Cycle time improvement within the pipe manufacturing process at Rocla (Pty) Ltd

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Submitted in partial fulfillment of the requirements for

the degree of

BACHELORS IN INDUSTRIAL ENGINEERING

in the

FACULTY OF ENGINEERING, BUILT ENVIRONMENT

& INFORMATION TECHNOLOGY

UNIVERSITY OF PRETORIA

PRETORIA

OCTOBER 2009

Executive Summary

Rocla (Pty) Ltd is a manufacturer of precast concrete products situated in Roodepoort, Johannesburg. This document highlights the current problems associated with the manufacturing of pipes resulting in excessive cycle times.

In the arrival of a proposed solution, literature was gathered and analysed in order to develop a successful methodology. The methodology employed in solving this problem highlights the use of value stream mapping enhanced by simulation.

The proposed solution entails the introduction of a continuous steam chamber, which will alleviate the congestion within the current process, in an attempt of decreasing the cycle time.

Opsomming

Rocla (Pty) Ltd vervaardig sementprodukte en is geleë in Roodepoort, Johannesburg. Hierdie dokument beklemtoon die probleme wat huidiglik ervaar word deur Rocla, wat gepaard gaan met onvoldoende prosestye by die vervaardiging van pype.

Nadat literatuur bestudeer is, het ‘n voorgestelde metodologie na vore gekom. Die voorgestelde metodologie vir die oplossing van die probleem, beklemtoon die gebruik van waarde-stroomkaarte wat verryk word deur simulasie.

Die voorgestelde oplossing fokus op die bekendstelling van ‘n kontinue stoomkamer in die plek van die gewone stoomkamer. Die kontinue stoomkamer sal opondhoud in die produksielyn uitskakel, wat sal lei tot korter prosestye.

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CHAPTER 1

INTRODUCTION

The use of value streaming has become an important part in organizational design, facilitating in overall production improvement. Simulation as a decision making tool is used extensively, in establishing the optimal positioning of elements within manufacturing systems.

1.1 Company background

Rocla (Pty) Ltd is a manufacturer of precast concrete products, which include pipes, culverts, manholes, poles and other related custom-designed products. Rocla has companies throughout South Africa, as well as in Namibia and Botswana. The project will be completed at the Roodepoort plant.

Figure 1: Plant layout

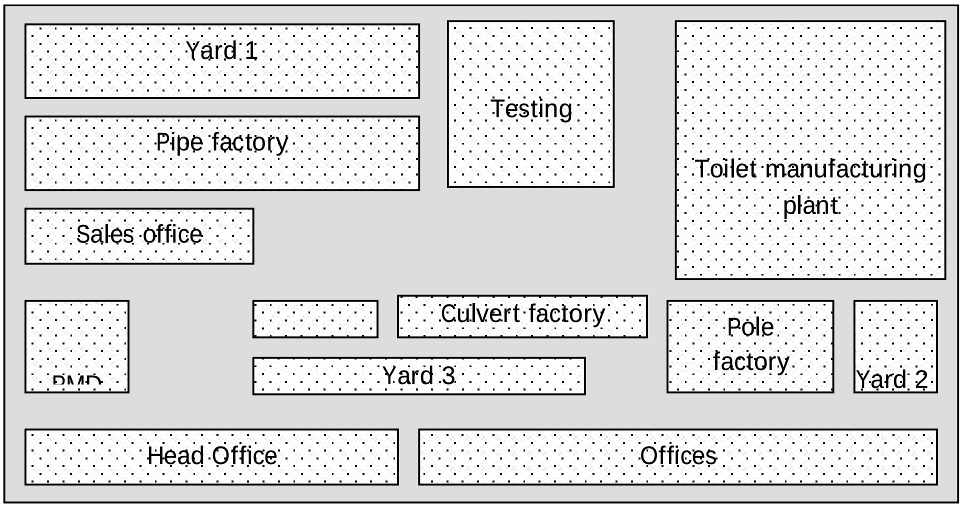


Figure 1 is a representation of the Roodepoort plant. Manufacturing happens in the following three factories:

- Pipe factory
- Culvert factory
- Pole factory

The yards are used for storage of finished products as well as scrap products, where it is allocated as follow:

- Yard 1 – Pipes
- Yard 3 – Culverts
- Yard 2 – Poles

A wide variety of pipes are manufactured at the Roodepoort plant. Including

- In-the-Wall Joint Pipe
- Interlocking Joint Pipe
- Rubber Ring Joint Pipe
- Rubber Ring Joint Pressure Pipe
- Rubber Ring Joint Pipe with Sacrificial Layer

Clearwater Mall, Big Bay (Blouberg), Upgrading of Kenyetta Drive (Malawi) and Palm Ridge Development (Germiston), are only a few of the completed contracts which Rocla has participated in.

1.2 Problem Definition

The current problem; experienced by Rocla (Pty) Ltd is associated with the manufacturing of pipes which result in long cycle times.

1.3 Project aim

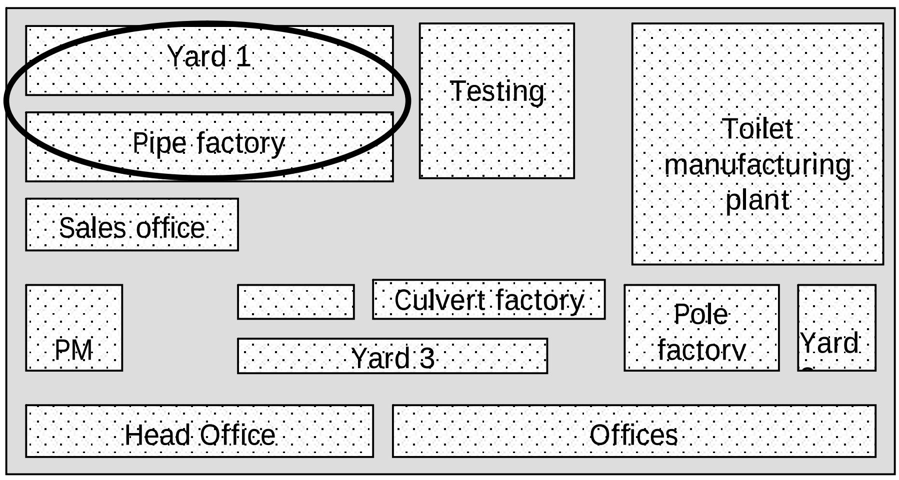
Reduce the cycle time of the pipe manufacturing process.

1.4 Project scope

The main focus will be on the circled areas in Figure 2. These include the

- Pipe factory, where the pipes are manufactured
- Yard 1, where the pipes undergo the curing process

Figure 2: Plant layout: Area of focus



The aim entails reducing the cycle time within the pipe manufacturing process. This narrows the investigation down to the pipe factory and the yard. An in-depth study regarding the current cycle time (lead time) of the process needs to be completed. For this to be achieved, time studies and analysis should be done on the following sub processes:

- Grid welding
- Inserting grid into mould
- Casting of pipes
- Steaming of pipes
- Stripping of the mould
- Stenciling and finishing off
- Curing of the finished pipe
- Testing

Once the investigation of the sub processes are completed, performance measures can be quantified and suggestions for change in the process can be given. One will see that there are definite opportunities for process improvements that will have a positive impact on flow time.

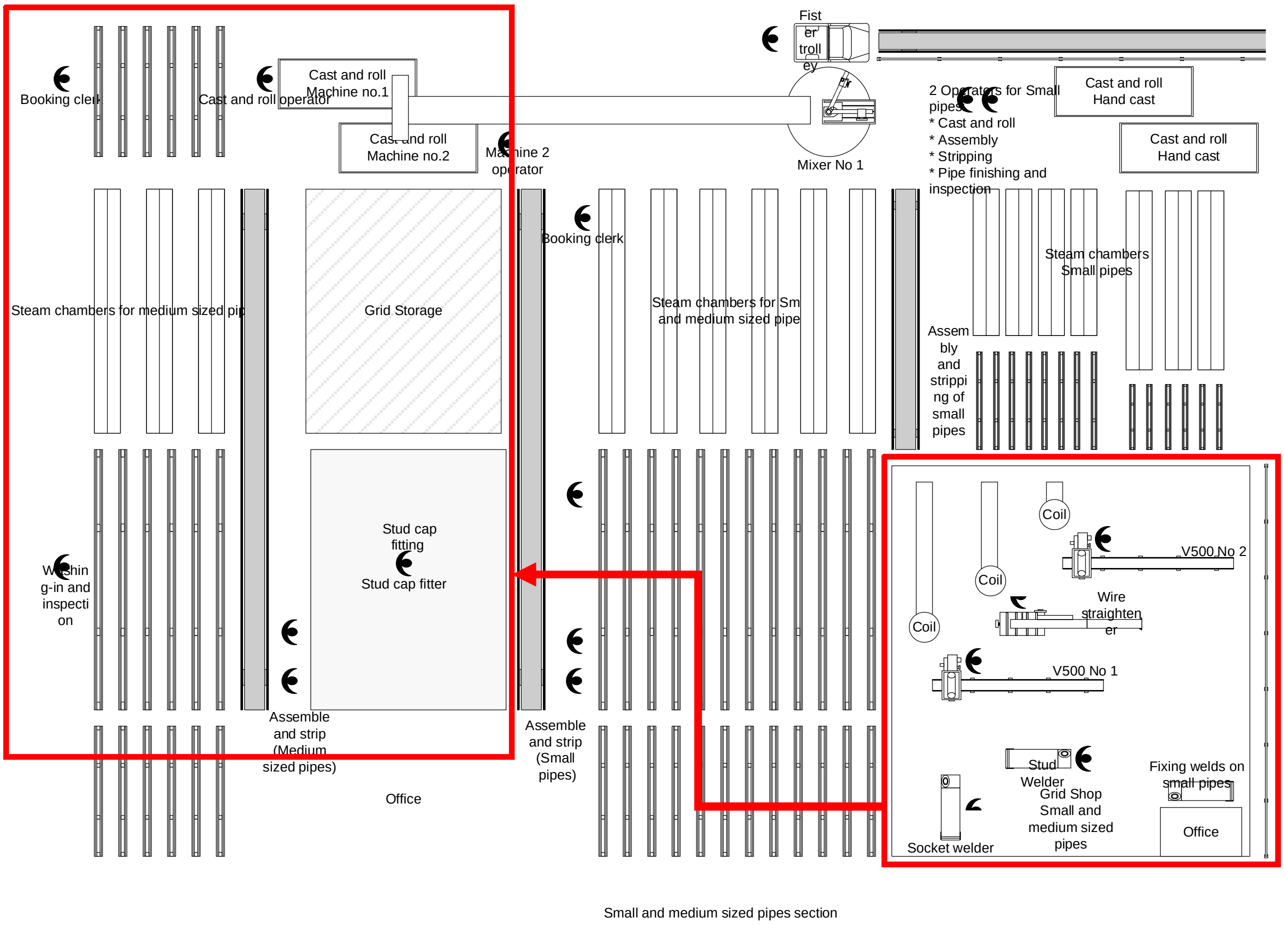
For the purpose of this project, the pipes will be grouped according to three types: small, medium and large, as shown in Table 1.

Table 1: Product ranking

Small Pipes	Medium pipes	Large pipes
150 IJ 100D	450 IJ 50D	750 IJ 50D
225 IJ 100D	450 IJ 75D	750 IJ 75D
300 IJ 50D	450 IJ 100D	750 IJ 100D
300 IJ 75D	525 IJ 50D	900 RJ 50D (Dol)
300IJ 100D	525 IJ 75D	825 IJ 50D
375 RJ 50D	525 IJ 100D	825 IJ 75D
375 RJ 75D	600 IJ 50D	825IJ 100D
375 IJ 100D	600 IJ 75D	900 IJ 75D
	600 IJ 100D	900 IJ 100D
	600 IJ 100D (PFR)	1050 IJ 50D
	675 IJ 50D	1050 IJ 75D
	675 IJ 75D	1050 IJ 100D
	675 IJ 100D	1200 IJ 25D
		1200 IJ 50D
		1200 IJ 75D
		1200IJ 100D
		1350 IJ 75D
		1350 IJ 100D
		1500 IJ 100D
		1650 IJ 100D

A product from the medium pipes section will be studied. On the factory layout, provided in Figure 3, the areas allocated for the manufacturing of the medium sized pipes are shown.

Figure 3: Factory layout



The basic flow of the pipe manufacturing process can be seen in Figure 3. The marked areas on the figure serve as a more detailed scope for the area of manufacturing, which will be investigated.

1.5 Structure of the document

Analysis of the literature is presented in chapter 2. This is followed by a proposed methodology that can be implemented, as discussed in chapter 3. The current state of the Rocla process is illustrated in chapter 4, followed by the "to-be" state in chapter 5. Chapter 6 presents the final results and chapter 7 will focus on the conclusion to the document.

CHAPTER 2

LITERATURE REVIEW

The main focus of this project is reducing the cycle time of the pipe manufacturing process. The lead time of the pipe manufacturing process is too long; leading to a longer reaction time. A possible cause for this can be the lack in process flow.

Value stream mapping is a proposed solution to the problem mentioned above. McManus and Millard (2002:1) refer to value stream mapping as a technique by which lean methods are applied. Because of the significant role lean concepts play in value stream analysis and mapping, a review of lean manufacturing will be used to commence this literature review.

2.1 Lean Manufacturing

According to Womack et al. (1990:1), the birth of the “lean” manufacturing concept occurred after the completion of World War II when Japanese manufacturers were confronted by extensive shortages of financial, material and human resources. This resulted in the development of the Toyota Production System (TPS), the most well known example of lean manufacturing (Burton et al., 2003:8). The focus of this system is the elimination of waste, making use of tools such as production smoothing, Just-In-Time (JIT) and setup time reduction to minimize waste.

Lean is based on the logic that production will only occur as soon as the specific product is needed (Chase et al., 2007:471). Womack et al (1990) identified five principles for creating a lean production system:

1. Specify value.
2. Identify value stream.
3. Make value flow uninterruptedly.
4. Let the customer pull value.
5. Aim for perfection.

These tools are aimed at waste reduction. Clark and Fujimoto indicate that there are six factors accountable for the lean process:

1. Project leadership.
2. Team work.
3. Simultaneous engineering.
4. Good communication.
5. Delegation of responsibility.
6. Customer orientation (Voss, 1992:200).

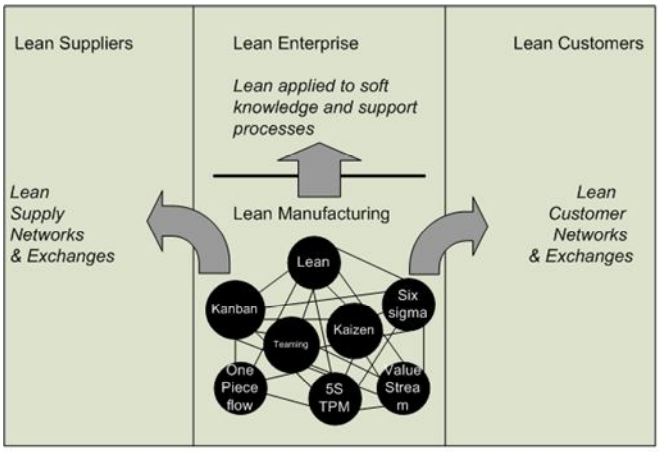
The basic principles required to be lean can differ. However, the fundamental ideas of waste elimination and respect for workers are universal for most manufacturing companies (Karlsson, 1999).

According to Womack et al. (1990), some benefits of lean manufacturing include: improved productivity, reduced work in progress and inventories, and lead times that drop from months to weeks.

2.2 Value Stream Mapping

Figure 4 (Burton, 2003:9) clearly shows the value stream concept to be part of the lean manufacturing methods.

Figure 4: The Lean Extended Enterprise (Burton, 2003:9)



If the original definitions and concepts given by Monden (1993) and Womack et al. (1990) are expanded, one sees that it is essential to map inter-company as well as intra-company value adding streams. Those specifics in a firm that add value to the product are referred to as the value stream. This is a much more focused view of the value adding process (Seth et al., 2005:44).

Value stream mapping was developed by Toyota in the 1950's. It has gained a lot of attention since then and is one of the key foundation principles for creating the lean enterprise (Burton et al., 2003:109). According to Chase et al. (2007:473) value stream mapping is becoming extensively used as a method for waste elimination. The value stream is a system of steps from start to end that delivers the result for the customer. Seth et al. (2005:47) further states that value stream mapping differs from other typical approaches as it aids in the visualization of inventory buffers, cycle times, manpower consumption, information flow and utilization of resources. The entire transformation from raw materials to the finished product is captured by the visual presentation. All the non-value added activities, as well as value added activities are mapped. According to Yasuhiro Monden (1993) there are three types of operations, (1) Non-Value Adding (NVA), (2) Necessary but non-value adding (NNVA), and (3) Value-adding (VA).

Non-value adding refers to pure waste and involves actions which are unnecessary and should be eliminated completely. Examples are: double handling, waiting time and stacking products. Necessary but non-value added actions are uneconomical, but may be useful under some operating conditions. Examples: Unpacking deliveries, walking long distances and transferring tools. Value-Adding operations involve the processing of raw materials. Examples: painting body work and sub-assembly of parts (Hines et al., 2000:14).

A value stream map has two parts according to Burton (2003:109), the first component being the flow of materials through processes to produce the finished goods. The second component centers on the information flow supporting the above processes.

Rother and Shook (1999) formulated several steps that can be useful in constructing the value stream:

1. Establish a target, a specific product or product family.
2. Draw current state map.
3. Create a future state map.
4. Finally, carry out implementations.

The current state map can be constructed by walking along the process line and capturing how things are currently done. The basis for analysis is provided by the current state map. The future state map is constructed by making use of lean tools to ensure optimal efficiency.

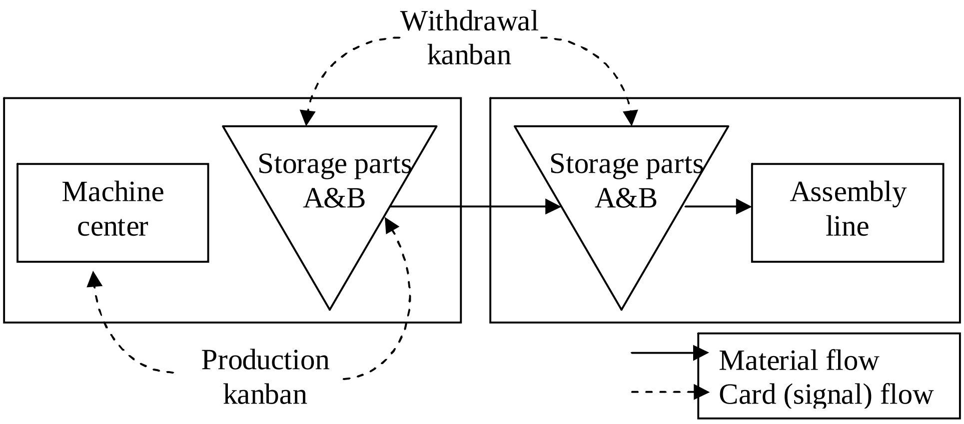
Some benefits of creating a value stream map according to Burton (2003:110) are; the graphic visualization of the current value stream, it shows connections between material and information flow, identifies waste, a common process language exist, it forms the basis of an implementation plan as well as identifies non-value added actions, lead time, amount of inventory and distances traveled in a process. Rother and Shook (1999) referred to some drawbacks in value stream mapping. Including the fact that a high level of complication cannot be addressed in the value stream, and that sometimes the value stream map is not used and ends up as a nice poster. These drawbacks are surpassed by the benefits and can be avoided.

2.3 The concept of kanban

The implementation of lean concepts in the value stream is extremely important. One of the main techniques that should be looked at when formulating the future state map is the concept of kanban. According to Hines et al. (2000:170), the term kanban means ‘signpost’ or ‘card’.

There are three types of kanban; two for the production system and one for the logistics associated with the movement of materials. The flow of two kanbans is shown in Figure 5 (Chase et al., 2007:476). One can only start producing or supplying additional parts when the authority comes from the downstream operations. The process works as follows: each container has a withdrawal as well as a production kanban (two-card kanban system). As soon as the production is at a maximum the production kanban is replaced with a withdrawal kanban. Cards serve as a signal to the workers of what should be done (Chase et al., 2007:476).

Figure 5: The Flow of Two Kanbans (Chase et al., 2007:476)



2.4 Simulation modelling

Kelton et al. elaborated on the history of simulation; in the 1950s and 1960s, simulation was a tool that was used only by large corporations; it was a very expensive tool. The value of simulation was being discovered, although it was only used in the case of a major disaster. The utilization of simulation, as we know it today, began during the 1970s and 1980s. Simulation became a tool of choice. Simulation began to establish its genuine roots in business during the late 1980s. This was mainly due to the introduction of the personal computer. Up until then simulation was only used for failed systems, but people started requesting simulations before production was to begin, however simulation was still uncommon in small firms.

During the 1990s simulation matured and became widely used among smaller firms. The use of simulation also started to occur at an earlier stage in the development of a process, which turned out to be beneficial. One cannot easily predict the future of simulation. The rate at which simulation has changed in recent years has accelerated and anything from automatic statistical analysis and even virtual reality will be possible in the future (Kelton et al., 1993:13). Since World War II, simulation has become a tool that is indispensable in many system-related activities (Altiok et al., 2001:2).

Altiok also states that simulation modelling has been applied to approximate performance measures, and has more recently been used to train workers. Simulation modelling is defined by Altiok et al. (2001:2) as a common prototype for analyzing complex systems. This prototype creates a simple representation for the process under investigation. A definition given by Kelton et al. (1999:3) is that simulation is used to mimic the behavior of real systems, on a computer with software that is appropriate. The reason why simulation modelling is the preferred choice for modelling is the fact that it can model complex systems.

Simulation analysis can also be done, after the model is set up. One can then proceed to experiment with it. Experimentation ranges from generating system histories and observation of system over time, up until statistics (Kelton et al., 1999:3).

Donald Craig (1996) weighed up some of the advantages and disadvantages of simulation. One of the main advantages is that simulation provides practical feedback to the user when constructing systems. One can now determine the feasibility of a design beforehand. Secondly, a problem can be studied at different levels.

A designer is now able to understand the high level, as well as the low level components of a system. Another benefit of simulation is that it can be used as an educational tool to demonstrate certain concepts. The popularity of simulation according to Kelton is overwhelming. Simulation was ranked as one of the best operations research tools in surveys performed by: Rasmussen and George (1978), Thomas and DaCosta (1979), Shannon, Long and Buckles (1980), Forgionne (1983), Harpell, Lane and Mansour (1989) and Morgan (1989). The main reason for this exceptional statistic is the fact that simulation can deal with very complex problems. This makes it a very flexible and influential tool. Despite the advantages of simulation, its not quite paradise either. One of the major drawbacks of simulation according to Kelton et al. (1999:8) is the unpredictability of the output. When entering random input, random output will be obtained from the model. Although nothing in the system has been changed, the output will continue to change. This can be dealt with, by making over-simplifying assumptions. This will however not reflect the correct model. According to Donald Craig (1996) the main disadvantage of simulation is the duration of a simulation run. Due to the computational complexity of certain problems, answers may not be readily available. Once again, like in value stream mapping, the advantages overshadow the disadvantages.

2.5 Work measurement

Work measurement is of utmost importance in the process of becoming lean. When looking at the current state map of the value stream, certain techniques will be required to make the process more efficient. According to Chase et al. (2007:181) work measurement methods are used to establish the most efficient way of completing a specific task, as well as to set sensible standards for completing it. The operations manager uses job design to structure the work.

The main approach to the study of work methods is the construction of charts. These charts include: operations chart, worker-machine charts, activity charts as well as time study data. One can choose the type of chart one needs to construct according to the following guidelines: identify if the focus is on a production process, worker at a fixed workplace, a worker interacting with equipment, or a worker interacting with other workers. See Table 2 for the techniques one can use according to the certain activity (Chase et al., 2007:186).

Chase et al. (2007:186) refers to four basic techniques when it comes to work measurement. Two of these methods are direct and the other two are indirect. The direct methods are: time study and work sampling. The two indirect methods are predetermined motion-time data systems (PMTS) and elemental data. Time study is when one uses a stopwatch to time the work. Work sampling is when data is gathered from random observations of a person at work. PMTS is to sum data from tables of generic movements, where elemental data sums similar times from a database. The level of detail required influences the choice of techniques.

When looking at time study compared to work sampling, Chase et al. (2007:199) refers to several advantages of work sampling. Several studies can be conducted simultaneously by the same observer, no timing equipment is required and the study may be delayed resulting in an effect that’s only temporary.

Table 2: Work Methods Design Aids (Chase et al., 2007:186)

ACTIVITY	OBJECTIVE OF STUDY	STUDY TECHNIQUES
Production process	Eliminate or combine steps; shorten transport distance; identifying delays	Flow diagram, service blueprint, process chart
Worker at fixed workplace	Simplify method; minimize motions	Operations charts, simo charts; apply principles of motion economy
Worker's interaction with equipment	Minimize idle time; find number or combination of machines to balance cost of worker and machine idle time	Activity chart, worker-machine charts
Worker's interaction with other workers	Maximize productivity; minimize interference	Activity charts, gang process charts

Time study is more appropriate than work sampling when the cycle time is short. Time study provides a more detailed breakdown of the tasks. Work sampling may give misleading results if the system is in the process of change.

Charts required for analysis

According to Table 2 of Chase et al. (2007:186), the following charts are required for the analysis of the current system:

a. Flow chart

Because of the impact that different activities have on one another, it is important to consider the simultaneous performance of a number of activities, operating at the same time. A diagram showing the basic elements of a process is a good way to start analyzing a process (Chase et al (2007:157)). A flow chart is exactly this; it shows the whole process with times of activities.

b. Worker-machine charts

According to Chase et al (2007:188), one must focus on the efficient use of the operator time and equipment time if the operator and equipment work together to perform a process. A worker machine chart is useful when the operator's working time is less than the equipment run time. This chart aids in finding the most economical combination of operator and equipment.

c. Activity chart

An activity chart is according to Chase et al. (2007:189) less limiting and may be used to monitor the interaction of a group of operators, whether equipment is present or not. These charts are particularly helpful when standardizing a procedure for a certain task.

d. Pareto chart

Also defined by Chase et al. (2007:327), a pareto chart helps with the breakdown of a problem into components relative to their contribution. It is based on the empirical result that 80% of all problems are due to 20% of all causes.

2.6 Simulation aided value stream mapping

Manager commitment is often difficult to gain when implementing lean methods; this is because they have long relied on traditional manufacturing approaches. According to Abdulmalek et al. (2006:6) management decisions on implementing lean manufacturing mostly depend on their belief in it. Merely revealing to them the benefits of lean manufacturing is insufficient. The magnitude of the benefits that one can gain from implementing lean methods is hard to predict and needs to be visualised. In some cases, the use of the future state map is sufficient, but in most of the cases, its not. One of the shortcomings of a static model is the fact that one cannot observe the variation in inventory levels (McDonald et al., 2002). In addition to the value stream, a tool is required to measure the gains at an earlier stage in the development.

McDonald et al. (2002:226) states that value stream mapping can be enhanced by simulation. He also says that the utilisation of simulation does not appear to be used in value stream mapping. This could be due to the fact that simulation is thought of as a lengthy and time-consuming process. Simulation is not needed in some cases where the production line can be rearranged quickly. However, by using simulation, results can be improved in a short time frame (Chan, 1995). Some questions can be complex and won’t be answered by value stream mapping alone, i.e. determining the work in process time.

The following method for simulation aided value stream mapping is proposed by Lian and van Landeghem (2007):

1. Construct a current and future state map of one product according to the standard method.
2. Build a simulation model based on the current and future state maps.
3. Investigate different conditions and parameters.

Simulation forms an integral part of the value stream mapping tool set (McDonald et al., 2002:231). It is thus beneficial to simulate the current state as well as the future state map, in order for accurate conclusions and improvements to be made for the process.

Available software includes:

- Process Simulator 2007 Lite, this enabling one to simulate flow charts and workflow diagrams and
- Arena's Professional Edition offers tools to create a value stream.

Arena is the preferred choice, as one can create modules according to the needs of the model.

2.7 Conclusion

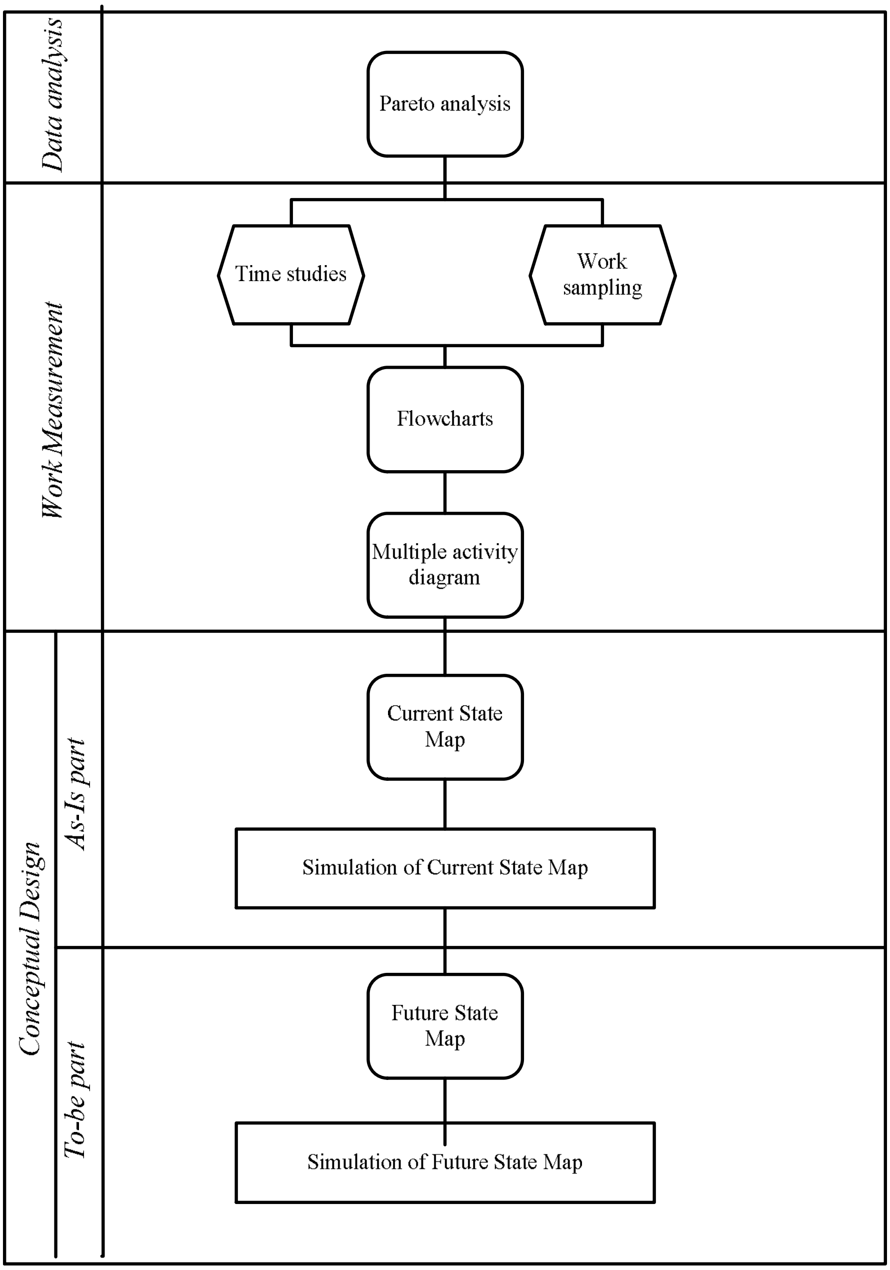
From the literature that has been reviewed it is evident that the problem can be solved by applying value stream mapping, enhanced by simulation in establishing lean manufacturing principles.

CHAPTER 3

SELECTION OF APPROPRIATE METHODS, TOOLS AND TECHNIQUES

Different methods, tools and techniques have been discussed within chapter two, where a combination of these tools and techniques will be utilised to solve the problem identified within Rocla (Pty) Ltd. The methodology displayed in Figure 6 is used to develop the additional tools and design.

Figure 6: Methodology



3.1 Methodology

3.1.1 Data analysis

Prior to any process analysis, production data was gathered. From this data, a pareto analysis was constructed in which a scope of the products investigated is provided, within the 80/20 principle.

3.1.2 Work measurement

As soon as the scope of products has been defined, the process was investigated. The processes have been analysed by means of time studies and work sampling. The information gathered from these two methods has been presented in diagrams, such as flow charts and multiple activity diagrams.

3.1.3 Design and problem solving

The first step in creating the solution to the problem is the construction of a current state map. Data was gathered from the final process up until the initial process. Information required for the construction of a current state map, was: (1) cycle times, (2) inventory levels, and (3) manning of process. A line drawn at the bottom of the value stream indicates the "inventory time" and manufacturing processing time. The observed lead time was calculated.

As soon as the current state map is constructed, it can be simulated using Arena® software. Different improvements and proposed changes to the system can be tested.

The last step is concerned with the construction and simulation of the future state map. There are eight questions that must be answered according to Rother and Shook (1999); these questions are displayed in Table 3.

The questions deal with different aspects of the system, as indicated in the table. The simulated map is the design of the proposed improved system. Simulating the model can be used to reduce uncertainty and to investigate alternative future states, by making use of eight design questions' responses.

Table 3: Design questions for Future State (Rother & Shook, 1999)

Future-State questions		
Basic	1.	What is the *takt* time?
	2.	Will production produce to a finished goods supermarket or directly to shipping?
	3.	Where can continuous flow processing be utilized?
	4.	Is there a need for a supermarket pull system within the value stream?
	5.	What single point in the production chain will be used to schedule production?
Heijunka	6.	How will the production mix be levelled at the pacemaker process?
	7.	What increment of work will be consistently released from the pacemaker process?
Kaizen	8.	What process improvements will be necessary?

3.2 Data and information gathering

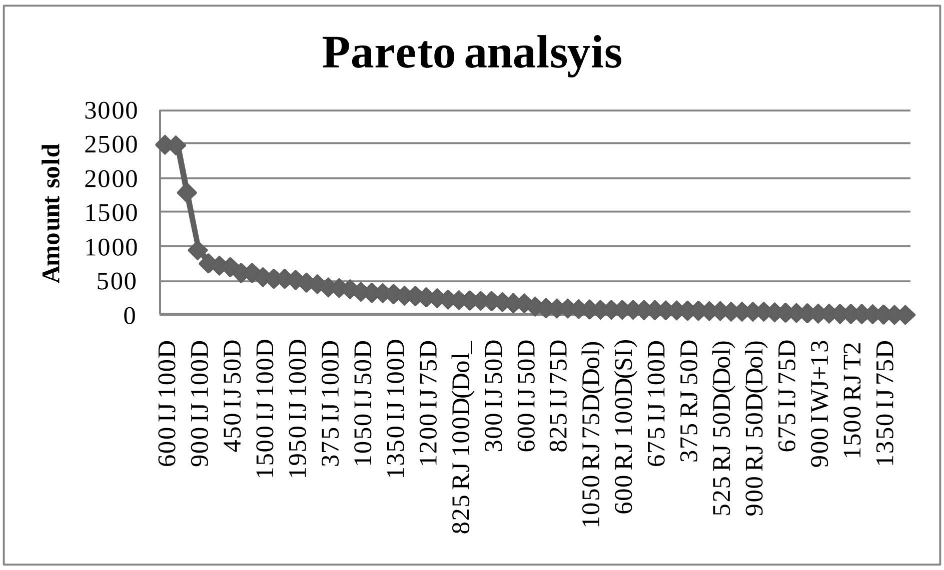
3.2.1 Data analysis

Before one can start with the development of methods and the design of a proposed solution, a pareto analysis on the products manufactured is required. Various aspects can be analyzed in relation to each other by making use of Pareto analysis. The objective is to answer the following question, "what 20% of products make up 80% of production?"

Rocla (Pty) Ltd. has three product families: (1) Small pipes, (2) Medium pipes and (3) Large pipes. Each product family contains a number of products.

The data which was used for the analysis is the manufactured pipes from July 2008 to March 2009. Firstly, the data was composed in a table, (Appendix A). It was then arranged in descending order according to the amounts manufactured (Appendix B). The chart in Figure 7 is constructed and shows the products that are impacted the most by production. The product to be tracked through its value stream is the 600IJ 100D pipe.

Figure 7: Pareto analysis



3.2.2 Work measurement

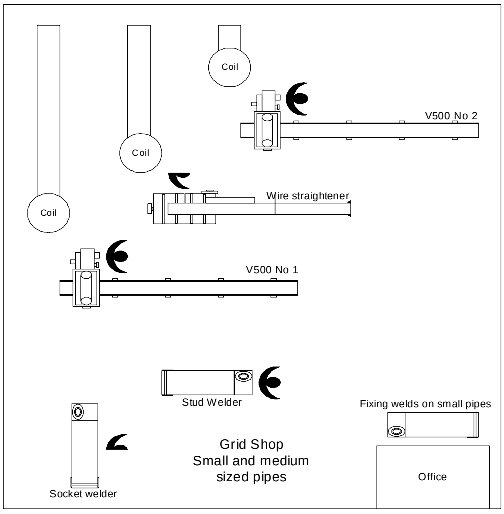
The processes have been divided into three categories, as displayed in Table 4.

Table 4: Process categories

Category	Process
Cage preparation	Wire straightening, Cage welding, and Stud Welding
Mould strip and assemble	Assemble mould, Strip and clean mould, Pipe finishing and inspection, and Stud cap fitting
Cast concrete and cure	Concrete mixing, Cast and roll, and Pre-cure and cure

After thorough analysis of the process, flow process charts were drawn up for the different processes (Appendix C and D). These charts were then used to construct multiple activity charts (Figure 8-10). Appendix C consists of the flow process charts of the three categories referred to in table 4, for the small sized pipes. The medium sized pipes' flow process charts of the three categories are shown in Appendix D.

Figure 8: Multiple activity chart for cage preparation



Capacity of 4 operators at the grid shop. Currently, only 3 operators, V500 No2 not in use.
1 Operator - Wire straightening and socket welding.
2 Operators - cage welding.
1 Operator - stud welding.

<table>
<tr><th>0</th><th>OPERATOR 1 - Wire straightening</th><th>OPERATOR 1 - Socket welding</th><th>OPERATOR 2- Cage welding</th><th>OPERATOR 3 - Stud welding</th></tr>
<tr><td>2</td><td rowspan="10">Setting up wire straightener. (Lifting coil onto jenny and adjusting machine)</td><td rowspan="10"></td><td rowspan="21">Set up machine</td><td rowspan="23"></td></tr>
<tr><td>4</td></tr>
<tr><td>6</td></tr>
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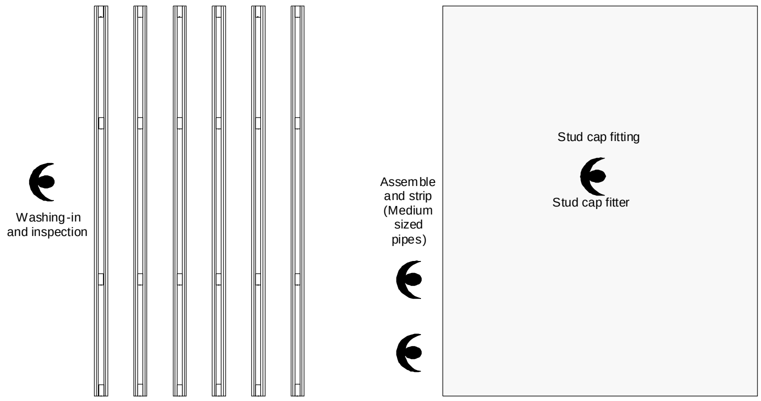
<tr><td>16</td></tr>
<tr><td>18</td></tr>
<tr><td>20</td></tr>
<tr><td>22</td><td rowspan="20">Cutting of wire pieces. The average weight for a large coil of wire is 1109kg while the weight for 1 piece of wire is 550g. The average total of wires cut per coil is thus, 2016 wires. Each wire takes 0.09min. Total time to cut a coil(left unattended) = 181.44 min.</td><td rowspan="5">Weld socket onto cage</td></tr>
<tr><td>24</td></tr>
<tr><td>26</td></tr>
<tr><td>28</td></tr>
<tr><td>30</td></tr>
<tr><td>32</td><td rowspan="5">Weld socket onto cage</td></tr>
<tr><td>34</td></tr>
<tr><td>36</td></tr>
<tr><td>38</td></tr>
<tr><td>40</td></tr>
<tr><td>42</td><td rowspan="5">Weld socket onto cage</td></tr>
<tr><td>44</td><td rowspan="2">Weld grid</td></tr>
<tr><td>46</td></tr>
<tr><td>48</td><td>Cut off grid and roll away</td><td>Weld studs onto grid</td></tr>
<tr><td>50</td><td rowspan="2">Weld grid</td><td>Weld studs onto grid</td></tr>
<tr><td>52</td><td rowspan="5">Weld socket onto cage</td><td>Weld studs onto grid</td></tr>
<tr><td>54</td><td>Cut off grid and roll away</td><td>Weld studs onto grid</td></tr>
<tr><td>56</td><td rowspan="2">Weld grid</td><td>Weld studs onto grid</td></tr>
<tr><td>58</td><td>Weld studs onto grid</td></tr>
<tr><td>60</td><td>Cut off grid and roll away</td><td>Weld studs onto grid</td></tr>
<tr><td></td><td rowspan="3">Repeat cycle</td><td rowspan="3">Repeat cycle</td><td rowspan="3">Repeat cycle</td><td rowspan="3">Repeat cycle</td></tr>
<tr><td></td></tr>
<tr><td></td></tr>
</table>

Figure 8 shows the multiple activity chart for the first category referred to in Table 4, cage preparation. The socket, cage and stud welding happen simultaneously with the wire straightening process.

Figure 9: Multiple activity chart for strip and assemble



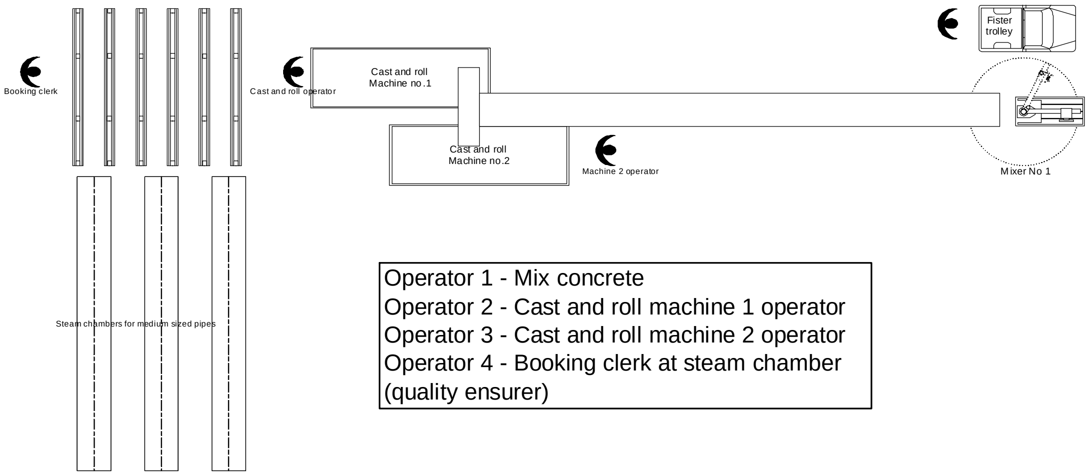
There are four operators at the medium pipe section for stripping and assembly.

Operator 1 – Assemble
Operator 2 – Strip
Operator 3 – Washing in
Operator 4 – Stud cap fitting

0	OPERATOR 1 - Strip	OPERATOR 2 - Assemble	OPERATOR 3 - Washing in	OPERATOR 4 - Stud cap fitting
0.5	Remove mould with pipe from steam chamber and put on bench		Washing in and stenciling of 1 pipe	Stud cap fitting of 1 cage
1				
1.5	Loosen bolts			
2	Remove front part and remove pipe from mould	Remove back part and clean mould		
2.5				
3		Assemble mould		
3.5				
4	Roll pipe away			
4.5	Repeat cycle			
5				Repeat cycle
5.5		Repeat cycle		
6				
6.5				
7				
7.5				
8			Repeat cycle	
8.5				
9				

Figure 9 shows the multiple activity chart for the second category referred to in Table 4, strip and assemble. The four processes can happen simultaneously, due to the four operators available.

Figure 10: Multiple activity chart for cast and cure



	OPERATOR 1	OPERATOR 2	OPERATOR 3	
0	Loading trolley - mix ready for use	Cast and roll operation	Cast and roll operation	Pre-Curing
1				
2				
3				
4				
5				
6				
7				
8		**Repeat**	**Repeat**	
9				
10	**Repeat**			
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				

Figure 10 shows the multiple activity chart for the third category referred to in Table 4, cast and cure. Operator one is responsible for the operation of the phister trolley and mixes the concrete while operator two and three are casting the product.

CHAPTER 4

DESIGN AND PROBLEM SOLVING: AS-IS PART

4.1 Current state value stream map

After careful analysis of the pipe manufacturing process and discussion with the operators, the current state map has been drawn up. A short description of the different processes is listed in Table 5.

Table 5: Process Descriptions

Process	Description
Wire Straightening	A cage consists of longitudinal and circumferential wires. This process refers to the straightening and the cutting of the longitudinal wires.
Cage Welding	The longitudinal wires are inserted into the grid welder. The circumferential wires are then welded on.
Stud Welding	At this process the studs are welded onto the cage. The studs are required on the cage for stud caps being fitted.
Stud Cap Fitting	The stud caps are fitted on each stud. The function is to ensure that the cage is a certain distance from the mould when assembled.
Assemble	The cages are placed in the moulds and the moulds are closed.
Mix concrete	At this process the phister trolley collects sand, concrete and stone. The trolley then dumps these components, together with water, in the mixer.
Cast and roll	The moulds are placed on the cast and roll machine. The mix is now inserted in the mould and spun until the whole pipe is formed.
Inspect	At this part in the process, the booking clerk checks the pipe and paints the size of the pipe onto it.
Pre-Steam and Steam chamber	The pipes are placed in a steam chamber. When the steam chamber has reached it capacity, the valve of the steam is opened.
Strip and clean mould	This refers to the pipe being removed from the mould. When the mould is empty, it can be cleaned by mopping it with water.
Pipe washing in, finishing and inspection	The pipe is being scraped and washed in, to ensure that there are no bumps on the pipe. The stencilling of the size of the pipe also happens here. After the pipe has been cleaned, it is inspected according to quality specifications.

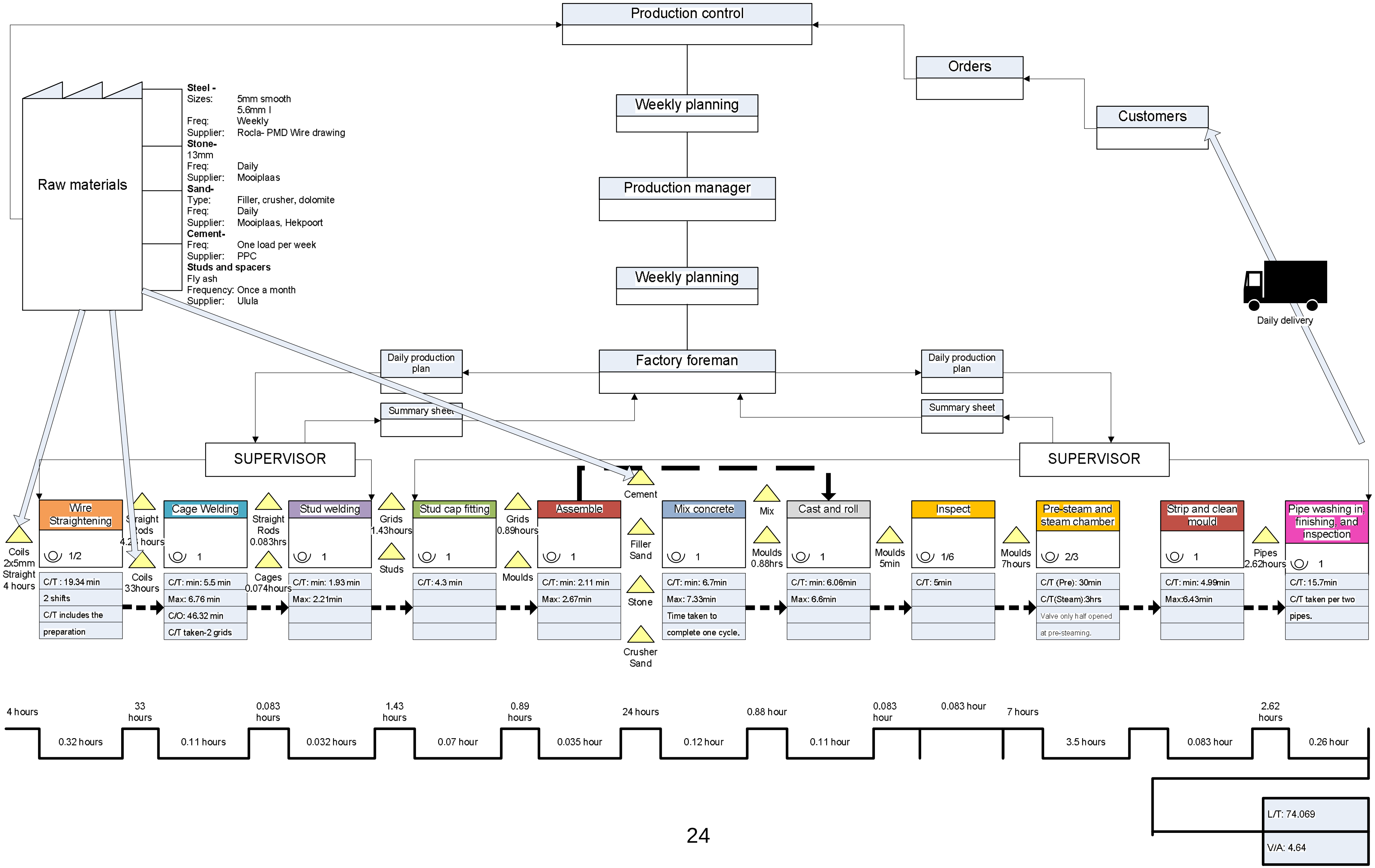
The current state map is there to understand the current operation of the process and shows the lead time and value added time of the product studied. The current state map can be viewed in Figure 11. The product that is mapped is the 600IJ 100D pipe, this product falls within the family of the medium pipes.

There is a vast variety of information that is displayed on a current state map; this information can be seen in Table 6. The variance of the cycle times, manning structure and machines used within a certain product family is very little; therefore only one product will be studied.

Table 6: Current State information

Cell	Cycle time	No. of operators	Value Added Time	Lead Time
Wire Straightening	19.34 min	½	19.34 min	6 hours
Cage Welding	Max – 6.76 min Min – 5.5 min	1	6.76 min	33 hours
Stud Welding	Max – 2.21 min Min – 1.93 min	1	2.21 min	0.083 hours
Stud cap fitting	4.3 min	1	4.3 min	64.5 min
Assemble	Max – 2.67 min Min – 2.11 min	1	2.67 min	1.38 hours
Mix concrete	Max – 7.33 min Min – 6.7 min	1	7.33 min	24 hours
Cast and roll	Max – 6.6 min Min – 6.06 min	1	6.6 min	0.88 hour
Inspect	5 min	1/6	5 min	5 min
Pre-Steam and Steam chamber	Pre – 30 min Full – 3 hours	2/3	3 ½ hours	60 min
Strip and clean mould	Max – 6.43 min Min – 4.99 min	1	6.43 min	51.44 min
Pipe washing in, finishing and inspection	15.7 min	1	15.7 min	4.2 hours
Curing	7 days		7 days	

Figure 11: Current State Value Stream Map



Definitions which are necessary in understanding the value stream map (Rother and Shook: 1999):

- Cycle time (C/T): The time taken for an operator to work through all of the process elements, before repeating it.
- Value-Added Time (VA): Time of work elements which transform the product in a valuable way.
- Lead Time (L/T): Total time from order to delivery.

One can see on the value stream in Figure 11 that, the total lead time of the pipe manufacturing process is 74.069 hours, of which 4.64 hours are value-added time. This means that the process has a percentage of 6.3% where value is added to the product. It is clear that there is definite room for improvement.

The main aim of this project is to reduce the cycle time; this can be achieved by aiming to increase the value-adding percentage.

4.2 Simulation of current state map

From the map in Figure 11, a simulation model was built using Rockwell's Arena 11.0. The primary objective of this simulation model is to provide a dynamic value stream which provides results and outcomes of the pipe manufacturing process.

4.2.1 Assumptions

A few assumptions can be made in the simulation model to compensate for uncertainties that are not present in the model:

- Raw material is always available

  Seeing as raw materials are delivered on a daily basis, the assumption is made that raw material is always available.
- No absenteeism

  It is assumed that operators are always available to work at the specific process; absenteeism has not been built into the model.

4.2.2 Parts of the simulation model

The simulation model will consist of:

- Resources: Resources represent the different operators in the pipe manufacturing process.
- Entities: The entities represent raw material being transformed into the final product.
- Processes: The processes are there to convert the raw material into the final product, therefore requires entities.
- Attributes: A specific value assigned to an entity. This value can differ from one entity to another.
- Queues: The queues provide a waiting place for resources.

The entity pictures used in the model can be seen in Table 7. A description of the different building blocks used in arena are given in Table 8, this is made available to clarify the use of the modules in the simulation model.

Table 7: Entity Pictures

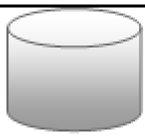
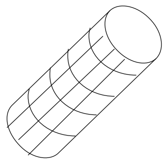
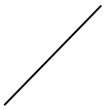
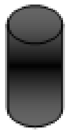
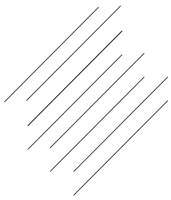
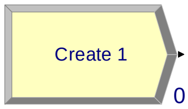
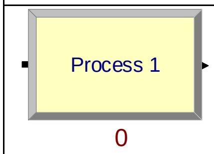
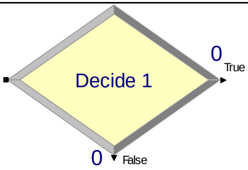
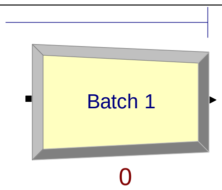
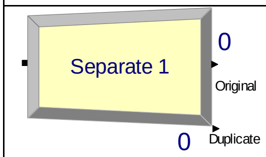
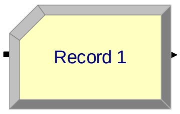
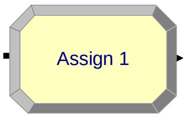
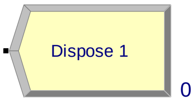
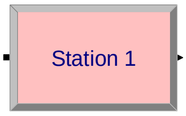
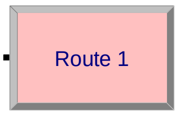
Resource	Animation	Resource	Animation
Coil		**Cage**	
Wire piece		**Mould with cage**	
Group of wires		**Pipe**	

Table 8: Building blocks of Arena

Building block	Description of building block
	The starting point of the simulation model is with this module. Entities are created in this module, specifying an entity type, and inter arrival time.
	This is the main processing method. The process time is specified in this module, and it can be indicated if the processing time is value-added or non value-added.
	This module allows for decision-making processes in the system. The option for decision making is either based on conditions or on probabilities.
	This module is the grouping mechanism in the simulation model. The batching can happen temporarily or permanently.
	There are two functions which this module can perform: It can either duplicate an entity or it can split an existing batch to retain its original values.
	Statistics are collected and stored in this module; it can also serve as a counter.
	This module is used for assigning new values. These values can be to variables, entity attributes, entity types, entity pictures, or other system variables.
	This model represents that a simulation model has come to an end.
	A station is defined in this model, which corresponds to a physical location in the simulation model.
	This module is used to transfer an entity between two stations on the physical location.

4.2.3 Description of model

a. Description of the first part of the simulation model, as seen in Figure 12.

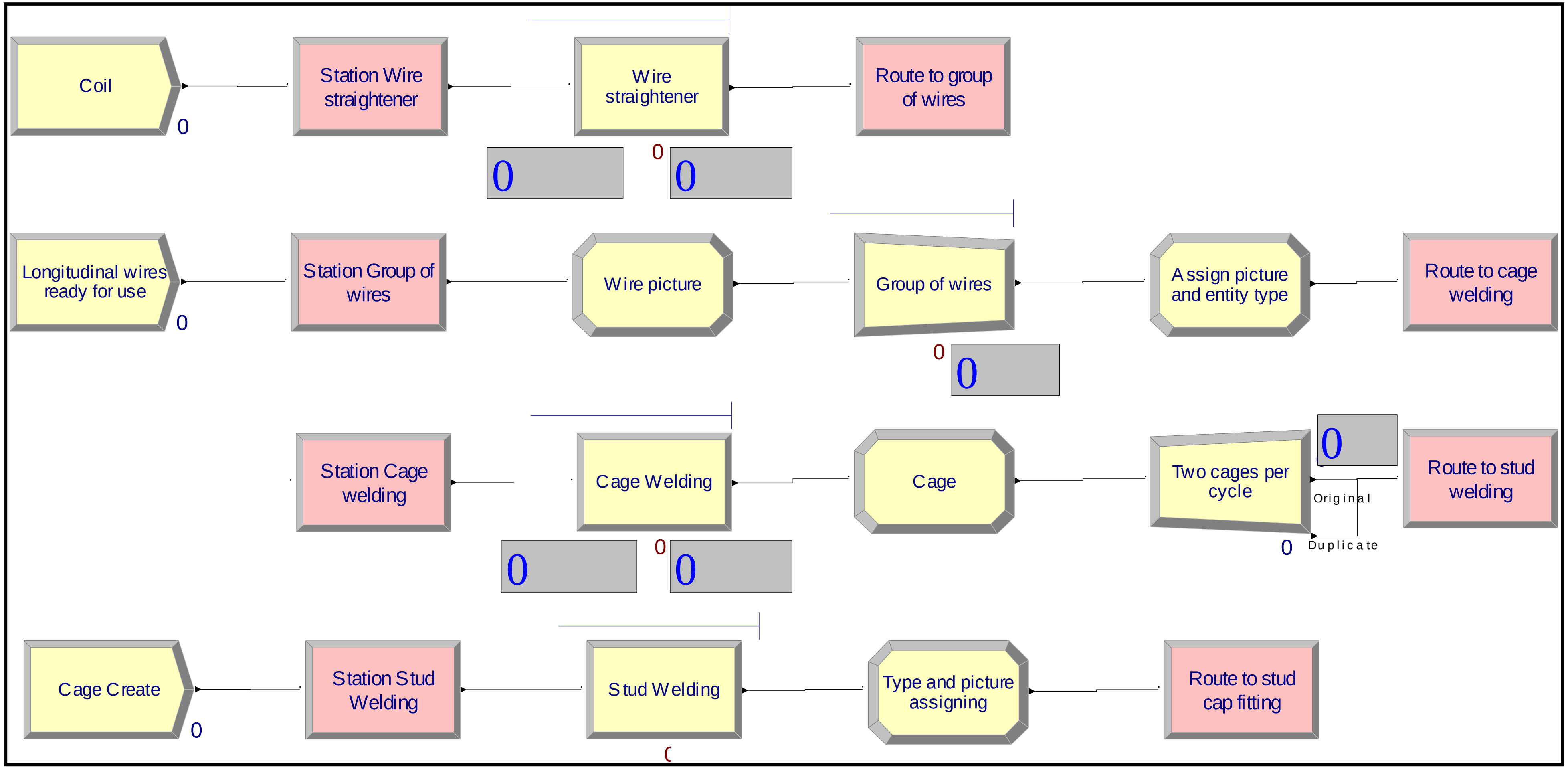
The simulation model starts off by creating a coil. One coil is created which represents 2016 pieces of wire. A station is created for the wire pieces, enabling it to be plotted on the value stream. The first processing block is the wire straightener. The coil is straightened and cut into pieces at a constant rate of 0.09 minutes per wire. These wire pieces are now being routed to the station for the group of wires.

The next create module, generates the inventory of the longitudinal wires. This inventory was already present when the cycle was noted. The longitudinal wire inventory as well as the wires straightened is now assigned an entity picture. In the case of grid manufacturing, eight pieces of longitudinal wire are needed. These single wire pieces must be permanently batched in groups of eight. After the batching process, these groups of wires are assigned an entity picture as well as an entity type. The batched group of wires are now being routed to the station for cage welding.

Seeing as the batching of the wires and welding of grid happens together, one will see that there is no inventory that represents the group of wires. The next process is the cage welding process. Longitudinal wire pieces are inserted into the cage welder and circumferential wires are being welded on at a uniform delay time. After the cage has been welded, an entity type and picture is assigned to the cage. In the case of the 600 IJ pipe, two cages are produced in one welding operation. These two cages are shown by making use of the duplicate module. These cages are now routed to the stud welding station.

Again, inventory is present. The cages in inventory is created at the create module and placed in the station. The studs are being welded onto the cages at a triangular rate at the stud welding process. For purposes of this project, the cage with the studs on will be referred to as a grid. In the factory, a grid and a cage is the same thing. This is just to make the inventory counts more understandable. An entity type and picture is now assigned to the grid and the grid is routed to the stud cap fitting station.

Figure 12: First part of the Simulation model



b. Description of the second part of the simulation model, as seen in Figure 13.

At the beginning of this part of the model, grids in inventory are being created and sent to the stud cap fitting station. The grids from the station are now being fitted with stud caps at the stud cap fitting process. These grids, together with inventory already on the factory floor are assigned with an attribute, namely Part type 1. Part type 1 is now being routed to the assembly station.

When assembling a grid into a mould there are two types required:

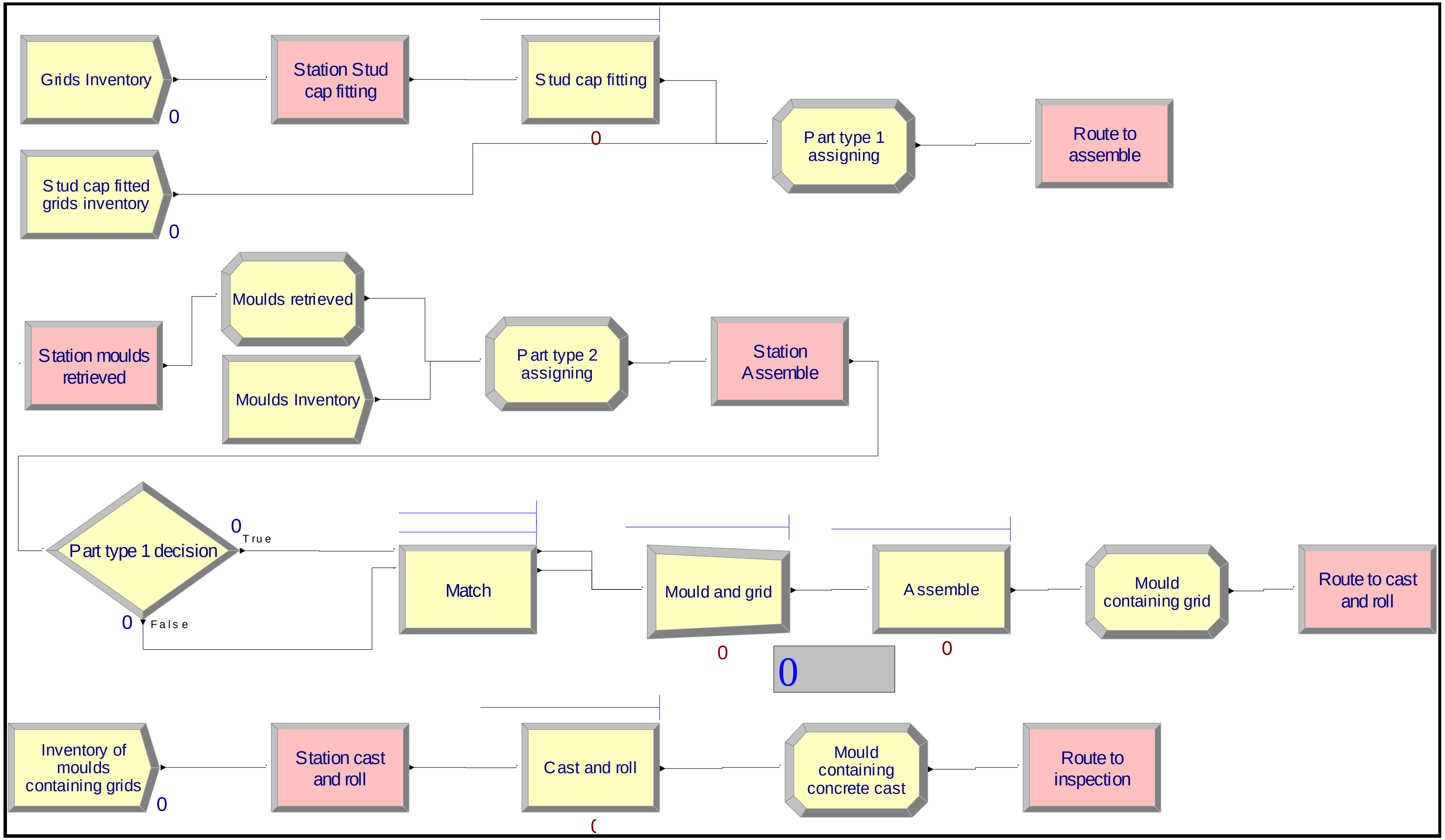
1. Part type 1 – The grids fitted with stud caps
2. Part type 2 – The moulds required

The station for the retrieved moulds are used for moulds being released after the final step in the process, stripping. The moulds in inventory as well as the retrieved moulds are being assigned with the part type 2 attributed and placed in the assembly station. The match module is used to group part type 1 and part type 2 together. These two parts are now batched together by attribute.

After the two different parts are grouped together, it can now be sent to the assembly process, where it is assembled at a triangular rate. An entity type and picture is now being assigned to the entity, which will be referred to as Mould with grid. It is now routed to the cast and roll station.

The inventory of the moulds containing grids is also sent to the station. The station's inventory is now being processed at a triangular delay time with the process module, named cast and roll. An entity type and picture is again assigned to the entity, and it can be referred to as mould with cast. The mould with cast is now being routed to inspection.

Figure 13: Second part of the Simulation model



c. Final part of the simulation model, as seen in figure 14

Initially, the inventory of the mould containing the concrete cast is also sent to the inspection station. These moulds as well as the moulds that were routed to the inspection station are being inspected at a constant rate by the booking clerk at the inspect process module. The entity is assigned a type and will be referred to as the inspected mould. These moulds are now routed to the steam chamber.

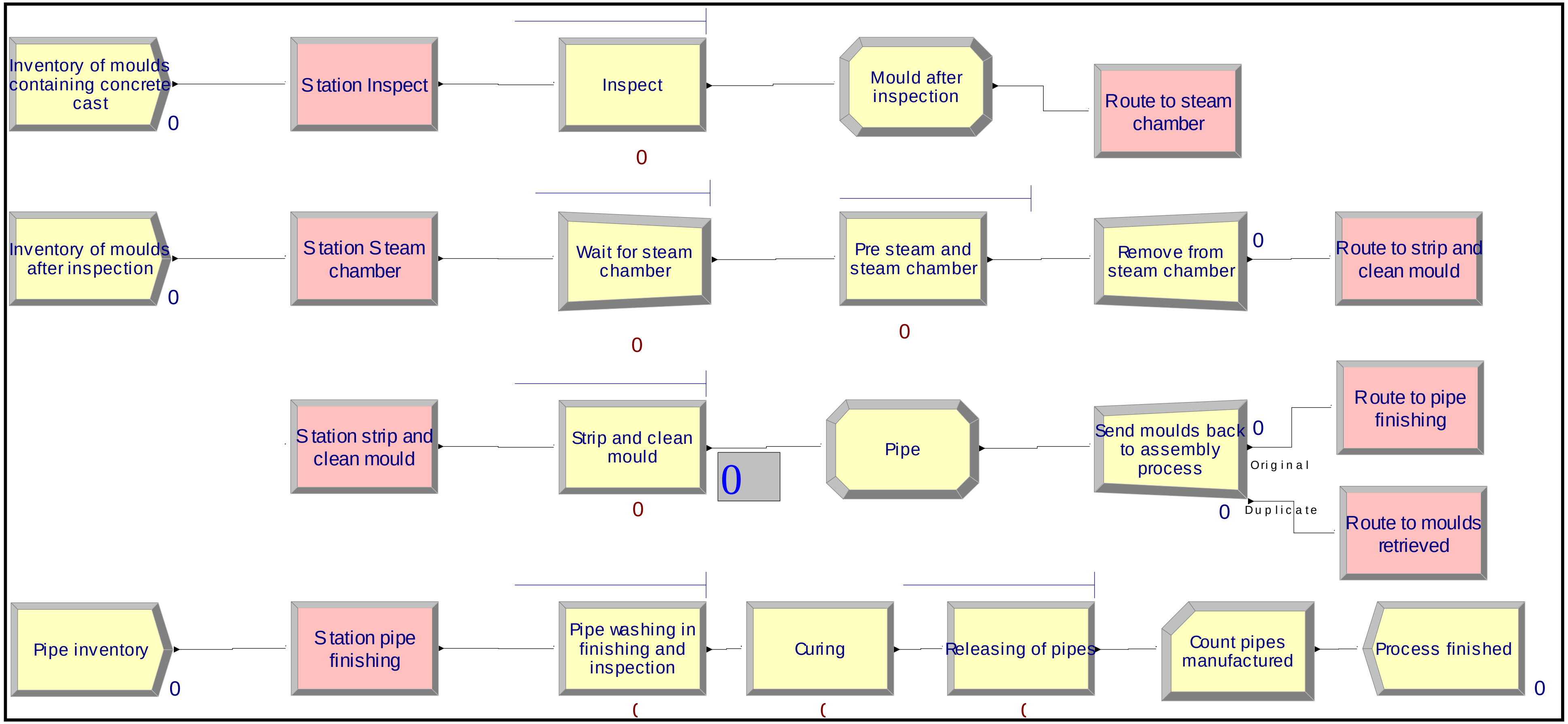
The inventory already on the shop floor is created and placed in the steam chamber station. The moulds that have finished the inspection process must wait until there are eight moulds, before it can be placed in the steam chamber. The batch module is used to group the moulds temporarily in groups of eight. Each entity of eight enters the steam chamber and is steamed for three and a half hours, which include pre-steaming as well. When the moulds are removed from the steam chamber, they are separated and take on their entire representative values. They are now being routed to the strip and clean station.

The pipes are stripped from their moulds at a triangular rate, and assigned the entity type of pipe. To ensure that the moulds are taken back into account, they will be sent to the retrieved moulds station. The pipes need to continue with the process, so the duplicate module will be used, to either route the mould entity to the "retrieved mould station", or to route the pipe to the "finishing station".

Again, there are already pipes in inventory that is created. These pipes together with the pipes already at the station are now being washed at a constant rate. The curing time of pipes is 7 days, this happens as soon as the pipes are released in the yard. The manufactured pipes as well as the cured pipes are counted, using a counter module. The pipes are now disposed to the yard.

The entity pictures used throughout the model can be seen in Table 7.

Figure 14: Final part of the Simulation model



4.2.4 Current State Simulation results

One shift consists out of nine hours, and a replication consists out of 30 days. The simulation model was run for twenty replications. The results follow in Table 9 to 12:

Table 9: Entities

Entity	Average Number in	Average Number out
Cage	580	580
Coil	0	0
Grids	862	593.75
Group Wires	289	289
Mould Cast	488.1	487.25
Mould Grid	491.5	487.1
Mould Inspect	489.25	480
Mould Pipe	540.95	540
Moulds	726	593.25
Pipe	970	852.75
Wire	2605	1529

In the above table, Table 8, it is clear that the amount that enters the system differs from the amount that exits the system. The most significant entity would be the moulds, as the average amount of moulds exiting the process is 132.75 less than the average number that enters the process.

Table 10: Work in progress times

Entity	WIP
Cage	0.11
Coil	0
Grids	458.96
Group Wires	14.46
Mould Cast	0.153
Mould Grid	0.63
Mould Inspect	12.56
Mould Pipe	1.53
Moulds	112.56
Pipe	101.8
Wire	1913.61

The work in progress times are shown in the above table. The total amount of pipes manufactured is 373 pipes.

Table 11: Queue waiting time

Queue	Average Waiting time (Minutes)
Assemble	25.02
Cage Welding	804.14
Cast and roll	14.496
Group of wires	0.27
Inspect	0
Match 1	7188.12
Match 2	0
Mould and grid	2.80
Pipe washing in and inspection	35.79
Pre steam and steam chamber	0
Releasing of pipes	0
Strip and clean mould	19.72
Stud cap fitting	427.8
Stud Welding	1.02
Wait for steam chamber	210.05
Wire straightening	90.68
Curing	0

When looking at the queue waiting times in Table 11, there is a definite bottleneck before assembly starts, when the parts wait to be matched. At this process, the finished grids wait for the moulds available before they are matched and assembled.

Figure 15: Waiting time

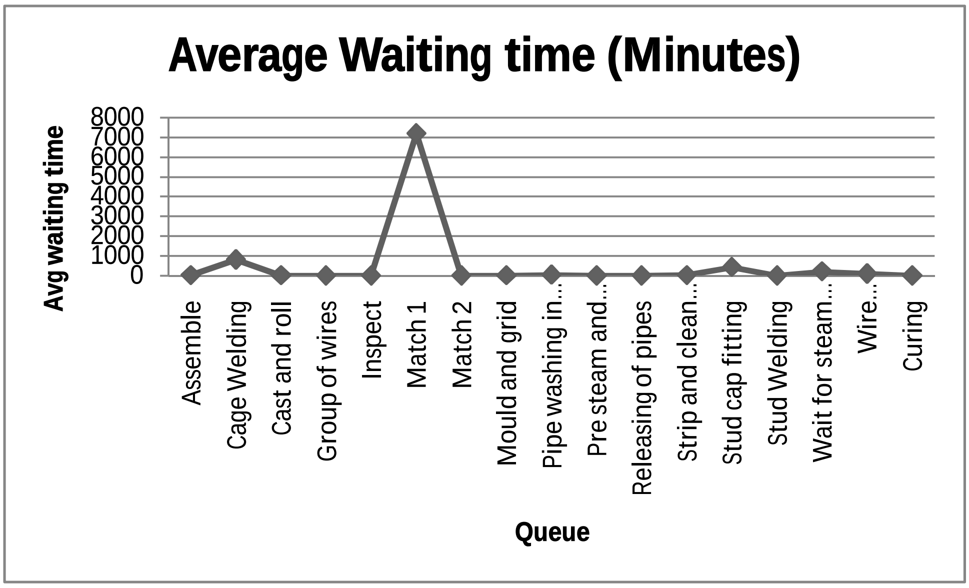


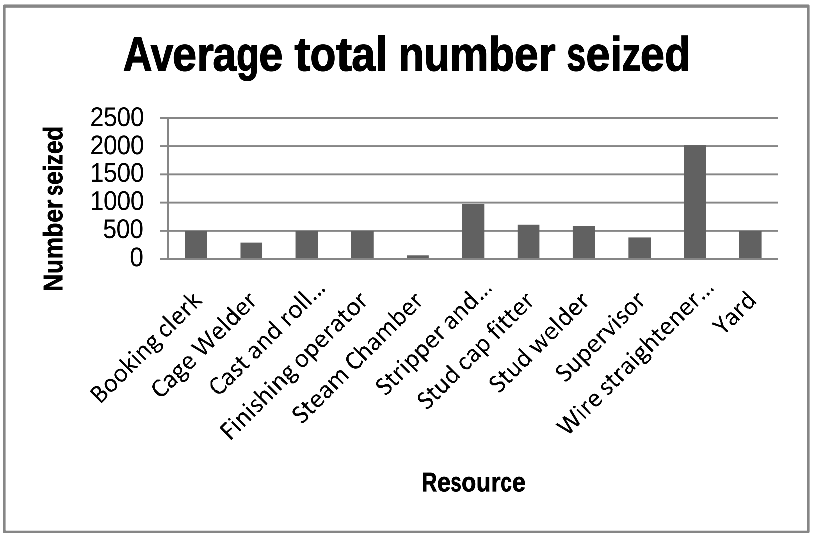
Figure 15 illustrates the bottleneck occurring before the assembly process at the match 1 queue.

Table 12: Number waiting in queue

Queue	Average number waiting
Assemble	0.747
Cage Welding	14.35
Cast and roll	0.44
Group of wires	3.99
Match 1	331.53
Mould and grid	0.1672
Pipe washing in and inspection	1.0815
Strip and clean mould	0.58
Stud cap fitting	15.84
Stud Welding	0.04
Wait for steam chamber	6.32
Wire straightening	11.28

Once again it is clear when looking at the number waiting in the queue in Table 12 that the bottleneck occurs in front of the assembly process at the match 1 queue.

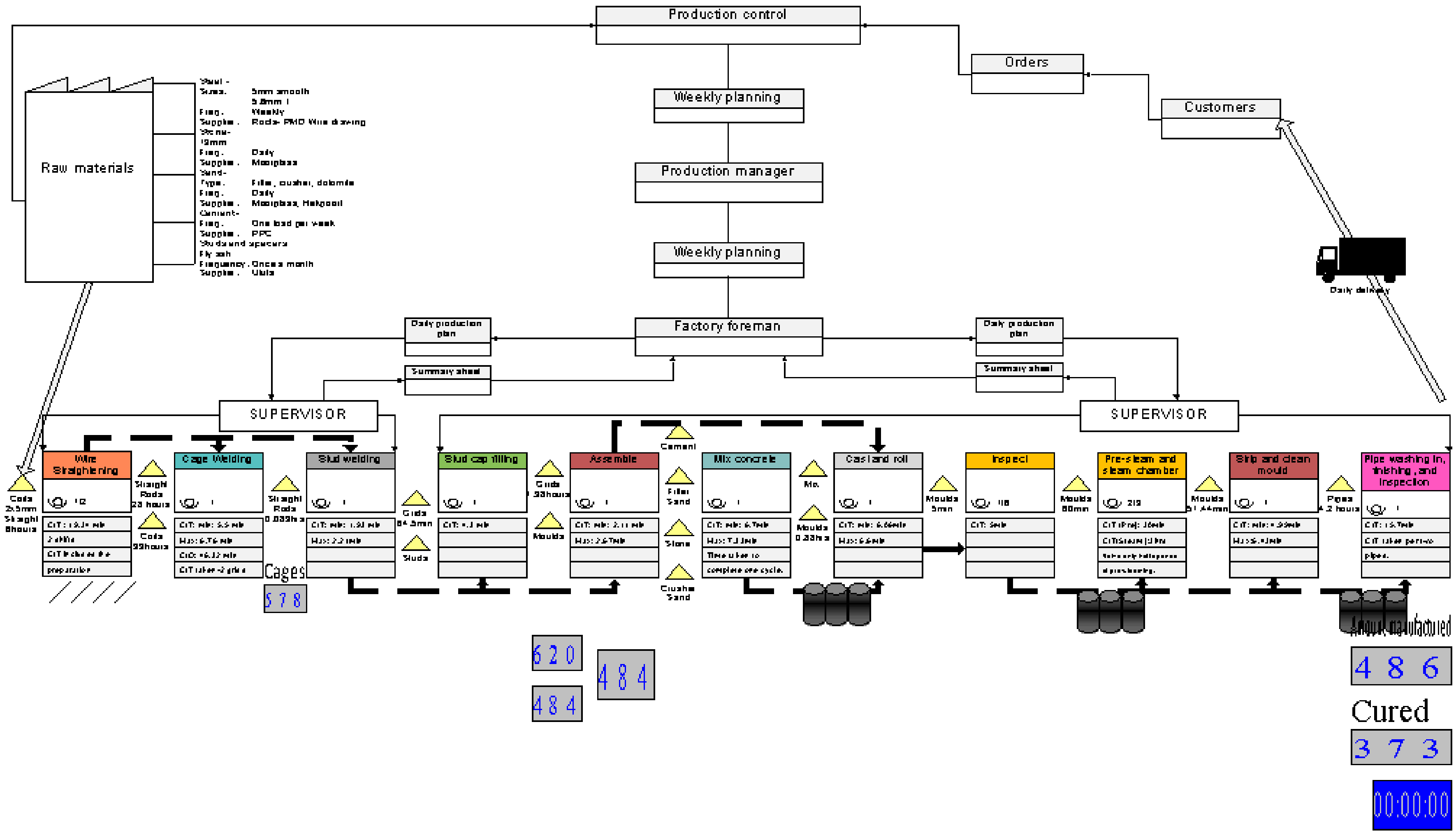
Figure 16: Resource usage



The resource usages are shown in Figure 16 and it is evident that the average total number of entities seized is the smallest at the steam chamber. This is a clear sign of under utilisation of the steam chamber. This under utilisation can be due to the fact that batches of eight needs to enter the steam chamber at a time. The steam chamber will be more efficient if pipes are able to enter the steam chamber individually, as soon as they are ready.

The Current State model which has run to completion can be seen in Figure 17.

Figure 17: Current State model run to completion



CHAPTER 5

DESIGN AND PROBLEM SOLVING: TO-BE PART

The aim of this project is to reduce the cycle time within the pipe manufacturing process, whilst improving processes individually as well. The cycle time can be immediately reduced, by removing the bottlenecks in the system. All the data needed to solve the problem has been gathered. The first step in solving the problem is to develop a future state map. The future and current state maps will be compared to identify the bottleneck and other problems in the assembly line area. The focus will then finally be on improving the operations of the pipe manufacturing process.

5.1 Bottleneck identification

From the results shown in Chapter 4, a definite bottleneck process is found to be the steam chamber. The number seized by the steam chamber is very little, and the queue waiting time is very long. This happens because batches of eight must enter the steam chamber. Another bottleneck occurs at the assembly process, where the grids are matched up with the moulds. The queue lengths are exceptionally long and this is due to the moulds not being readily available.

5.2 Problem Identification

After reviewing the results, the main problems were identified:

- Steam chamber – the amount seized by the steam chamber is significantly lower than the other processes, this means that the steam chamber, in comparison with the other processes takes too long.

- Availability of moulds – from the results above, one can see the queues in front of the assembly process, where the grids have to be matched up with the moulds. One can see there are definitely enough grids in the system when looking at the *amount out* in Table 9. The problem then lies at the availability of the moulds.

5.3 Future State value stream map

The future state value stream map represents that state of the assembly line which is optimal. The main aim with this future state map is to reduce the amount of operators as well as the amount of inventory, which will then show the way to a better lead time. A few changes have been made, the icons used in the value stream is shown in Appendix E.

The following changes have been made to the current state map, in order to obtain the required future state map:

a. Number of operations

   There are only nine operations in the future state map. Four of the operations were combined to obtain two processes. The *Stud Welding* and *Stud Cap fitting process* are now done in the same cell, at the operation *Stud Welding and fitting*. The *Steam chamber* and the *Inspection* process also happens at the same cell in the future state map, *Inspect and Pre-steam and Steam Chamber*. This change can be seen in Figure 18.

b. Supermarket

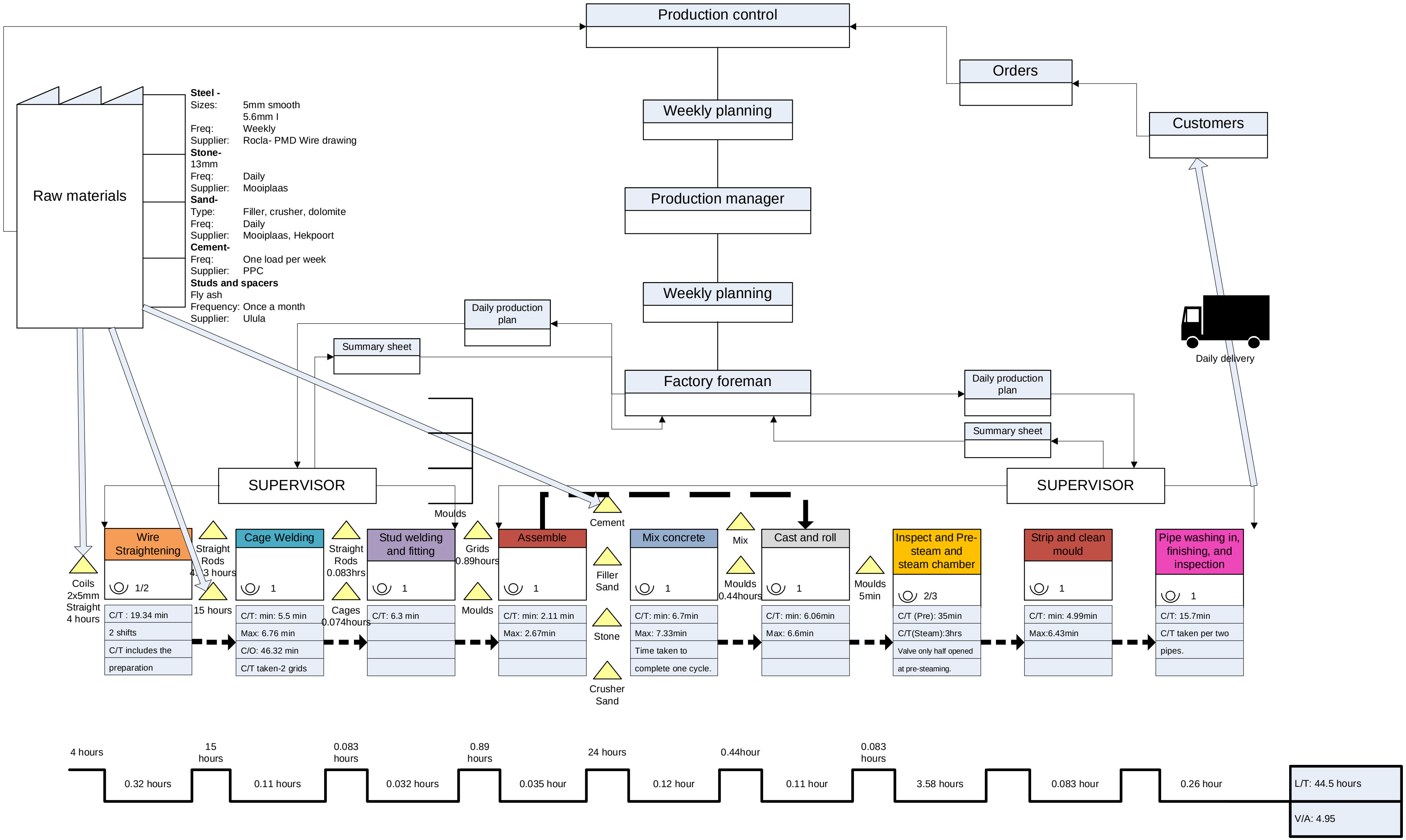
   A supermarket is created at the stud cap fitting cell. This supermarket is used to regulate production at an upstream process. The Future State Value Stream map can be viewed in Figure 18, where one can see the supermarket as well.

The information used in the Future State map differs slightly from the information used in the Current State map. The information can be viewed in Table 13.

Table 13: Future state information

Cell	Cycle time	No. of operators	Value Added Time	Lead Time
Wire Straightening	19.34 min	½	19.34 min	4 hours
Cage Welding	Max – 6.76 min Min – 5.5 min	1	6.76 min	15 hours
Stud Welding and fitting	6.3 min	1	6.3 min	0.083 hours
Assemble	Max – 2.67 min Min – 2.11 min	1	2.67 min	1.38 hours
Mix concrete	Max – 7.33 min Min – 6.7 min	1	7.33 min	24 hours
Cast and roll	Max – 6.6 min Min – 6.06 min	1	6.6 min	0.44 hour
Inspect and Pre-Steam and Steam chamber	Pre – 30 min Full – 3 hours	1	3.58 hours	5 min
Strip and clean mould	Max – 6.43 min Min – 4.99 min	1	6.43 min	51.44 min
Pipe washing in, finishing and inspection	15.7 min	1	15.7 min	
Curing	7 days		7 days	

Figure 18: Future State Value Stream Map



The total lead time of the pipe manufacturing process in the Future State map showed in Figure 18, is 44.5 hours, of which 4.72 hours are value added time. This means that the future state process have a percentage of 11% where value is added to the product.

When comparing this to the current state map, one can definitely see that the lead time has been reduced; the value added time has been increased, leading to the overall percentage being increased.

5.3.1 Simulation of future state map

From the Future State value stream map, a simulation model was built using Arena Software. The same modules and entity pictures were used as referred to in Chapter 4.

5.3.1.1 Description of model

The model resembles the model of the current state simulation, with only a few changes. Because of the bottleneck and other problem areas identified, there will be three proposed simulation models with certain changes and results. The optimal model will be chosen after the results have been concluded. The descriptions of the three models follow:

There will be a basic model description for each proposed solution, and then minor changes on this basic model.

The basic model:

All three models will be built using the basic future state simulation model; this model has the following differences in comparison with the current state model:

- Less coils as inventory in front of the cage welding process, leading to a shorter lead time.(One cannot see this change on the model)
- The Stud Welding and Stud Cap Fitting process are combined into one process, stud welding and fitting. This process has a constant processing time of 6.3 minutes.

- Instead of having eight moulds with grids in inventory at the cast and roll process, there is only four. This can be seen in the create node: Inventory of moulds containing grids.
- The Inspect process has been combined with the pre-steam and steam process, this leading to a constant processing time of 3.58 hours in the process module: Pre steam and steam chamber.
- To fit into all the combined processes, some of the routes and stations have been changed accordingly.
- The inventory at the last process before curing has also been eliminated.

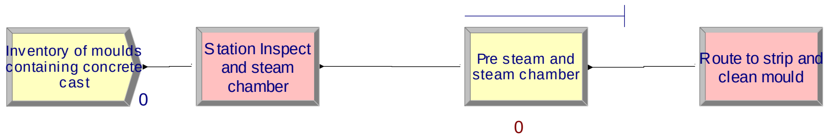
a. Proposed solution 1

In the first proposed solution, the bottleneck process will be targeted. The steam chamber is the bottleneck process, seeing as the pipes accumulate in front of the steam chamber. The pipes queue up because only batches of eight are allowed in the steam chamber at a time. This means that as soon as the steam chamber is filled up with eight pipes, the steam chamber can be closed and the steam can be opened.

A proposed solution to the above problem is to implement a continuous flow steam chamber. This will also eliminate the queue at the stripper and assembler, as they will have to operate on the moulds at a continuous level.

The batch and separate module have been taken away from the simulation model, and the capacity of the steam chamber resource has been changed to eight. The model can be viewed in Appendix F, and the changed part can be viewed in Figure 19.

Figure 19: Changed part for proposed solution 1



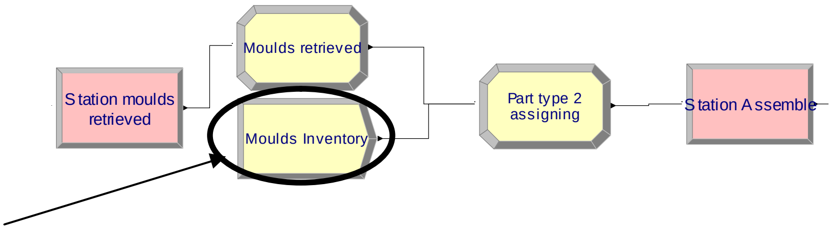
One can see from Figure 19, that the batch nodes were removed, in order to make the steam chamber a continuous steam chamber. The separate module was also removed as a result of the batch module's removal.

b. ***Proposed solution 2***

The second proposed solution is to eliminate the problem experienced by the unavailability of the moulds. The amount of grids not being matched up with moulds influence the amount of pipes manufactured.

In the model, the amount of moulds in inventory before the cast and roll section will be increased to eight. The model can be viewed in Appendix G, and the changed part to the model can be viewed in Figure 20.

Figure 20: Changed part for proposed solution 2



The circled module creates the amount of moulds in inventory. With this proposed solution, the amount of moulds in inventory will be changed from four to eight.

c. ***Proposed solution 3***

The final solution will be a combination of the above two solutions.

- The steam chamber will be developed into a continuous steam chamber, by eliminating the batch and separate modules.

- The amount of moulds in inventory will also be increased to eight. This model can be viewed in Appendix H, and the two changes are displayed in Figure 19 and 20.

CHAPTER 6: RESULTS

6.1 Future State map results

The aim of this project was to reduce the cycle time within the pipe manufacturing process, whilst improving processes individually as well.

The cycle time was immediately reduced, by removing the bottlenecks in the system. In Chapter 5 it is evident that the total lead time of the pipe manufacturing process in the Future State map is 44.5 hours, of which 4.72 hours are value added time. This means that the future state process have a percentage of 11% where value is added to the product. This compared to the Current State map in Chapter 4, where the total lead time is 74.069 hours, of which 4.64 hours are value-added time. This means that the process had a percentage of 6.3% where value is added to the product. It is clear that the improvements made were successful.

The focus was finally on improving the individual operations of the pipe manufacturing process, by means of the simulation model.

6.2 Future State simulation results

Table 14: Total number of pipes manufactured

	Current state model	Model 1 – Steam chamber	Model 2 – Mould availability	Model 3 – Both
Total number of pipes manufactured	373	427	346	456

It is noticeable in Table 14 that the proposed solutions have a definite positive improvement on the process. On the table one can see that model three has the best improvement, of 83 pipes per simulation run. Model one's improvement of 54 pipes is also significant. Model two does not show a positive improvement with the amount of pipes manufactured.

Table 15: Amount seized

Resource	Current state model	Model 1 – Steam chamber	Model 2 – Mould availability	Model 3 – Both
Booking clerk	488.1	-	-	-
Cage Welder	289	289	289	289
Cast and roll operator	488.1	568	468	604
Finishing operator	486.7	561	456	598
Steam Chamber	60.95	569	58	605
Stripper and Assembler	963.7	1125	920	1200
Stud cap fitter	600	580	580	580
Stud welder	580	-	-	-
Supervisor	372.75	426.5	346.15	456
Wire straightener operator	2016	2016	2016	2016
Yard	485.7	561	456	587

In table 15, the amounts seized by the resources are shown. The highlighted blocks show the best proposed solution. In this case the proposed solution which resources seize the most entities is model three. Overall, model one also seizes a lot of entities. There is a clear improvement with the amount of entities seized by the resource, steam chamber, in model one and three.

Table 16: Number waiting in queue

Queue	Current state model	Model 1 – Steam chamber	Model 2 – Mould availability	Model 3 – Both
Assemble	0.747	0.05	0.71	0.16
Cage Welding	14.35	14.3	14.3	14.3
Cast and roll	0.44	0.08	0.42	0.12
Group of wires	3.99	3.99	3.99	3.99
Match 1	331.53	252.37	300	230
Mould and grid	0.1672	1.53	0.1	0.3
Pipe washing in and inspection	1.0815	0.58	0.99	1.1
Strip and clean mould	0.58	0.07	0.56	0.14
Stud cap fitting	15.84	-	-	-
Stud Welding	0.04	33.61	33.6	33.6
Wait for steam chamber	6.32	0.05	4.72	3.9
Wire straightening	11.28	11.28	11.28	11.28

In table 16 the numbers of entities waiting in the specific queues are shown. It is evident that the number waiting in the specific queues is the least at model one. Model three also shows significant improvements. The queue length of the match 1 queue is reduced by 100 in model three.

When looking at the above results, a choice must be made whether to choose model one, two or three.

When looking at the improvements showed in the above tables, the first suggestion would be to choose model 3, where both the steam chamber and mould availability are targeted. Seeing as the most improvement is made by this model.

This is not the optimal choice though, as a lot of funding is required in order to acquire new grids and to convert the steam chamber into a continuous steam chamber. The proposed solution which will have the least financial impact on the company in a negative way, but will also ensure improvements to the current system, is model 1.

In this model the steam chamber is converted into a continuous steam chamber. This will ensure that pipes will not pile up in front of the steam chamber when waiting to enter the steam chamber. Another benefit that is gained from the continuous steam chamber is the fact that the stripper operator will be paced when stripping the moulds, as they will arrive at a continuous pace and not in a batch format. This solution has a reduced lead time as well as higher manufacturing rates with smaller queues.

CHAPTER 7:

CONCLUSION

The aim of this project was to reduce the cycle time within the pipe manufacturing process. To reduce the lead time, all factors influencing the production were investigated.

Analysis of the results indicates that the assembly line currently has a lead time of 74 hours and a value-added time of 4.64 hours. These measures are a reflection of the inadequacy of the process, as only 6.3% of the production time is useful.

In the arrival of the results, to isolate the problematic area within the current process, data analysis and work measurement was used. This included the completion of a pareto analysis, time studies and work sampling.

These findings were implemented within the concept, which provided the means of mapping the process in its current and future state. Simulation aided value stream mapping was used.

In running the simulation models, it was found that the main bottleneck lies within the steam chamber, due to the fact that batches of pipes enter the steam chamber simultaneously. Another problem that was identified within the system was concerned with the availability of the moulds.

Both of the above problems are addressed within the proposed solutions, where it was found that the optimal solution entailed the alteration of the current steam process to that of a continuous steam chamber. This will alleviate congestion and reduce the cycle time most notably.

REFERENCES

Abdulmalek, Fawaz A., and Rajgopal, Jayant 2006, *Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study.* USA.

Altiok, Tayfur and Melamed, Benjamin 2001, *Simulation modeling and analysis with arena.* Cyber Research, Inc and Enterprise Technology Solutions, Inc, USA.

Burton, Terence T., Boeder, Steven M. 2006, *The Lean Extended Enterprise – Moving Beyond the Four Walls to Value Stream Excellence.* J Ross Publishing, USA.

Chase, Jacobs & Aquilano 2007, *Operations Management for Competitive Advantage with Global Cases.* International Edition.

Craig, Donald 1996, *Extensible hierarchical object-oriented logic simulation with an adaptable graphical user interface.*

Hines, Peter, Lamming, Richard, Jones, Dan, Cousins, Paul and Rich, Nick, *Value Stream Management- Strategy and Excellence in the supply chance.* Prentice hall-Financial Times, Great Britain.

Karlsson, *C Japanese Production Management in Sunrise or sunset* (Stockholm, Sweden: Stockholm School of Economics, EFI/The Economic Research Institute.

Kelton, David W, Sadowski, Randall P and Sadowski, Deborah A 1999, *Simulation with Arena.* McGraw-Hill, international edition.

Lian, Y and van Landeghem, H 2007, *Analysing the effects of Lean Manufacturing using value stream mapping – based simulation generator.* International Journal of Production Research.

McDonald, T, van Aken, E and Rentes, A.F Utilizing simulation to enhance value stream mapping: a manufacturing case application, International Journal of Logistics: Research and applications 5 (2002) (2), pp 213-232.

McManus, Hugh and Millard, Richard L. 2002, Value stream analysis and mapping for product development. Massachusetts Institute of Technology, Canada.

Rother, Mike & Shook, John 1998, *Learning to See - value stream mapping to add value and eliminate muda.* The Lean Enterprise Institute, Inc., Brookline, MA.

Seth, Dinesh and Gupta, Vaibhav 2005, *Application of value stream mapping for lean operations and cycle time reduction An Indian case study.* National Institute of Industrial Engineering, India.

Voss, Christopher, A 1992, *Manufacturing Strategy – Process and content.* Chapman & Hall, London.

Womack, J.P, Jones, D.T and Ross,D (1990). The Machine that changed the world. Macmillan Publishing, Canada.

Appendix A: Product Data

[redacted]

Appendix B: Manufactured products in descending order

[redacted]

Appendix C: Flow Process charts- Small sized pipes

Cage Preparation

Wire Straightening

Flow Process Chart for: Wire Straightening IE: Lana Steyn Date__31/03/09______

Page__1___ of__1___

No.	Description of Action	Equipment/Tool	Part No.	Qty	Dist	Time	Oper	Handle	Transp	Delay	Inspect	Store	Why, What, Where, When, Who, How Remark
1	Lifting coil onto wire jenny	Crane				6.65			⇨				
2	Removing crane	Crane				0.98		⬭					
3	Moving jenny	Operator				0.30			⇨				
4	Cutting coil's packaging wire	Cutter				1.07		⬭					
5	Removing packaging wire	Operator				3.75			⇨				
6	Setting machine	Operator				4.33		⬭					
7	Inserting wire until first correct length is reached	Wire Straightener				2.17	○						
8	Cutting of wire	Wire Straightener				0.09	○						

Cage Welding

Flow Process Chart for: Cage Welding (small pipes), V500 No1 IE: Lana Steyn Date 2009/04/02

Page__1___ of__1___

No.	Description of Action	Equipment/Tool	Part No.	Qty	Dist	Time	Oper	Handle	Transp	Delay	Inspect	Store	Why, What, Where, When, Who, How Remark
1	Insert Wires	Cage Welder				0.59		⬭					Coil: 600cm, 4mm diameter
2	Hook wires onto spider wheel	Spider wheel				0.34		⬭					
3	Test	Cage Welder				0.32	○						
4	Weld	Cage Welder				1.90	○						Use 4 longitudinal wires per
5	Tag	Operator				0.24		⬭					grid.
6	Cut loose from machine	Cutter				0.53		⬭					
7	Cut in 3 parts	Cutter				0.81		⬭					One length cage, delivers
													3 separate 225IJ cages.

Stud Welding

Flow Process Chart for: Stud Welding (Small Pipes) IE: Lana Steyn Date__2009/04/02_____________

Page___1__ of___1__

No.	Description of Action	Equipment/Tool	Part No.	Qty	Dist	Time	Oper	Handle	Transp	Delay	Inspect	Store	Why, What, Where, When, Who, How Remark
1	Lift onto jig	Operator				0.40			⇨				At small pipes no socket
2	Weld	Studwelder				1.33	○						welding occurs as there
3	Repair (if needed)	Studwelder				1.64	○						is only IJ pipes.
4	Load into transportation trolley	Operator				0.18		⬭					

Mould Strip and Assemble

Assemble Mould

Flow Process Chart for: Assemble mould							IE: Lana Steyn						Date___2009-04-02__
													Page__1___ of __1__
													Why, What, Where, When, Who, How
No.	Description of Action	Equipment/Tool	Part No.	Qty	Dist	Time	Oper	Handle	Transp	Delay	Inspect	Store	Remark
1	Insert grid into mould	Operator				1.29		⬡					
2	Closing up mould	Operator				1.34	○						
3	Tightening bolts	Air wrench				2.57	○						
4	Move to casting area	Operator			6m	0.18			⇨				

Strip and clean mould

Flow Process Chart for: Strip and clean mould							IE: Lana Steyn						Date___2009-04-02__
													Page__1___ of __1__
													Why, What, Where, When, Who, How
No.	Description of Action	Equipment/Tool	Part No.	Qty	Dist	Time	Oper	Handle	Transp	Delay	Inspect	Store	Remark
	IDLE TIME -WAITING FOR ASSEMBLY TO FINISH					4.81							
1	Lift pipe and move onto workbench	Crane			4m	0.49			⇨				
2	Loosen bolts	Air wrench				1.28	○						
3	Loosening top part	Operator				0.48	○						
4	Lift pipe out with crane	Crane				0.51	○						
5	Clean mould	Mop				2.12		⬡					
6	Move pipe	Crane			4m	0.87			⇨				

Pipe finishing and inspection

Flow Process Chart for: Pipe finishing and inspection							IE: Lana Steyn						Date_2009-03-09_____________
													Page_1____ of __1__
													Why, What, Where, When, Who, How
No.	Description of Action	Equipment/Tool	Part No.	Qty	Dist	Time	Oper	Handle	Transp	Delay	Inspect	Store	Remark
1	Light Scrape	Scrape paper		2		0.47	○						There are 2 operators at
2	Wash Pipe	Brush		2		1.75	○						this process. Some events
3	Grind burrs off side	Grinder		2		3.09	○						happen simultaneously.
4	Plaster/patch sides	Cement mix		2		4.88	○						Two pipes are handled per
5	Wipe clean	Cloth		2		1.34	○						action.
6	Inspect	Operator		10		2.93					□		

Stud cap Fitting

Flow Process Chart for: Stud cap Fitting							IE: Lana Steyn						Date___2009-04-02__
													Page__1___ of __1__
													Why, What, Where, When, Who, How
No.	Description of Action	Equipment/Tool	Part No.	Qty	Dist	Time	Oper	Handle	Transp	Delay	Inspect	Store	Remark
1	Place grid on floor/bench	Operator			2m	0.33			⇨				There is one operator
2	Put studs on grid	Stud caps				2.28	○						which fits the stud caps
3	Take grid to assembler	Operator			3m	0.07			⇨				for No. 1 and No.2
													cast & roll machines.

Cast concrete and cure

Concrete mixing

Flow Process Chart for: Concrete Mixing								IE: Lana Steyn					Date__2009-04-02
													Page__1___ of ___1__
													Why, What, Where, When, Who, How
No.	Description of Action	Equipment/Tool	Part No.	Qty	Dist	Time	Oper	Handle	Transp	Delay	Inspect	Store	Remark
1	Loading of sand, stone and cement	Fister trolley				2.66	○						
2	Throw mix into hole	Fister trolley				0.47			⇨				
3	Mix cement and fly ash	Mixer				3.85	○						
4	Transport mix upwards	Conveyor				0.98			⇨				
5	Mix	Mixer				0.31	○						

Cast and roll

Flow Process Chart for: Cast & Roll								IE: Lana Steyn					Date__2009-04-02
													Page__1___ of ___1__
													Why, What, Where, When, Who, How
No.	Description of Action	Equipment/Tool	Part No.	Qty	Dist	Time	Oper	Handle	Transp	Delay	Inspect	Store	Remark
1	Take pipe to machine	Crane			7m	0.70			⇨				
2	Put on shaft and close	Crane				0.48		⬡					
3	Cast (by hand)	Spade				3.60	○						
4	Remove from shaft and place in front of chamber	Crane			7m	2.64			⇨				

Pre-cure and cure

Flow Process Chart for: Pre-curing and curing								IE: Lana Steyn					Date__2009-04-01
													Page__1___ of ___1__
													Why, What, Where, When, Who, How
No.	Description of Action	Equipment/Tool	Part No.	Qty	Dist	Time	Oper	Handle	Transp	Delay	Inspect	Store	Remark
1	Place moulds in steam chamber	Operator				60		⬡					After cast & roll.
2	Pre-Steaming	Steam				30	○						Initiated when full. Valve of
3	Steaming	Steam				180	○						steam only half open for
													pre-steaming. Opened
													completely for steaming.

Appendix D: Flow Process charts- Medium sized pipes

Cage Preparation

Wire Straightening

Flow Process Chart for: Wire Straightening | IE: Lana Steyn | Date__31/03/09______

Page__1___of__1___

No.	Description of Action	Equipment/Tool	Part No.	Qty	Dist	Time	Oper	Handle	Transp	Delay	Inspect	Store	Why, What, Where, When, Who, How Remark
1	Lifting coil onto wire jenny	Crane				6.65			⇨				
2	Removing crane	Crane				0.98		▭					
3	Moving jenny	Operator				0.30			⇨				
4	Cutting coil's packaging wire	Cutter				1.07		▭					
5	Removing packaging wire	Operator				3.75			⇨				
6	Setting machine	Operator				4.33		▭					
7	Inserting wire until first correct length is reached	Wire Straightener				2.17	○						
8	Cutting of wire	Wire Straightener				0.09	○						

Cage Welding

Flow Process Chart for: Cage Welding | IE: Lana Steyn | Date : 31-03-09

Page__1___of__1___

No.	Description of Action	Equipment/Tool	Part No.	Qty	Dist	Time	Oper	Handle	Transp	Delay	Inspect	Store	Why, What, Where, When, Who, How Remark
1	Moving trolley (wire jenny)	Wire jenny				0.35			⇨				
2	Lift crane	Crane				2.43			⇨				
3	Move coil	Crane				0.72			⇨				
4	Put coil on wire jenny	Crane				0.18		▭					
5	Cut the coil's packaging wire	Cutter				2.60		▭					
6	Test (up until 1st correct weld)	Cage Welder				3.23	○						
7	Adjust grid welder's face plate	Cage Welder				22.60		▭					
8	Adjust size of spider wheel	Cage Welder				7.32		▭					
9	Final checks	Operator				0.13					□		
10	Insert wires	Cage Welder				1.06	○						
12	Fasten spider wheel's hooks					0.91		▭					
13	Welding test	Cage Welder				0.46	○						
14	Weld grid	Cage Welder				4.23	○						
15	Tag	Operator				0.40		▭					
16	Cut grid loose	Cutter				1.54		▭					

Socket Welding

Flow Process Chart for: Socket Welding | IE: Lana Steyn | Date________2009-03-31_______

Page__1_of__1

No.	Description of Action	Equipment/Tool	Part No.	Qty	Dist	Time	Oper	Handle	Transp	Delay	Inspect	Store	Why, What, Where, When, Who, How Remark
1	Put grid on welder	Operator				0.57			⇨				
2	Cut ends of grid and bend accordingly	Cutter				3.35		▭					
3	Put socket onto grid	Operator				1.26		▭					
4	Welding of socket	Socket Welder				2.77	○						
5	Remove grid	Operator				1.12			⇨				

Stud Welding

Flow Process Chart for: Stud Welding | IE: Lana Steyn | Date__2009-03-31_____________

Page__1___of__1_

No.	Description of Action	Equipment/Tool	Part No.	Qty	Dist	Time	Oper	Handle	Transp	Delay	Inspect	Store	Why, What, Where, When, Who, How Remark
1	Lift grid onto welder	Operator				0.23			⇨				
2	Weld on studs	Stud Welder				1.63	○						
3	Put grid with studs in trolley	Operator				0.21			⇨				

Mould Strip and Assemble

Assemble Mould

Flow Process Chart for: Assemble mould — IE: Lana Steyn — Date_2009-03-09

Page_1 of 1

No.	Description of Action	Equipment/Tool	Part No.	Qty	Dist	Time	Oper	Handle	Transp	Delay	Inspect	Store	Why, What, Where, When, Who, How Remark
1	Insert grid into mould	Operator				0.63			⇨				When there is only limited
2	Place cover of one side on mould	Operator				0.15		⬭					moulds, this process
3	Tighten one side	Operator				0.27	○						occurs directly after
4	Place cover of second side on mould	Operator				0.33		⬭					stripping.
5	Fasten mould	Air wrench				0.91	○						
													Otherwise this process
													occurs when a pipe needs
													to be made.
													The operator that
													assembles the moulds.
													Also help with the

Strip and clean mould

Flow Process Chart for: Strip and clean mould — IE: Lana Steyn — Date_2009-03-09

Page_1 of 1

No.	Description of Action	Equipment/Tool	Part No.	Qty	Dist	Time	Oper	Handle	Transp	Delay	Inspect	Store	Why, What, Where, When, Who, How Remark
1	Remove pipes from steam chamber	Operator				0.25			⇨				
2	Lift pipe(in mould) and place on bench	Crane				0.78			⇨				
3	Remove crane	Operator				0.24			⇨				
4	Loosen bolts	Air wrench				0.39	○						
5	Remove one side's cover	Operator				0.15	○						
6	Clean cover	Mop				0.97	○						
7	Remove pipe from mould	Crane				1.45	○						These 2 actions happen
8	Clean mould	Mop				1.24		⬭					simultaneously, while the
9	Roll away	Operator				0.25			⇨				first operator is removing
													and moving the pipe, the
													second operator is
													cleaning the mould/

Pipe finishing and inspection

Flow Process Chart for: Pipe finishing and inspection — IE: Lana Steyn — Date_2009-03-09

Page_1 of 1

No.	Description of Action	Equipment/Tool	Part No.	Qty	Dist	Time	Oper	Handle	Transp	Delay	Inspect	Store	Why, What, Where, When, Who, How Remark
1	Light Scrape	Scrape paper		2		0.47	○						There are 2 operators at
2	Wash Pipe	Brush		2		1.75	○						this process. Some events
3	Grind burrs off side	Grinder		2		3.09	○						happen simultaneously.
4	Plaster/patch sides	Cement mix		2		4.88	○						Two pipes are handled per
5	Wipe clean	Cloth		2		1.34	○						action.
6	Stencil	Spray+stencil		2		3.58	○						
7	Inspect	Operator		10		2.93					□		

Stud cap Fitting

Flow Process Chart for: Stud cap Fitting — IE: Lana Steyn — Date 2009-04-02

Page 1 of 1

No.	Description of Action	Equipment/Tool	Part No.	Qty	Dist	Time	Oper	Handle	Transp	Delay	Inspect	Store	Why, What, Where, When, Who, How Remark
1	Place grid on floor or bench	Operator			2m	0.22			⇨				
2	Put studs on grid	Stud Caps				3.98	○						
3	Take grid to assembler	Operator			3m	0.1			⇨				

Cast concrete and cure

Concrete mixing

Flow Process Chart for: Concrete Mixing							IE: Lana Steyn						Date__2009-04-02
													Page__1___ of ___1__
													Why, What, Where, When, Who, How
No.	Description of Action	Equipment/Tool	Part No.	Qty	Dist	Time	Oper	Handle	Transp	Delay	Inspect	Store	Remark
1	Loading of sand, stone and cement	Fister trolley				2.66	○						
2	Throw mix into hole	Fister trolley				0.47			⇨				
3	Mix cement and fly ash	Mixer				3.85	○						
4	Transport mix upwards	Conveyor				0.98			⇨				
5	Mix	Mixer				0.31	○						

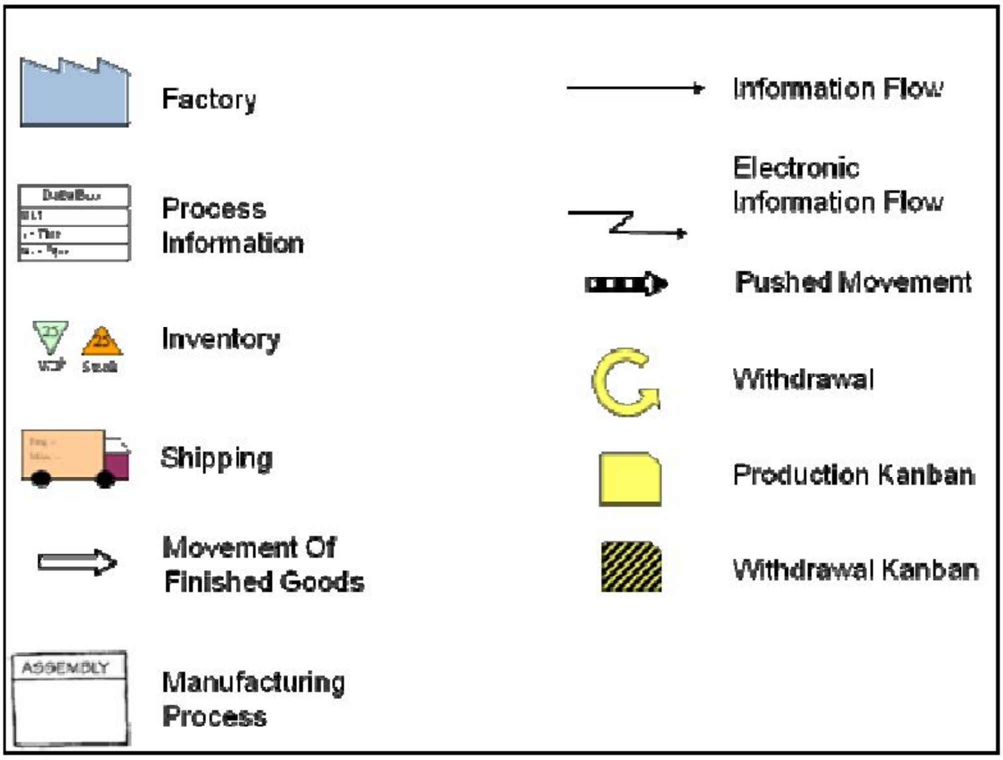
Cast and roll

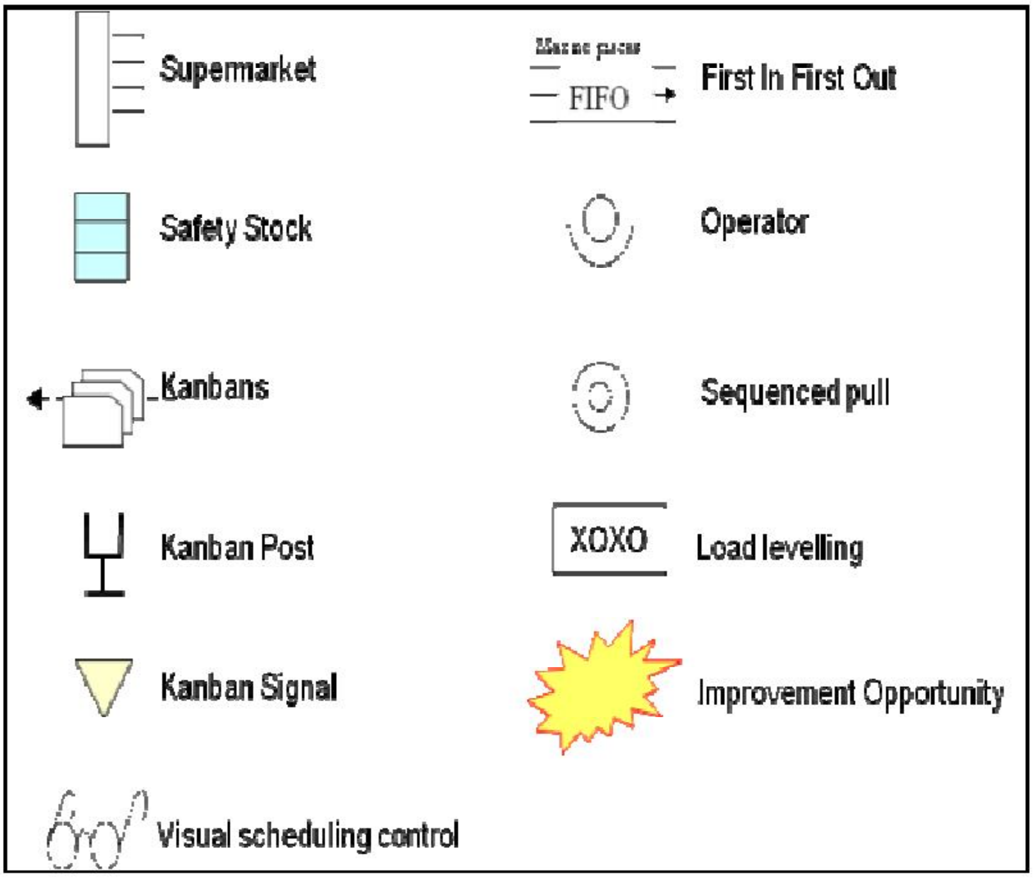
Flow Process Chart for: Cast & Roll							IE: Lana Steyn						Date__2009-04-02
													Page__1___ of ___1__
													Why, What, Where, When, Who, How
No.	Description of Action	Equipment/Tool	Part No.	Qty	Dist	Time	Oper	Handle	Transp	Delay	Inspect	Store	Remark
1	Lift mould into cast machine	Crane				1.54			⇨				
2	Slow speed cast	Roller				1.15	○						
3	Medium speed cast	Roller				0.98	○						
4	Fast cast	Roller				0.65	○						
5	Cast while throwing in sand	Operator+Roller				0.76	○						
6	Lift mould	Crane				1.28			⇨				

Pre-cure and cure

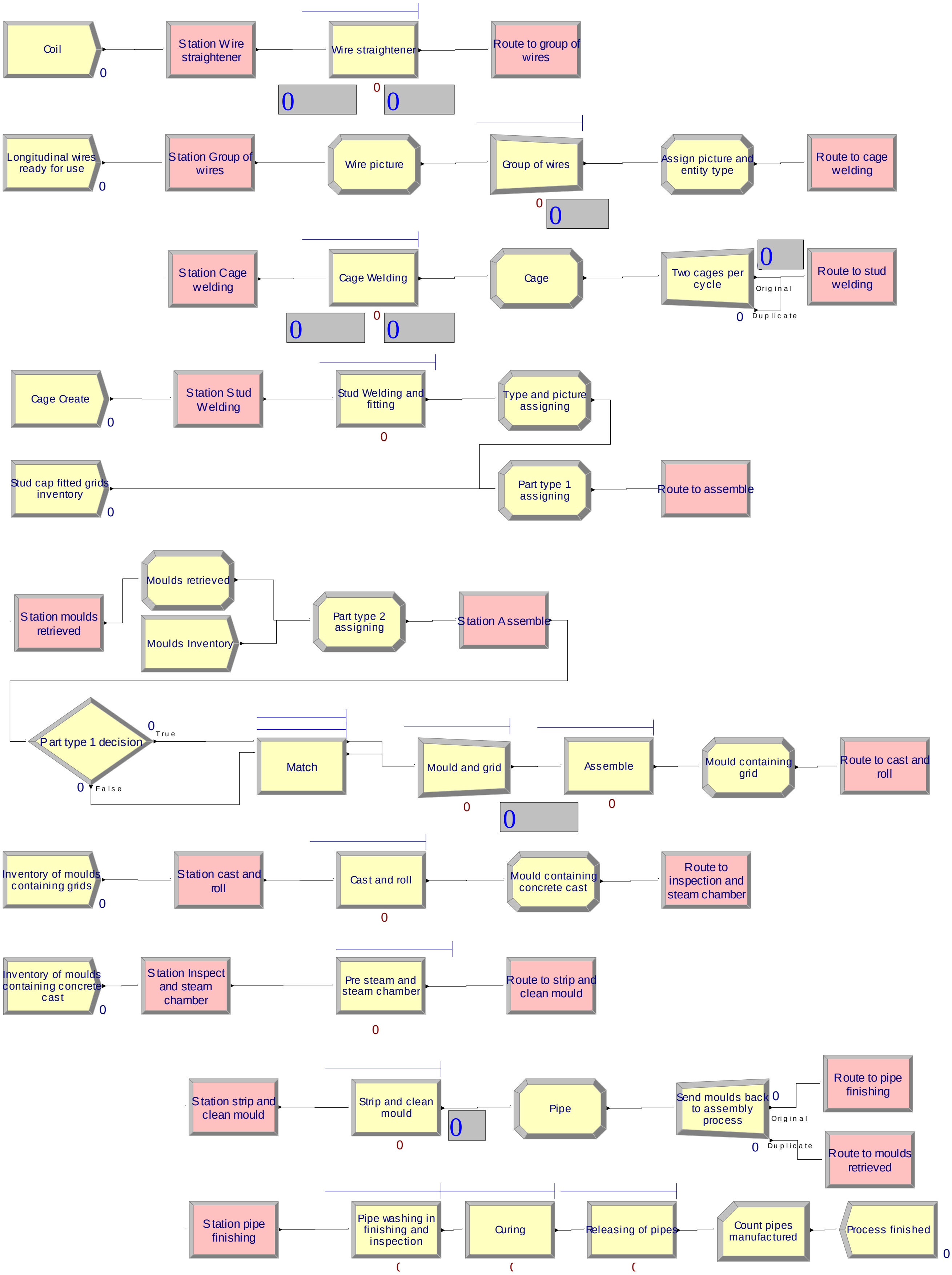
Flow Process Chart for: Pre-curing and curing							IE: Lana Steyn						Date__2009-04-01
													Page__1___ of ___1__
													Why, What, Where, When, Who, How
No.	Description of Action	Equipment/Tool	Part No.	Qty	Dist	Time	Oper	Handle	Transp	Delay	Inspect	Store	Remark
1	Place moulds in steam chamber	Operator				60		⬡					After cast & roll.
2	Pre-Steaming	Steam				30	○						Initiated when full. Valve of
3	Steaming	Steam				180	○						steam only half open for
													pre-steaming. Opened
													completely for steaming.

Appendix E: Value Stream Mapping Icons

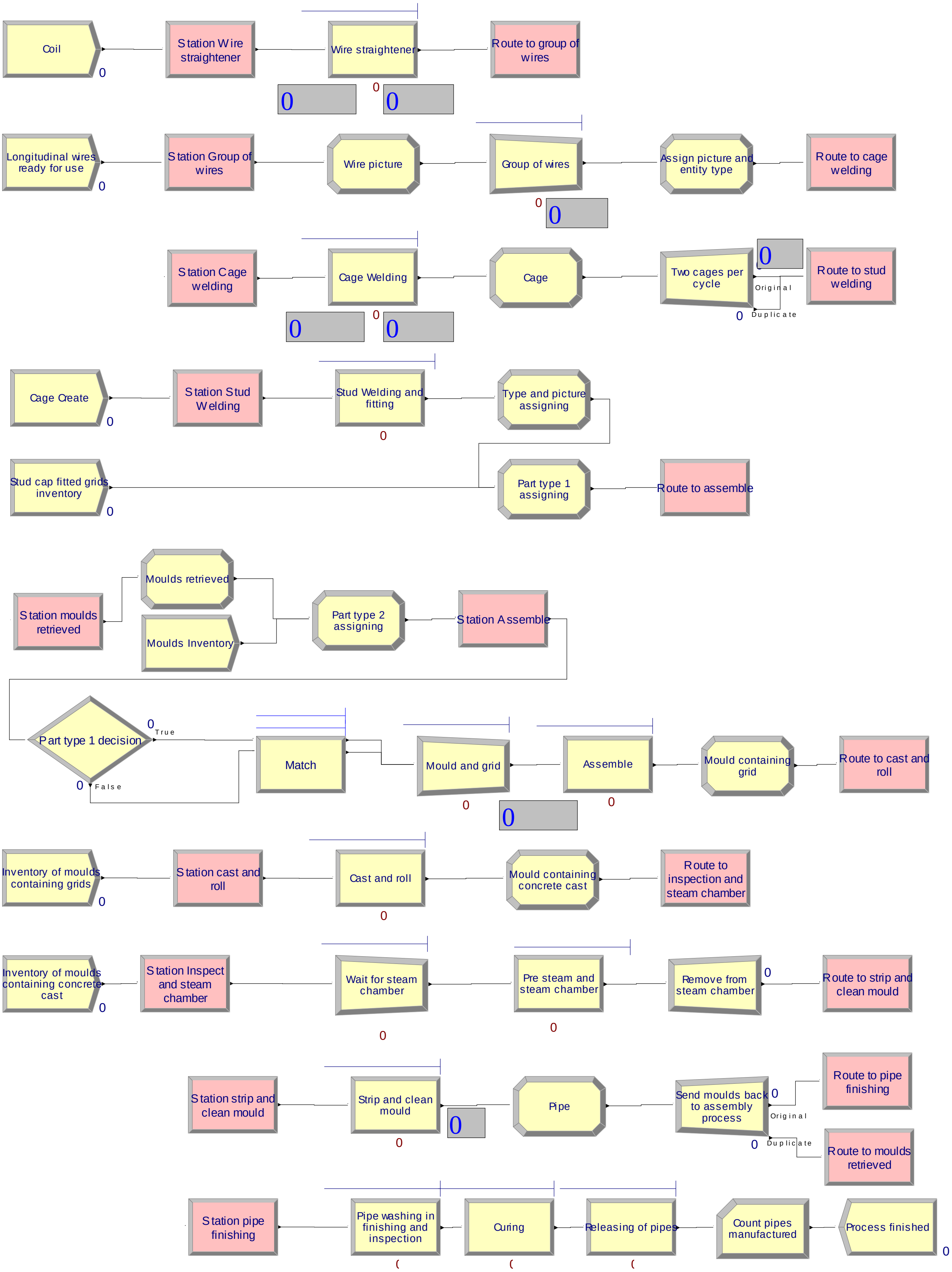




Appendix F: Proposed Solution 1



Appendix G: Proposed solution 2



Appendix H: Proposed Solution 3