determination needed to be done to evaluate whether or not the case study could be performed by the students using the

software provided. This also determined whether or not they would come to the same conclusions that McClellan reached.

To evaluate the case study, I used a future state map generated by Student A in the Manufacturing Systems class. I saw after the students completed their future state maps, that most of the future state maps created by the students were similar because many of the students worked together on the project rather than individually. Therefore, it would make no difference whose future state map I chose to work with over another. By using Student A's map, I felt that I would more likely see some of the problems that the students would face while creating their own map because of the similarities between the group's future state maps. Student A's map included many of the same icons that many of the other students used in the class. There are four different types of icons used within a VSM. These icons include production-flow icons, material-flow icons, information-flow icons, and lean manufacturing icons. From my observations, most of the icons used within this particular case study were supermarkets, kanban cards, and manufacturing processes. The common icons used are indicated in *Figure 2*. A copy of Student A's future state map is located in Appendix B.

After asking many questions of experts, I was able to successfully create a simulation of Student A's future state map. A picture of the simulation as well as a picture of the simulation object explorer (or simulation computer logic, meaning the simulation programming, similar to computer programming like java or C++) are located in Appendix C. This creation did not come easily by any means. Many of the icons created specifically for Process Simulator stencil in Microsoft Visio did not perform the operation that they were supposed to when trying to run the simulation. The Supermarket activity and the FIFO routing lines were not recognized as a location or connector tool within the logic of the simulation. In order to correct this problem

other generic icons were used from the original Microsoft Visio program that were converted to represent the supermarket or FIFO routing lines.

The largest problem faced while creating the future state map was the limited use “demo version” of Process Simulator. This particular version only allowed for 15 activities, 3 entities, 5 variables and 3 attributes. This limited the BullFrog Spa case study, many of these problems were solved by combining operations into single locations. This meant that the cycle times represented multiple locations at times. Even though this assumption was made, it did not affect the final throughput of the system or the results that they were able to obtain related to McClellan’s results. The demo version of Process Simulator also did not allow for understanding of problems that were occurring within the simulation. In the commercial version of the program, the computer prompts the user where logic does not compile and indicated those areas where logic needed to be defined. This limitation was aggravating as the user could not determine where the problem within the simulation was located and therefore had great difficulty in understanding why the simulation was not running properly. This problem was solved by giving the integrated approach group a copy of the commercial version to complete their simulations.

The student version of ProModel imposed limitations on the case study, including the limits of 20 locations, 5 attributes, 8 entity types, and 8 resource types. More assumptions were made as the students asked questions for behavioral clarifications of the BullFrog process.

Table 1 indicates the assumptions for the case study made before the students performed the BullFrog Spa Case Study as well as those assumptions made during the course of the students’ performances.

Table 1: Indication of assumptions before class

Assumptions from the original BullFrog	Assumptions made during the study
<p>The times that were listed in McClellan's thesis were complete and accurate to real-time</p> <p>The capacities determine cycle-time</p> <p>If there are two capacities, the single pump spa is the greater of the two</p>	<p>85% uptime for all machines (listed downtimes for the machines were no longer looked at).</p> <p>1 out of every 10 machines is tested.</p> <p>Any changes can be made to the system regardless of cost (i.e. they can add other machines)</p> <p>The parts do go through the flipper twice</p> <p>The move times of the forklifts can be considered as "smoke".</p>

3.4 CONDUCTING SIMULATION EXPERIMENTS

The approach groups were given deadlines in order to complete their simulation experiments as were outlined in the case study handout. These time constraints were based on the allotted time that the students had to complete the assignment with maximum help from expert professors, as well as the limitations of the semester for them to complete their other assignments for other classes.

The case study outlined the current state for BullFrog Spa as was mentioned earlier in section 3.2. This factor was a source for validation of the students' simulations. Both simulation approaches were performed as follows: a future state VSM was created from the current state VSM in the case study, and then both states (current and future) were created in a simulation program. The current state VSM was simulated to validate that their simulation program was running correctly as they were given the information for how many spas are currently being produced. The future state VSM was simulated for comparison of improvements with the current state VSM and also for the purpose of comparison with McClellan's results. The Traditional

approach group created a current state simulation and then created a future state simulation from VSMs that were created on paper using the ProModel simulation software.

The Integrated approach group created their current and future state maps in Microsoft Visio and then used Process Simulator to create the simulations. Validation came as before with comparison to the current state VSMs and McClellan's results. In other words by completion, the students should have been processing an average of 21.8 spas produced per 14-hour workday for the current-state, which were McClellan's results. A simulation requires a warm-up period in order to ensure that the simulation is running properly and values were not just "chance happening". Once the two groups consistently reached something close to McClellan's value they were able to perform the level loading and machine improvements that they defined for their future state. After they implemented the changes into their simulations the students should have realized that about a 60/40 ratio of level loading the spas produced the desired results for BullFrog, which were also McClellan's results. I attended the Manufacturing Systems class weekly to make observations on group performance and answer questions about the case study or simulation programs. This was to try and eliminate confusion and motivate the groups toward completion. The groups passed all assumptions by me. This created common boundaries for each group and ensured that everyone had the same information and were performing the same case study.

3.5 DATA COLLECTION

The information gathered throughout the study was qualitative in nature and was based on my observations and the opinions of the respective approach groups. The information obtained indicated whether or not a static picture of a process (VSM) contained all the information to

create a model of the behavior (simulation) of a manufacturing process. How the students' simulations perform as compared to the results of McClellan's research were a large determining factor toward validity of the simulations created.

This information was gathered through surveys that were given to the students after the completion of each section of the study. These surveys contained questions about the time that it took for each student to complete each section as well as the number of questions they asked for help. They also included the problems encountered as they started to simulate the process and in calculating the results of their simulations.

The following are copies of each of the original surveys that the students filled out after the completion of each of the sections of the study as outlined for the original case study.

3.5.1 Survey one

Survey one was a basic survey that evaluated the background knowledge of the students with VSM and simulation before performing the simulation approaches of the case study. All nine students filled out this survey after they completed creating their future-state VSMs. The questions involving Microsoft Visio indicated how well the students understood the Microsoft Visio program as some of the students used Microsoft Visio to create their future-state VSMs, regardless of which simulation approach they were assigned to. A copy of the first survey is as follows:

Survey 1 BullFrog Spa Case Study
Given October 15th, 2004

By completing this survey it is assumed that the future state map for the case study involving BullFrog Spa has been completed by the student.

1. On a scale of 1 to 5 (five being most difficult and 1 being least difficult) circle how you felt creating a Future State Map of BullFrog Spa

1 2 3 4 5

2. On a scale of 1 to 5 (five being most difficult and 1 being least difficult) circle how well you understood the process as described by the case study and current state map of the process for BullFrog Spa.

1 2 3 4 5

3. How many questions did you ask about generating your future state map? _____

4. On a scale of 1 to 5 (five being most difficult and 1 being least difficult) circle how you felt using the Microsoft Visio VSM stencil to create your future state map.

1 2 3 4 5

5. Have you ever used Microsoft Visio before to create a value stream map? _____

6. Have you ever used Microsoft Visio before to create other things besides a value stream map? _____

7. If the answer to the above statement is yes, please indicate what you have used Microsoft Visio for. If no, and 5 is extremely difficult and 1 is extremely easy indicate how hard it was to learn how to use the Microsoft Visio program.

1 2 3 4 5

8. If 5 is proficient and 1 is novice, answer how well you understood the process of value-stream mapping before creating the future state map for BullFrog Spa.

1 2 3 4 5

9. Indicate what problems you encountered with the program and or VSM stencil below:

3.5.2 Survey two

Survey two was given to the traditional simulation approach group. The purpose of this survey was to indicate the number of questions that the students asked while performing the study as well as understand the students' background before simulating. This survey also described what problems the students were presented with as well as what the results of their

completed simulations showed. This information allowed for easy comparison with McClellan's results as well as indicated the opinions that the students had about the traditional approach. The following is a copy of the second survey.

Survey 2 BullFrog Spa Case Study
Given November 5, 2004

By completing this survey it is assumed that the student not only is participating in the Simulation Class (instructed by Professor Harrell), but that they have completed the simulation of the BullFrog Spa case study in ProModel.

1. With 5 being most difficult and 1 being least difficult circle how you felt using ProModel to generate a simulation from your future state map completed during the first half of this experiment.

1 2 3 4 5

2. How many questions did you ask while generating your simulation for BullFrog Spa? _____

3. On a scale of 1 to 5 (5 being proficient and 1 being novice) circle the number that describes how you felt completing a simulation using a value stream map.

1 2 3 4 5

4. Have you ever used a Simulation package like ProModel before? _____

5. If the answer to #4 is yes, do you think that that knowledge assisted you in generating a simulation model?

6. If the answer to #4 is no, on a scale of 1 to 5 (five being most difficult) circle how hard it was to learn how to use ProModel to create a simulation of BullFrog Spa.

1 2 3 4 5

7. If there were any problems you faced while simulating BullFrog Spa, list them below.

8. Was three weeks a long enough time to simulate and optimize the BullFrog Spa Case Study?

9. With 5 being most confident and 1 being least confident, circle your confidence level in the results that you obtained from your BullFrog Simulation.

1 2 3 4 5

10. In your opinion, did the value stream map indicate all the information that was needed for you to justifiably complete a sound simulation model of BullFrog Spa?

11. If the answer to #10 was no, indicate the other information needed to complete the simulation that was not shown on the value stream map.
12. What were the conclusions that you came to about BullFrog Spa after completion of level loading?
13. What suggestions would you give to others starting the simulation process using only a value stream map?
14. In your opinion, did the use of a value stream map increase or diminish your understanding of the BullFrog Spa process and why?
15. Indicate below any other suggestions or comments you may have that were not addressed in previous questions.

3.5.3 Survey three

Survey three was given to the integrated simulation approach group. This survey showed the number of questions that the students asked while performing the integrated approach as well as the time that it took for the group to complete their simulations. The results from their simulations were given to allow for easy comparison with McClellan's results. This survey was also used for the purpose of getting feedback on the group's opinions of using the integrated approach and what problems they faced while completing the case study. A copy of the third survey is shown as follows.

Survey 3 BullFrog Spa Case Study
Given November 12, 2004

By completing this survey it is assumed that the student is participating in the Lean Manufacturing class (instructed by Professor Miles), and has completed the simulation for BullFrog Spa in Process Simulator.

1. With 5 being most difficult and 1 being least difficult circle how you felt using Process Simulator to generate a simulation from your future state map completed during the first half of this experiment.

1 2 3 4 5

2. How many questions did you ask while generating your simulation for BullFrog Spa?_____

3. On a scale of 1 to 5 (5 being proficient and 1 being novice) circle the number that describes how you felt completing a simulation using a value stream map.

1 2 3 4 5

4. Have you ever used a simulation package before?_____

5. If the answer to #4 is yes, what package and do you think that that knowledge assisted you in generating a simulation model?

6. If the answer to #4 is no, on a scale of 1 to 5 (five being most difficult) circle how hard it was to learn how to use Process Simulator to create a simulation of BullFrog Spa.

1 2 3 4 5

7. If there were any problems you faced while simulating BullFrog Spa, list them below.

8. Was two weeks a long enough time to simulate and optimize the BullFrog Spa Case Study using Process Simulator?

9. With 5 being most confident and 1 being least confident, circle your confidence level in the results that you obtained from your BullFrog Simulation.

1 2 3 4 5

10. In your opinion, did the value stream map indicate all the information that was needed for you to justifiably complete a sound simulation model of BullFrog Spa?

11. If the answer to #10 was no, indicate the other information needed to complete the simulation that was not shown on the value stream map.

12. What were the conclusions that you came to about BullFrog Spa after completion of level loading?

13. What assumptions did you make?

14. What suggestions would you give to others starting the simulation process using only a value stream map?

15. In your opinion, did the use of a value stream map increase or diminish your understanding of the BullFrog Spa process and why?

16. How long (time) did it take you to complete the simulation?

17. Indicate below any other suggestions or comments you may have that were not addressed in previous questions.

3.6 EVALUATING PERMORMANCE

The information received was evaluated according to the student's surveys and also their simulation outputs. The outputs from the student's simulations were compared to the conclusions that Jack McClellan achieved in his thesis study. For the current state VSM the students should have gotten close to 21.8 spas per 14-hour shift. For the future state VSM the students should have gotten close to a 60/40 ratio after level loading the spa process and obtaining the desired 200 spas per week increase from the current 109 spas produced.

Through a qualitative approach, the results from the surveys indicated not only the difference in user application but also in the abilities of each program based on user opinion. Many of the evaluations that were received were based on personal opinion of the students or my personal observation of the simulation approaches. These opinions were difficult to compare and evaluate simply because they were based on personal opinion. These opinions indicated how the student actually felt while performing their respective simulation approaches. This gave valuable information about the user friendliness of the programs and also showed the feasibility of using a static picture of a process as the information to build a simulation of the behavior of that process.

CHAPTER 4

RESULTS

4.1 COMPARATIVE QUALITATIVE ANALYSIS

A comparative analysis was performed to evaluate the feasibility of an integration of VSM and simulation. Two simulation approach groups were studied with reference to their responses to surveys and with comparison to Jack McClellan's thesis study based on BullFrog Spa. The responses from the survey although qualitative in nature were evaluated by terms of understanding of their respective approaches as well as the usefulness of a VSM in creating a simulation for a process. Conclusions made from these responses were based on observation of myself as well as a comparison between the two study groups.

4.1.1 Case study assumptions

In reference to the BullFrog Spa case study and its structure, most of the students had a hard time understanding what was actually happening within the BullFrog Spa process. While attending class and administering the case study, some assumptions about the process were made to help the students understand the processing easier. These assumptions were validated through my personal simulation created from the case study. *Table 2* indicates the assumptions that were made in order to accommodate the understanding of the students as well as allow them to obtain the same results as McClellan.

Table 2: Indication of assumptions from class

Problem	Assumptions made
VSM didn't directly convert over to the simulation package	Use of the icons and logic for the programs had to be simplified for understanding
Cycle times at each location was ambiguous	If there was a distribution, it was assumed to be normal, cycle times were simplified
Not enough information given	They were able to ask for finalizing information from Me or Dr. Harrell, this was done to limit confusion and give a common basis for the case study for all the students.
How exactly to improve the process	The students were given no limitations on the number of machines that they could add, or changes that they could make
What is the down time for the workers?	The downtimes are clock based, meaning there is no assumed variation for the downtimes.
Do the spas go through the flipper twice?	Yes every spa goes through the flipper twice.
Are all the spas treated the same at each station?	The cycle time differences at the stations determine the differences in production for the different spas. Longer the time, generally indicated a double pump spa.
What goes through the rework station?	1/10 spas are reworked
The program didn't allow for multiple locations	Entities and locations were combined to simplify the process

4.1.2 Survey one

The first survey given to all the students gave background research on each of the students included in the study. Nine students filled out the survey and participated in the research. Four students completed the traditional approach and the remaining five students completed the integrated approach. *Table 3* indicates the first group of questions as they related to each other and what the responses from the students indicated.

Table 3: Group A questions from survey one

Question	Responses
1. On a scale of 1 to 5 (5 being most difficult and 1 being least difficult) circle how you felt creating a Future State Map of BullFrog Spa	Average response of students: 3.7 (4) Six students = 4 Three students = 3
3. How many questions did you ask about generating your future state map?	Average number of questions = 5.7 High = 10; Low = 2; no answer = 2 persons
7. If 5 is proficient and 1 is novice, answer how well you understood the process of value stream mapping before creating the future state map for BullFrog Spa.	Average response of students: 2 Three students = 1 Three students = 2 Three students = 3
8. Indicate the problems you encountered with the program and or VSM stencil below:	Problems: certain icons did not function correctly, stencil didn't work correctly (8 students), and one didn't understand VSM.

Questions 1, 3, 7, and 8 within the survey all deal with the student's previous knowledge and understanding of VSM. From the responses indicated in Table 1.1 it has been determined that the students were not experts with VSM.

The responses to question 1 concerning the difficulty of creating a VSM were all answered on the higher end of the 1 to 5 scale by the students. This indicates that it was difficult for the students to really understand how to create a future state VSM. Question 7 supports this statement as the students responded to their proficiency level with VSM. All the students in this case responded on the lower end of the scale indicating their lack of confidence in understanding VSM. From personal observation I noticed that the students had a difficult time understanding which icon to use at certain places while creating their future state maps. Question 8 indicates many of the problems that the students encountered being mostly involved with the Microsoft Visio Process Simulator stencil of icons.

Table 4 shows the questions as well as the responses for questions 4, 5, 6, and 8. Question 8 was indicated in Table 3 but has relevance with questions 4, 5, and 6 as they involved the functionality of the Microsoft Visio Process Simulator stencil specifically.

Table 4: Group B questions from survey one

Question	Response
4. On a scale of 1 to 5 (5 being most difficult and 1 being least difficult) circle how you felt using Microsoft Visio VSM to create your future state map.	Average: 2.7 Three students = 3 or 2 Two students = 4 One student = 1
5. Have you ever used Microsoft Visio before to create a VSM?	All students = no
6. Have you ever used Microsoft Visio before to create other things besides a VSM?	Five students = no Four students = yes
8. Indicate the problems you encountered with the program and or VSM stencil below:	Problems: certain icons did not function correctly, stencil didn't work correctly (8 students), and one didn't understand VSM.

Questions 4, 5, 6, and 8 involve the function of the Microsoft Visio program and various stencils that were generated for the Process Simulator program that the integrated simulation approach group would use for later sections of the case study. These questions addressed everyone in the study as some of the students would use Microsoft Visio to create their VSMs regardless of which study group they were assigned to. Like the previous responses to questions 1, 3, 7 and 8; the students indicated that they did not have any real previous background to Microsoft Visio before performing the case study for BullFrog Spa.

4.2 TRADITIONAL APPROACH VS INTEGRATED APPROACH

4.2.1 Simulation class; traditional simulation approach

Survey two was designed to assess the abilities of the students in the Simulation Class. The four students performed the BullFrog case study using the ProModel simulation program. After the completion of level loading the BullFrog process the students completed survey two. The results from the survey are indicated according to their importance in the following *Tables 5*

– 8.

Table 5: Group A questions from survey two

Question	Response
1. With 5 being the most difficult and 1 being least difficult, circle how you felt using ProModel to generate a simulation from your future state map completed during the first half of this experiment.	Average: 4 Three students = 4 One student = 3
6. (Having never used a simulation package before), on a scale of 1 to 5 (five being most difficult) circle how hard it was to learn to use ProModel to create a simulation of BullFrog Spa.	Average: 4 One student = had used a simulation package before Three students = 4

Question 1 and 6 directly addressed the ProModel simulation software. The students indicated that using ProModel was above average in difficulty. Three of the four students answered 4 on a scale of 1 to 5 (5 being most difficult). The fourth person answered 3 for average difficulty using ProModel. Question 6, which was required only if they answered “no” to question 4, had the same results with three of the students answering 4 for difficulty learning how to use ProModel for simulation. The fourth person had previous knowledge of simulation programs, which assisted them in simulating using ProModel, whereas the other three students had never used a simulation program before. From this and my personal observations during the traditional simulation approach, it was difficult for the students to understand the computer logic for ProModel. This lack of understanding often confused the students and they had more problems getting their simulation to run correctly.

Table 6: Group B questions from survey two

Question	Responses
3. On a scale of 1 to 5 (5 being proficient and 1 being novice) circle the number that describes how you felt completing a simulation using a VSM	Average: 3.3 Two students = 4 One student = 3 One student = 2
4. Have you ever used a simulation package like ProModel before?	Three students = no One student = yes
5. (having used a simulation package before) do you think that that knowledge assisted you in generating a simulation model?	One student response = yes (this student is also known as Student B)

Questions 3, 4, and 5 addressed simulation programs directly. Question 3 involved using a value-stream map for the generation of a simulation. The scale was from 1 to 5 with 5 being proficient. Two of the students felt above average using the VSM to create a simulation. One student felt just below average using the VSM and the last student felt average (3) using the VSM. As was mentioned previously question 4 verified previous work with simulation software and question 5 asked if that previous knowledge assisted with the use of ProModel. One student said that the previous knowledge did assist in their work using ProModel. The other three students had never used a simulation package before, so they did not have to answer question 5.

Table 7: Group C questions from survey two

Question	Responses
3. On a scale of 1 to 5 (5 being proficient and 1 being novice) circle the number that describes how you felt completing a simulation using a VSM	Average: 3.3 Two students = 4 One student = 3 One student = 2
10. In your opinion, did the VSM indicate all the information that was needed for you to justifiably complete a sound simulation model of BullFrog Spa?	All four students = NO “more assumptions had to be made” “I needed more information to understand the nature of flow of products”
11. If the answer to 10 was no, indicate the other information needed to complete the simulation that was not shown on the VSM.	No clear goal, number of spas tested, hidden assumptions, unclear flow indicated.
14. in your opinion, did the use of a VSM increase or diminish your understanding of the BullFrog Spa process and why?	All four students = increased understanding One also said that it diminished a little because of lack of clarity. “visual representation”

Questions 3, 10, 11, and 14, shown in *Table 7* all addressed using a VSM as the primary source of information for generating a simulation. The results from question 3 were discussed previously. Questions 10 and 11 addressed the amount of information located in a VSM and whether or not, in their opinion, the VSM contained all the information needed to complete a simulation of BullFrog Spa. All four students indicated that just the value-stream map was not enough to create a sound simulation program of BullFrog Spa and that more information was needed or that more assumptions were necessary. Some of the problems that the students indicated that were vague from the VSM included:

- Understanding the flow of the spas
- How many spas were tested
- Confusion with cycle times
- Unclear goals
- Personal lack of understanding of the use for a VSM
- More assumptions had to be made
- How many spas go where and what the routing limitations for the process were.

All of these answers directly relate to the behavioral aspect of creating the simulation. Similarly when the students were asked whether or not the value stream map increased or diminished their understanding of the BullFrog Spa process all four students indicated that the VSM increased their understanding of BullFrog spa. Some of the anonymous comments about the usage of VSM included the following:

- “it gave me a visual representation of the process required to make spas”
- “it’s an organized way to collect data”
- “increase[d my understanding] in some ways and diminish[ed] in others. I could better understand parts of the system, but in other parts the lack of clarity mislead me and confused me.”
- “[VSM] helped increase [my understanding of the BullFrog process], [it] made me delve into the specifics of the system.”

These responses indicated that VSM is a useful tool in understanding the process because they could see the flow from the current state map. Problems arose when they tried simulating the future state map with understanding the underlying information. From observation of the traditional approach I noticed the difficulty in understanding which resources were used where. This often left the students confused and frustrated. The questions labeled in *Table 8* show the confidence level of the students in their final results as compared to McClellan’s results.

Table 8: Group D questions from survey two

Question	Responses
9. With 5 being most confident and 1 being least confident, circle your confidence level in the results that you obtained from your BullFrog simulation.	Average: 3 Two students = 3 One student = 2 One student = 4
12. What were the conclusions that you came to about BullFrog Spa after completion of level loading?	Level-loading works, 60/40 ratio (student B), didn’t finish level-loading portion, level-loading increases throughput.

Questions 9 and 12 involved the results after level loading the process. One student came to the 60/40 conclusion or two double spas for every one single spa. One student did not finish

the level loading portion of the assignment. The remaining two students stated that they learned that level loading increased throughput from the system. When asked about their personal confidence in their results, two of the students answered average confidence. One answered just below average and the remaining student answered a little above average confidence in their results from the simulation. Student B was the student that was successful at meeting McClellan's results, a copy of the code for Student B's simulation program is included in Appendix D.

The remaining questions involved problems while simulating BullFrog specifically and the suggestions that they would make for individuals in the future that would be using only a VSM for information to build a simulation model. Most of the problems arose from the lack of understanding the current state map given to them. Or not fully understanding the simulation software's capabilities and specific logic functions that ProModel uses.

The responses resulting from the second survey given to the simulation class indicated frustrations with the BullFrog Spa case study itself being misinterpreted or misunderstood. While using the VSM the overall conclusion was that it helped guide the students through the process of traditional simulation but it did not contain all the information that was needed to create the simulation. There were problems that they faced while generating their simulation programs, but those problems, according to the responses on the survey, can be attributed to their inexperience with the simulation software, confusion while using the simulation software, and lack of given information on with the VSM.

4.2.2 Integrated simulation approach

Survey three was designed for the five students that used Process Simulator as their means for simulating the BullFrog Spa case study. After completion of their simulations the students completed the survey anonymously. The questions as well as the responses from the students are indicated in the following *Tables 9 -12*.

Table 9: Group A questions from survey three

Question	Responses
1. With 5 being most difficult and 1 being least difficult circle how you felt using Process Simulator to generate a simulation from your future state map completed during the first half of this experiment.	Average: 3 One Student = 5 Two students = 2 Two students = 3
6. (Having never used a simulation package before), on a scale of 1 to 5 (5 being most difficult) circle how hard it was to learn how to use Process Simulator to create a simulation of BullFrog Spa.	Average: 4 Three students = 4 Two of the students have used a simulation package before.

Similarly to survey two, questions 1 and 6 were directly related to the Process Simulator software. Question 1 addressed the use of Process Simulator specifically as a means to create their BullFrog Spa simulation. On a scale from 1 to 5 (5 being most difficult) the students were asked to circle their level of difficulty using a VSM to build their simulation, two students answered 2, two answered 3, and one answered 5. Question 6 was also based on a scale of difficulty from 1 to 5 (5 being most difficult) for the students to learn how to use the Process Simulator program. Two of the students did not respond to the question and the remaining three students indicated that it was somewhat difficult (4) to learn the software.

Table 10: Group B questions from survey three

Question	Responses
3. On a scale of 1 to 5 (5 being proficient and 1 being novice) circle the number that describes how you felt completing a simulation using a VSM	Average: 2.4 Three students = 3 One student = 1 One student = 2
4. Have you ever used a simulation package before?	Two students = No Three students = Yes
5. (Having used a simulation package before), do you think that that knowledge assisted you in generating a simulation model?	Two used ProModel before, one said it helped, the other stated that it didn't help. The last used a flight simulator program and said that it didn't help.

Questions 3, 4, and 5, shown in *Table 10*, dealt with the student's familiarity with simulation software. Question 3 indicated on a scale from 1 to 5 (5 being proficient) the proficiency of the student using a VSM to complete a simulation. Two of the students answered just above novice (2), two students answered average (3), and one student answered proficient (5). That same student that answered proficient answered that he or she had never used a simulation program before (question 4). Another student said that they never used a simulation package before whereas the other three students stated that they had used another simulation package before. Two students stated that the simulation package that they used was the ProModel simulation package, but that it was only a once or twice usage. The other student that had used a simulation software package before indicated that it was a flight simulator and that it did not aide them in creating the simulation for the case study.

Table 11: Group C questions for survey three

Questions	Responses
10. In your opinion, did the VSM indicate all the information that was needed for you to justifiably complete a sound simulation model of BullFrog Spa?	Three students = yes Two students = no
11. If the answer to 10 was no, indicate the other information needed to complete the simulation that was not shown on the VSM	“You had to add logic and routing for the computer.” “it lacked a concise list of times for each station.”
15. In your opinion, did the use of a VSM increase or diminish your understanding of the BullFrog Spa process and why?	Four students = increased understanding One student = diminish, because he or she didn’t really understand the process at all.

Questions 10, 11, and 15, shown in *Table 11* involved the usage of a VSM as their source for information to build their simulation. Three of the students stated that the VSM contained all the information that they needed to build the simulation for BullFrog Spa. The remaining two students stated that the VSM was a little hard to understand or that the routing and logic had to be changed from the original VSM. In terms of the VSM specifically, one student said that the VSM did not increase their understanding of the process because they were not sure that they understood it really well in the first place. The remaining four students indicated that the VSM allowed them to logically think through the process. As the VSM showed what the exact product flow was, and “the VSM did allow me to think of questions that I would ask and things I would look at if I could observe the process.”

Table 12: Group D questions from survey three

Question	Responses
2. How many questions did you ask while generating your simulation for BullFrog Spa?	Average: 17.5 (15, 50, 0, 12, 10) High = 50 Low = 0
7. If there were any problems you faced while simulating BullFrog Spa, list them below.	Combining entities, Logic (three students specifically), wrong version of Process Simulator, did not understand the VSM.
9. With 5 being most confident and 1 being least confident, circle your confidence level in the results that you obtains from your BullFrog simulation.	Average: 2.8 Two students = 4 Two students = 3 One student = 0 (didn't obtain results)
13. What assumptions did you make?	Combine operations into cells, normal distributions, able to make changes, cellular manufacturing

The final questions 2, 7, 9, and 13 shown in *Table 12* are all related in terms of how well the students understood VSM and the case study in order to complete a simulation that they could have confidence in. The average number of questions that were asked during the simulation process was 17.5. One student was not able to get results from their simulation, so they stated that they could not answer the question regarding their confidence level for their results. The remaining students were split with their confidence level in their results. Two students answered that they felt they were above average (4). And the remaining two students felt average (3) in their results.

During the simulation process it was discovered that restrictions in the demo version of Process Simulator required that the students simplify their future state maps by combining some processes. This simplification process confused some students causing more questions about the case study. For example, one comment was, "Didn't really understand how the value stream related to the processes. It was a little ambiguous." Most of the other problems that were mentioned were considering the logic to make the simulation work.

- “The value stream map did not convert directly over. I had to make a whole new map using the Process Simulator icons. Setting up the logic was a little complex and could be more intuitive.”
- “I didn’t understand at the beginning how to use logic. I was using the demo so I had to simplify everything.”

From the results given from the surveys and personal observation of the integrated process it was determined that it is most important to make sure that the process and what cycle times, and other process information is clearly understood before trying to create a simulation from the information. Other suggestions also included a better knowledge of Process Simulator functions and understanding of computer logic.

4.3 STATISTICS

A statistical confidence level is defined as “[a] range of values used to estimate some population parameter with a specific level of confidence; also called an interval estimate.”(Triola, 1998) It is used to see the difference in confidence levels between the two sample groups. In order to see a significant difference between the sample groups, the size of the group needs to be quite large. The sample size of nine was all that was available to be researched due to the limited number of people that are enrolled in the classes and in the manufacturing systems graduate program. Even though significant confidence levels could not be generated for a larger population, two t-tests were performed on the time it took to complete the simulations from each of the simulation groups. The results from the t-tests show the confidence levels from the difference in times associated with the completion of the simulation approaches. The results from the t-tests are as follows in *Table 13*.

Table 13: Statistics for both approaches

T-tests on time for completion for the two simulation approaches	Mean	Standard Deviation	95% Confidence Intervals
Traditional	8.125	1.245	(5.181, 11.068)
Integrated	8.400	1.113	(5.767, 11.032)

Difference between means: 0.275

Standard error of difference: 1.670

Probability that there is no difference: 87.39%

95% Confidence Interval on difference of means: (-4.224, 3.674)

From the statistical results shown above it states that the difference between the times that it took the students to perform the different simulation projects could be anywhere between -4 and 4. The differences between the means is 0.275 and the probability that there is no significant difference between the times is 87.39%. Meaning that there really is no significant difference between the times for completion between the two simulation approaches. These results come from the limited number of students taking the class and participating in the study. Since there was a limitation on the number of students enrolled in the class, the remaining information and test results are left to personal preference and opinion of the students participating in the study.

4.4 COMPARISON WITH MCCLELLAN'S THESIS

Jack McClellan analyzed three different scenarios for level loading using his simulation model of the BullFrog Spa process. For his simulation research he used the ProModel simulation package. The three scenarios include a 50/50 ratio for scenario one 60/40 ratio in favor of single pump spas for scenario two, and a 40/60 ratio in favor of the double pump spas for scenario three. After performing different runs using the simulation program McClellan came to conclusions about which ratio would be most beneficial for maximum throughput of the two spa

types. It was discovered that the 60/40 or the 40/60 ratios were best to maximize the throughput by 58.7%. The 50/50 ratio only improved by 49.1%.

The results that the students obtained from the case study based on McClellan's work with BullFrog Spa were very similar. For verification, students compared their output levels with that of McClellan's for their current state maps. Once they obtained the average of 21.8 spas a day, they were able to change their simulations according to their future state VSM and start level loading. One of the students in the traditional approach group claimed "3 to 2, or 2 to 1, or the 60/40 ratio." The simulation code for the student that was most successful in the traditional approach group, Student B, is included in Appendix D as an example of the computer logic that was required for the traditional simulation software. From the results of each simulation approach it was realized after completing the assignment that level loading the process improved the output for BullFrog Spa. Two of the students in the integrated approach group obtained the same results for the improvements given by the 60/40 ratio and the code for one of their simulations and the results from the simulation are given in Appendix C and E.

The results obtained in both classes compared with the results from McClellan's thesis study, validated that the 60/40 or 40/60 ratio is the best level loading arrangement for BullFrog Spa's processing. The results of the comparison test also confirmed that a VSM increases understanding of processes before they are simulated as eight of the nine students included in the study stated that the VSM increased their understanding of the BullFrog Spa process. The results also show that a VSM, although helpful in understanding the process, did not contain all the information needed to complete a simulation. This resulted from personal observation and six of the nine students stating that it did not contain all the information needed to create the logic for the simulation.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 SUMMARY

Value stream mapping is a process used in Lean manufacturing that indicates the value flow through a process by using simple icons and process information like Takt times, cycle times, number of operators, etc. A VSM forces an individual to think about the two different types of flow through a system, information flow and production flow. This deeper thought process helps the individual see what processes are dependent on each other and may “spark ideas” on how to improve the flow through the system. When improvements are being made to a system generally two types of VSMs are created. First the current state VSM is created to take a “static picture” of the flow through the system as it currently exists. From the current-state VSM, a future state VSM is created taking into account the changes made using the Lean manufacturing system. A deeper look into the flow of the system is also required for a simulation model. When using simulation as a tool with VSM, both VSMs are simulated to see the behavioral effects the changes from the current state VSM to the future state VSM made to the system. There are two approaches to simulation that involve VSM, the traditional simulation approach and the integrated simulation approach. Students enrolled in the Manufacturing Systems class in Fall 2004 were used as the study groups for the research of these two simulation approaches as they relate to VSM.

A case study based on the simulation performed by Jack McClellan on BullFrog Spa was used for this comparative analysis. The students were required to use the information given to them about BullFrog Spa and create a future state VSM. From the VSMs they were to create a simulation of the process and compare it to the results from McClellan's thesis research. At the completion of their simulations the students were asked to complete surveys about the approach that they performed. Three surveys were completed: one before the students were split into groups then one to the traditional approach group, and one to the integrated approach group after completion of their simulations. These results were compared to each other and McClellan's results.

5.1.1 The surveys

The results from the first survey indicated that the case study was confusing. It also indicated that most of the students had never created a value stream map. This lack of experience may have added to the ambiguity of the case study as the students were just learning the meaning of many of the icons used in value stream mapping.

The results from survey two, which was given to the traditional approach group, had the same concerns about ambiguity and understanding of the process. One student had used a simulation package before, whereas the other three students had not. This extra understanding helped the student with creating the simulation of BullFrog Spa and also helped him obtain the same throughput results that McClellan obtained. The ratio should have been either 60/40 or 40/60 for level loading the process and getting the desired 200 spas of output per day.

Survey three was given to the integrated approach group and also indicated that most of the problems came from the limitations with the simulation programs that the students were

using. The demo versions did not allow all the applications the simulation software can perform. Some of these things were the troubleshooting and compiling applications that find problems within the computer logic. It was also determined that two of the five students were also successful in obtaining McClellan's same results.

5.1.2 Statistics

Statistically the differences in times for completion between the two approaches were almost negligible as the 95% Confidence Interval between the averages of the two approach's completion times was between -4 and 4. And the probability that there was no difference between the times was 87.39%. The size of the sample groups limit any indication of large differences in confidence between the two groups. Due to limitations of enrollment, I was not able to get a significant sample size.

Because of the limitations for statistics, I evaluated the opinions of the students from the surveys that they filled out after completion of their assigned simulation approach. As stated by eight of the nine students, even though they were confused at times, the VSM increased their understanding of the BullFrog Spa system. It was also determined from both approach results, that VSM did not contain all the information that they needed in order to simulate the process. This result comes from personal observation of both processes as well as the statements from six of the nine students involved in the study.

5.2 CONCLUSIONS

VSM showed some of the needed information for simulation such as cycle times, down times, order of operations, and number of machines and operators, etc. But some information

was not given that would be needed in future applications for simulating, like the time that operators take for lunches, how often that happens, what monetary constraints the company has on making changes within the process, etc. These bits of information describe the behavioral effects of the process that are not always indicated on the VSM. A VSM is a static picture of a manufacturing process looking at the specific operation times and machine problems. It does not take into account the behavioral issues of employees or resources that also affect the throughput from a system. This information is needed to create a valid simulation that reflects the actual outcomes of the system in real time. These conclusions support the statement made by Profozich (1998), which was, “You cannot use a static tool to study a dynamic problem. A static tool gives an optimistic performance assessment. The greater the variability in the system, the greater the error in static analysis.”

Since the results from statistics do not show that there is a significant difference between either simulation approach (87.39% probability that there is no difference in time to completion). The conclusion can be made that VSM and simulation combined in either the traditional or integrated simulation approaches, will help the understanding of a manufacturing process as based from the student responses and personal observation.

The hypothesis that an integrated approach can produce a justified simulation from a VSM is supported by the students responses, actual results, and limited exposure to both simulation approaches. Over half of the students surveyed (8/9) stated that the VSM increased their understanding and allowed them to think about the BullFrog system in its intricate details in order to simulate the process better. Three of the students were able to get the same or very similar results to that of Jack McClellan with the 60/40 or 40/60 ratio. From personal observations, I determined that the students were able to create simulations that reflected

McClellan's results because of the outside information that I gave them as well as the background of information that was given along with the VSM of the current state for BullFrog. This added information gave the students the "hidden assumptions", as one student stated, that they needed for the logic within their simulation programs. These observations as well as the six responses from the students determined that even though the VSM aided in understanding of the manufacturing process, it did not contain all the information that was needed in order to create a simulation. Outside information, like that given along with the current state VSM for BullFrog helped the students understand how the logic needed to be written in order to reflect real life behaviors of the system.

5.3 RECOMMENDATIONS

The conclusions arrived at through this research were drawn from opinions of the students. In future applications and studies for these two simulation approaches there should be a higher number of participants in the study group. This higher number of participants will allow for statistical critical intervals. Also, in the future, the study groups should consist of individuals that are more experienced with simulation and VSM. By doing so, the learning curve will not be a major factor in the results obtained from the case study.

For future evaluations of the differences between the two simulation approaches, the number of people in the focus groups should be equal. The individuals within those study groups should also be close in the same ability level as those in the other study group. These abilities can be evaluated through surveys and evaluation of individual exposure to simulation software as well as their familiarity with the process given as a case study. The study group should also be focused solely on the case study and not performing other activities at the same time, thus

allowing for complete focus on the case study. The students were often distracted because of other assignments that they had to turn in throughout the semester, which from observation, added to their confusion of the case study.

Finally, for complete evaluation of whether or not a VSM contains all the information to create a simulation, the case study should only contain a current-state VSM and no background information of the system given as the case study. From this the only information given to the study groups will be that of the information from the VSM. This will indicate what assumptions were made to create the simulation and directly evaluate whether or not it contains all the information that a simulation needs.

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APPENDICES

APPENDIX A:

Copy of the BullFrog Spa Case study and VSM as given to the students in the two approach groups.

Case Study – BullFrog International, L.C.

The following page contains the value stream map (VSM) for the current state for BullFrog International, L.C. BullFrog International, L.C. was founded by David Ludlow in the 1980s and is Utah's 4th fastest growing company. This growth has encouraged BullFrog to continue to increase their company profits, although, the way that the system currently stands cannot support a high level of growth simply because of the complexity of the two different spa types, batch sizes, and lengthy changeover times at the system's bottleneck.

Changeover times at the vacuum former operation are making it difficult to produce the maximum amount of throughput for each spa type. Currently the changeover time is 10 min, BullFrog's target changeover time is 5 min. Through these quick changeover times batch sizes can be reduced for each spa type.

The two types of spa include: single pump spa and a double pump spa. The processing times at each operation for each spa are identical except for the plumbing station, assembly station, and rework station. Where the capacities for the different spa types are indicated. The parentheses indicate the maximum capacity for the double pump spa type at that particular station. If there are no parentheses shown then it is assumed that the capacity for each spa type at that location are identical. All cycle times and down times are represented as minutes. If there is no down time specified then it is assumed that the down time is negligible. There are 5 res (resources, i.e. forklifts) in the facility. Two of the resources are dedicated to the hydraulic flipper, clean, detail, inspect (move time negligible), one is dedicated to the Toeplate operation (move time 10 min), one is dedicated to the panel and cabinet operations (move time 5 min), and the last is dedicated to the vacuum former line (move time 5 min). The Toeplate operation is assumed to be a separate operation that is fed into the assembly operation.

BullFrog is a build-to-order company. Currently the demand for single pump spas is 60% more than that of double pump spas. On average BullFrog is able to produce a total of 21.8 spas per day, according to Jack McClellan's thesis study. In order to stay ahead of competition and get the spas to customers quicker, BullFrog would like to be producing 200 total spas per week as opposed to the 109 spas they are currently producing. They run two shifts per day encompassing 14 hours of work per day on average. By decreasing the changeover times for the vacuum former from 10 to 5 minutes, moving resources and operators, and level loading the process, What is the optimum batch size for the operation to still meet its customer demand? Or can they not meet the demand for 200 total spas?

Applications and Due Dates:

Generate a VSM for the future state for BullFrog Spa: **Oct 1**

Transfer your future state VSM into Visio: **Oct 8**

ProModel group build simulation model of the future state to determine level loading of the operation:

Oct 22

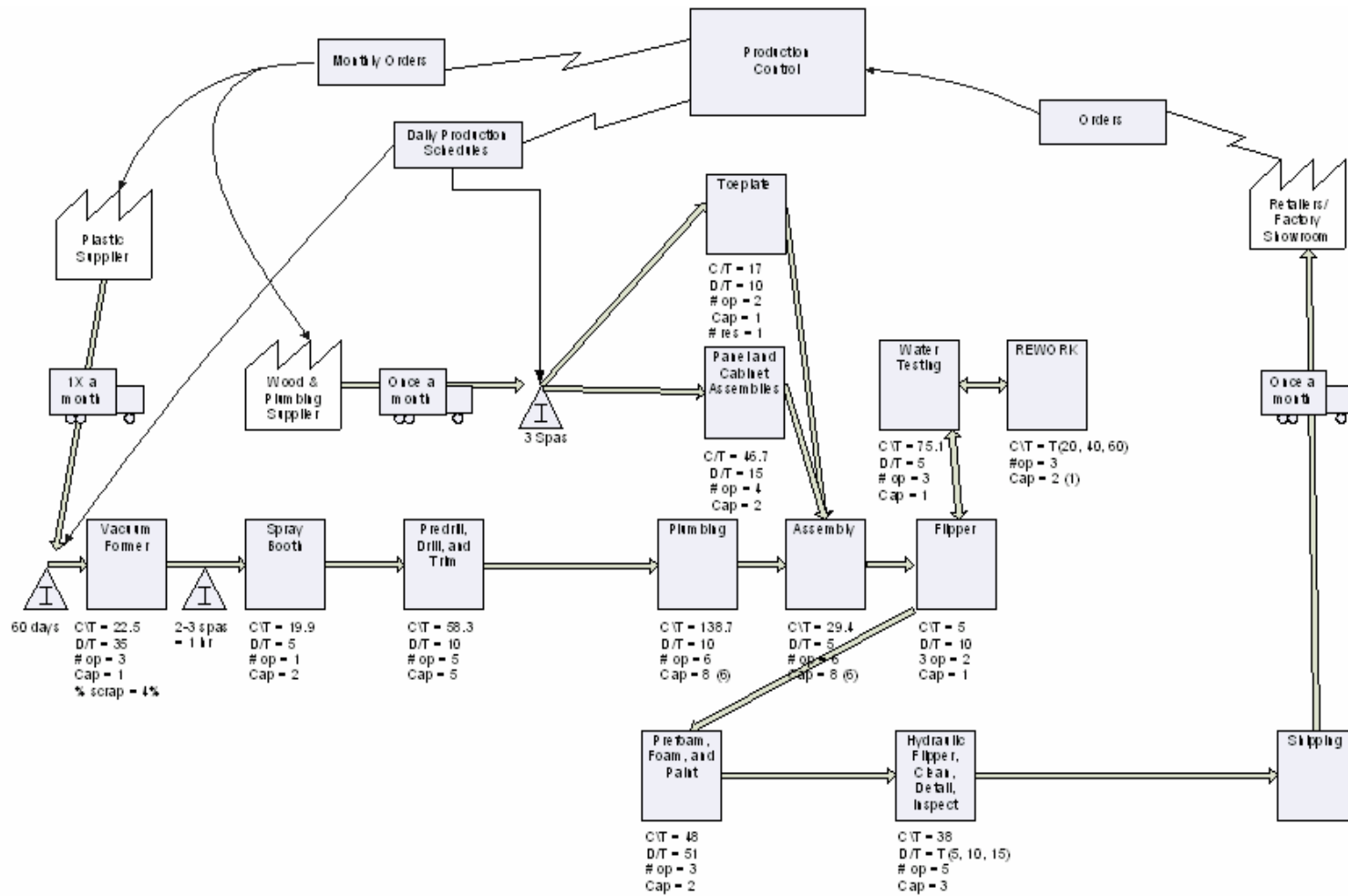
Remainder of the class and ProModel group build the future state map in Process Simulator to determine the level loading of the operation: **Oct 29**

Requirements:

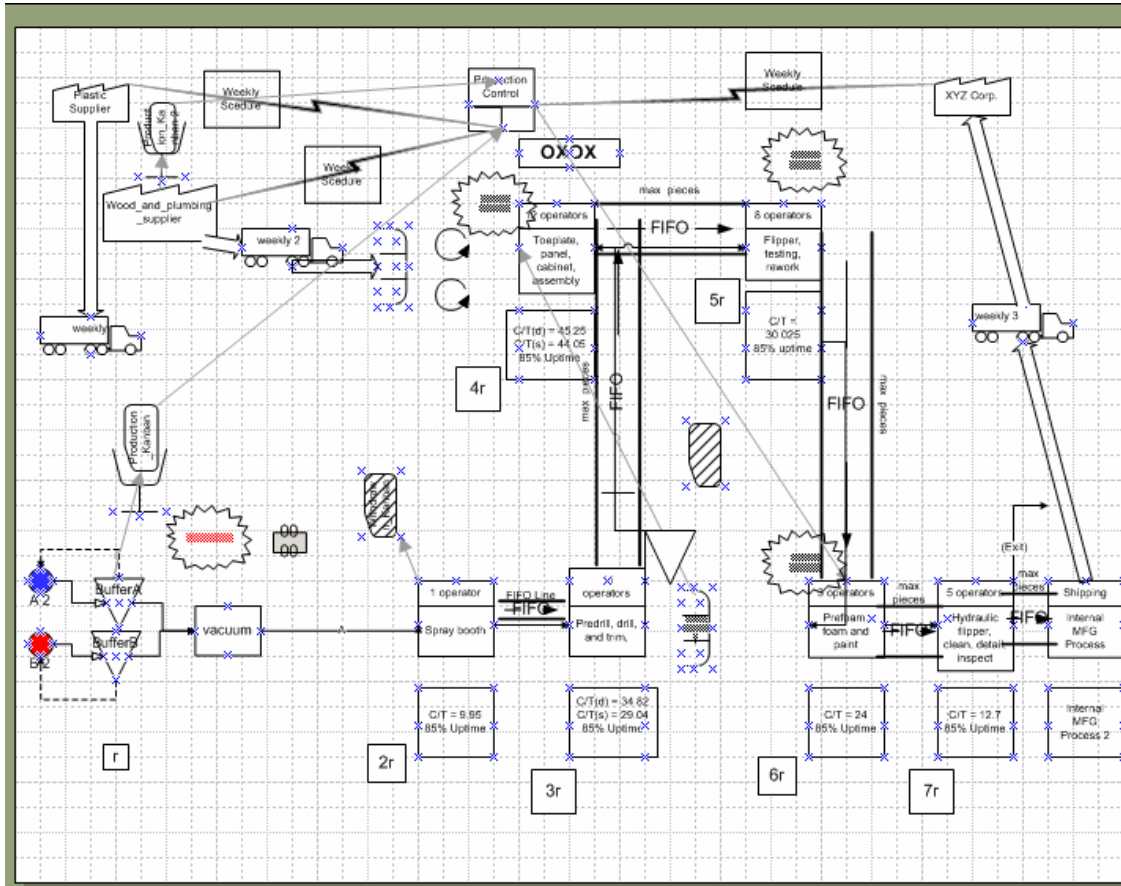
Keep a timeline of how long it took you to create the future state VSM as well as the time that you took creating the simulation models.

Keep track of how much help you received and how many questions were asked while creating the simulation models.

Answer the surveys that you will receive honestly.

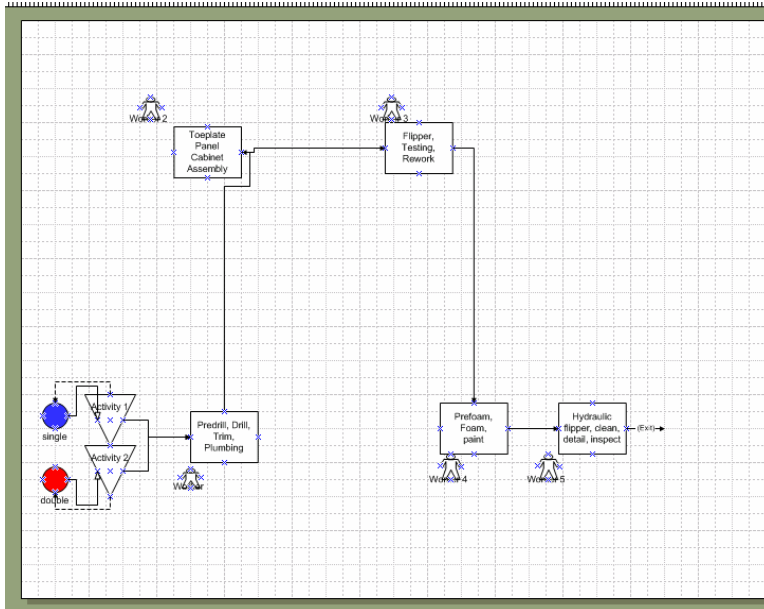


APPENDIX B:

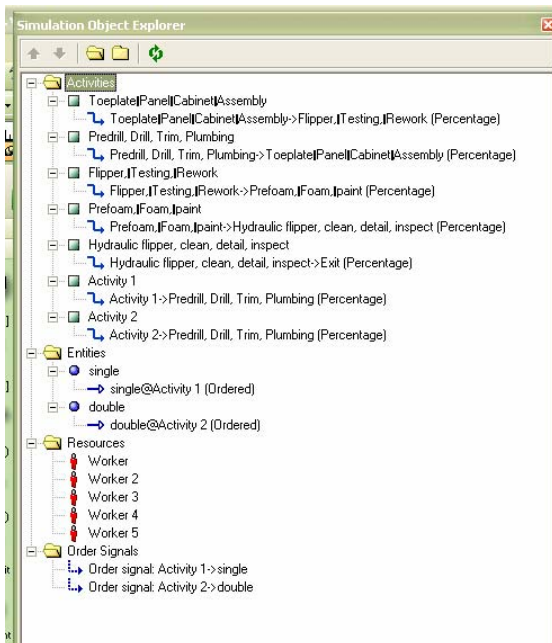


Screen capture of Student A's future state VSM of the BullFrog Spa case study.

APPENDIX C:



Copy of Student A's future state simulation VSM in a screen capture form.



Copy of Student A's Simulation Object Explorer which indicates the order of processes and what resources, entities, and orders the simulation performs the behavioral characteristics of the simulation in Process Simulator.

APPENDIX D:

Student B's simulation program logic is as follows:

```
*****
*
*           *
*       Formatted Listing of Model:           *
*       C:\Program Files\ProModel\Models\jake_olsen_simulation.MOD       *
*           *
*****
**
```

Time Units: Minutes
Distance Units: Feet

```
*****
**
*           *
*       Locations           *
*           *
*****
**
```

Name	Cap	Units	Stats	Rules	Cost
Loc1	INFINITE	1		Time Series Oldest, FIFO,	
Vacuum_Former	1	1		Time Series Oldest, ,	
Loc2	3	1		Time Series Oldest, ,	
Spray_Booth	1	1		Time Series Oldest, ,	
Predrill_Drill_Trim	1	1		Time Series Oldest, ,	
#					
#capacity is 6 for dps, 8 sps					
Plumbing	1	1		Time Series Oldest, ,	
#					
#capacity is 6 for dps, 8 sps					
Assembly	1	1		Time Series Oldest, ,	
Flipper	1	1		Time Series Oldest, ,	
Prefoam_Foam_Paint	1	1		Time Series Oldest, ,	
Hydraulic_Flipper_Clean_Detail	1	1		Time Series Oldest, ,	
Shipping	1	1		Time Series Oldest, ,	
Water_Testing	1	1		Time Series Oldest, ,	
#					
#2sps, 1dps					
Rework	1	1		Time Series Oldest, ,	
Toeplate	1	1		Time Series Oldest, ,	
Panel_and_Cabinet_Assemblies	1	1		Time Series Oldest, ,	
Loc3	INFINITE	1		Time Series Oldest, ,	

```

Loc4          INFINITE    1  Time Series Oldest, ,
Loc5          1            1  Time Series Oldest, ,
Loc6          1            1  Time Series Oldest, ,

```

```

*****
**
*           Clock downtimes for Locations           *
*****
**

```

Loc	Frequency	First Time	Priority	Scheduled	Disable	Logic
Vacuum_Former	N (33,1)	U (16.5,9.75)	99	No	No	WAIT 5
Loc2	N (33,1)	U (16.5,9.75)	99	No	No	WAIT 5
Spray_Booth	N (33,1)	U (16.5,9.75)	99	No	No	WAIT 5
Predrill_Drill_Trim	N (33,1)	U (16.5,9.75)	99	No	No	WAIT 5
Plumbing	N (33,1)	U (16.5,9.75)	99	No	No	WAIT 5
Assembly	N (33,1)	U (16.5,9.75)	99	No	No	WAIT 5
Flipper	N (33,1)	U (16.5,9.75)	99	No	No	WAIT 5
Prefoam_Foam_Paint	N (33,1)	U (16.5,9.75)	99	No	No	WAIT 5
Hydraulic_Flipper...	N (33,1)	U (16.5,9.75)	99	No	No	WAIT 5
Shipping	N (33,1)	U (16.5,9.75)	99	No	No	WAIT 5
Water_Testing	N (33,1)	U (16.5,9.75)	99	No	No	WAIT 5
Rework	N (33,1)	U (16.5,9.75)	99	No	No	WAIT 5
Toeplate	N (33,1)	U (16.5,9.75)	99	No	No	WAIT 5
Panel_and_Cabi...	N (33,1)	U (16.5,9.75)	99	No	No	WAIT 5

```

*****
**
*           Setup downtimes for Locations           *
*****
**

```

Loc	Entity	Prior Entity	Logic
Vacuum_Former	ALL	ALL	wait 5

```

*****
**
*           Entities           *
*****
**

```

Name	Speed (fpm)	Stats	Cost
------	-------------	-------	------

```

-----
Single_Pump_Spa 150    Time Series
Double_Pump_Spa 150    Time Series
Toe              150    Time Series
Wood             150    Time Series
Raw_Materials   150    Time Series

```

```

*****
**

```

```

*                Path Networks                *
*****
**

```

Name	Type	T/S	From	To	BI	Dist/Time	Speed Factor
Net1	Passing	Time	N1	N2	Uni 10		1
			N2	N1	Uni 5		1
NET2	Passing	Time	N1	N2	Uni 5		
			N2	N1	Uni 2		
NET3	Passing	Time	N1	N2	Uni 5		1
			N2	N1	Uni 2		1

```

*****
**

```

```

*                Interfaces                *
*****
**

```

Net	Node	Location
Net1	N1	Toeplate
	N2	Assembly
NET2	N1	Panel_and_Cabinet_Assemblies
	N2	Assembly
NET3	N1	Vacuum_Former
	N2	Loc2

```

*****
**

```

```

*                Resources                *
*****
**

```

Name	Units	Stats	Res Search	Ent Search Path	Motion	Cost
Forklift 1	1	By Unit	Closest	Oldest NET2	Empty: 150 fpm Home: N1 Full: 150 fpm (Return)	
Forklift2 1	1	By Unit	Closest	Oldest Net1	Empty: 150 fpm Home: N1 Full: 150 fpm (Return)	
Forklift3 1	1	By Unit	Closest	Oldest NET3	Empty: 150 fpm Home: N1 Full: 150 fpm (Return)	

 **
 * Processing *

 **

Entity Rule	Location Move Logic	Process Operation	Blk Output	Routing Destination
ALL	Loc1	1	Single_Pump_Spa	Vacuum_Former
IF spatype = 1, 1	sub1()		Double_Pump_Spa	Vacuum_Former IF
spatype = 2	sub1()			
ALL	Vacuum_Former	WAIT 22.5	1 ALL	Loc2
FIRST 1	MOVE WITH Forklift3	THEN FREE		
ALL	Loc2	1 ALL		Spray_Booth
FIRST 1				
ALL	Spray_Booth	WAIT 9.95	1 ALL	Predrill_Drill_Trim
FIRST 1				
ALL	Predrill_Drill_Trim	WAIT 11.66	1 ALL	Plumbing
FIRST 1				
ALL	Single_Pump_Spa	Plumbing	WAIT 17.84	
ALL	Double_Pump_Spa	Plumbing	WAIT 23.12	
ALL	Plumbing		1 ALL	Assembly
FIRST 1				
ALL	Assembly	JOIN 1	Toe	


```

JOIN 1 Wood
IF ENTITY() =Double_Pump_Spa THEN
{
WAIT 4.9
}
ELSE
{
WAIT 3.675
}

1 ALL Flipper 0.100000 1
ALL Prefoam_Foam_Paint
0.900000
ALL Flipper WAIT 5
INC PASS 1 ALL Prefoam_Foam_Paint
IF PASS = 2, 1
ALL Prefoam_Foam_Paint WAIT 24 1 ALL Loc6 IF PASS = 1
Hydraulic_Flipper_Clean_Detail FIRST 1
ALL Hydraulic_Flipper_Clean_Detail WAIT 12.6 1 ALL Shipping
FIRST 1
ALL Shipping 1 ALL EXIT FIRST
1
ALL Water_Testing WAIT 75.1 1 ALL Rework
0.100000 1
ALL Loc3 ALL Loc5 0.900000
1 Wood
Panel_and_Cabinet_Assemblies EMPTY 1
Toe Toeplate EMPTY
ALL Toeplate WAIT 17 1 ALL Assembly
JOIN 1 MOVE WITH Forklift2 THEN FREE
ALL Panel_and_Cabinet_Assemblies WAIT 23.35 1 ALL Assembly
JOIN 1 MOVE WITH Forklift THEN FREE

ALL Rework IF ENTITY() = Double_Pump_Spa THEN
{
WAIT 40
}
ELSE
{
WAIT 20
}

1 ALL Water_Testing,1 FIRST 1
ALL Loc6 1 ALL Water_Testing
FIRST 1

```

ALL Loc5 1 ALL Flipper FIRST 1

**
* Arrivals *

**

Entity Location Qty Each First Time Occurrences Frequency Logic

Raw_Materials Loc1 200 0 1 1
Raw_Materials Loc3 400 0 1 1

**
* Attributes *

**

ID Type Classification

PASS Integer Entity

**
* Variables (global) *

**

ID Type Initial value Stats

mix Integer 1 Time Series
spatype Integer 1 Time Series

**
* Subroutines *

**

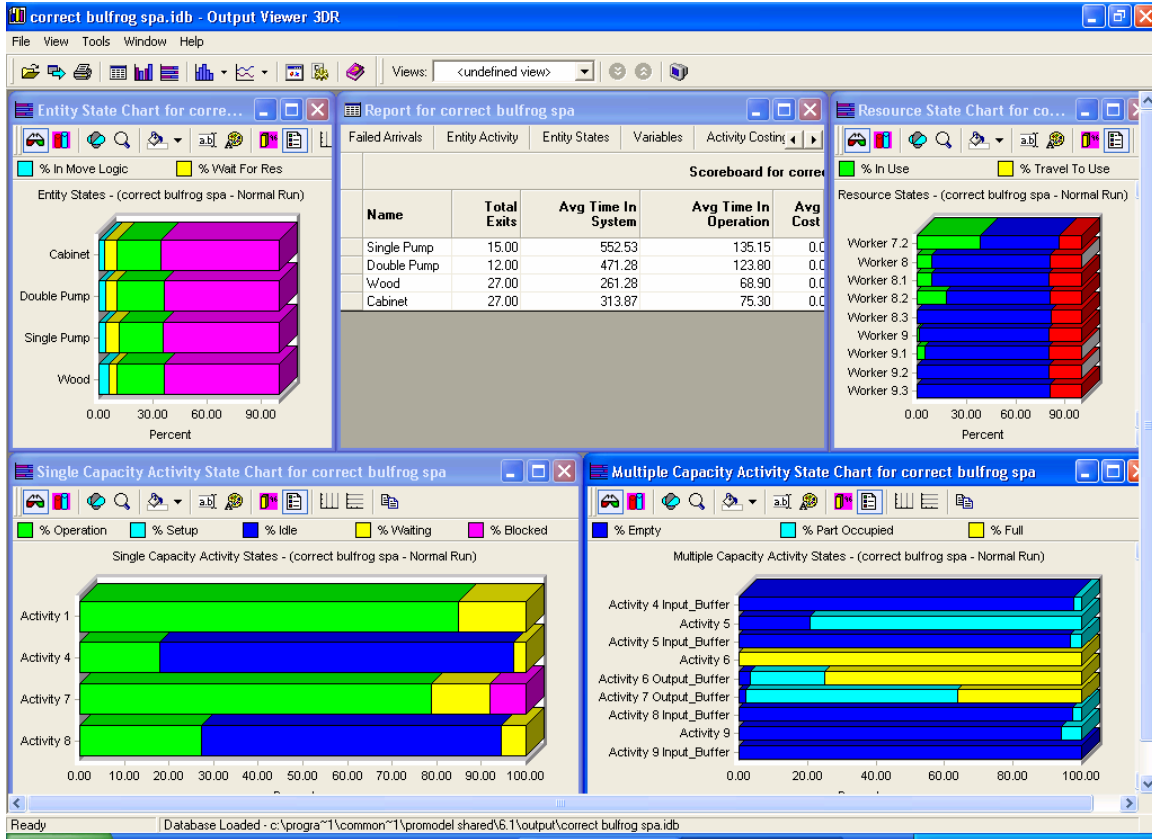
ID Type Parameter Type Logic

sub1 None

```
INC mix
IF mix = 41 THEN
{
mix = 1
}
IF mix < 25 THEN
{
spatype = 1
}
ELSE
{
spatype = 2
}
```

APPENDIX E:

The following is the screen capture for the results obtained from Student C's simulation using Process Simulator:



APPENDIX F:

Copy of VSM icons paraphrased MacInnes, 2002.

NAME	SYMBOL	DESCRIPTION
Push movement of production materials		Shows the movement of raw materials or components that are "pushed" by the production process rather than being requested by the customer
Pull movement of production materials		Shows the movement of raw materials or components that are requested by the customer (i.e. they are not pushed).
FIFO		Indicates that products need to be pulled and delivered on a first-in, first-out (FIFO) basis: the oldest remaining items in a batch are the first to move forward in the production process
Truck Shipment		Shows the movement of materials by truck. Be sure to show the frequency of shipments on your map.
Inventory		Indicates the inventory count and time.
Storage (Supermarket)		Shows all products contained in a storage area. You can note the minimum and maximum levels within each bin or row location.
Manual Information Flow		Shows information that is transferred by hand.
Electronic Information Flow		Shows information that is transferred via computer.
Information Type		Indicates the type of information being communicated.
Production Kanban		A card used to initiate the production of a certain item. (used for Kanban systems only)
Withdrawal Kanban		A card used to obtain an item from a storage area. (used for Kanban systems only)
Signal Kanban		A card used to initiate a batch operation. (used for Kanban systems only)
Kanban Card Post		This indicates the use of physical mailbox location for kanbans. It is used for kanban systems only.
Load Leveling Box		Used for kanban systems to indicate load leveling.
Department or Manufacturing Process		The top of the icon shows the name of the department of the process being mapped. The bottom of the icon shows resources, information, or a relevant lean-enterprise technique.
Outside Sources		These include customers and suppliers.
Data Box		This is a place for key data such as machine availability; number of product variations; product changeover times; whether or not parts are run daily, weekly, or monthly; cycle time; process capacity; equipment efficiency; whether or not it is a constraining operation.
People		Shows the number of employees required to perform an operation.