FINAL REPORT

Simulating for Better Performance of Cosira Manufacturing

Using Simulation Modelling to Improve Manufacturing System and Flow

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ACKNOWLEDGEMENTS

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ABSTRACT

Since the economic downturn in 2009 Cosira International found that the order winning criteria came down to supply price. The order qualifying criteria became reliable delivery and quick response times.

This project will look at the Cosira Vulcan manufacturing plant and its operation. This workshop will be optimised though computer simulation in order to streamline the manufacturing process and thus increasing the potential profitability of the manufacturing division.

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INTRODUCTION

BACKGROUND OF COSIRA INTERNATIONAL

1988: John da Silva Senior has the vision to start a small, entrepreneurial, family-owned business in Heriotdale, Johannesburg, occupying just one portion of what later became known as Cosira Shop 1. The business starts off with only three staff members, as a second tier supplier to larger fabricators. Through John da Silva Senior's inspired leadership and his recognition of the need for personalised, flexible, reliable service, the business quickly becomes known as a reputable supplier to the steel industry in South Africa. Built on the strong cornerstones of quality, timely delivery and correct pricing, the Cosira Group starts to grow.

1999: This was a significant growth point for the group as it became a first tier supplier for the Anglo Platinum Waterval 400 KTPM concentrator. This led to the award of other key projects including Maandagshoek concentrator and the Pietersburg smelter; all of which bear testimony to Cosira's ability to not only operate successfully at a new level, but indeed to set the industry benchmark for project execution.

2000: Cosira enters the new millennium as an industry-leading first tier supplier to the South African steel industry, and doubles its turnover year-on-year from 2000 to 2006.

2001: Cosira decides to change its vision from that of only being a steel fabricator to a construction company, otherwise known as 'the construction solutions group'. This precipitates the establishment of Cosira Developments, the retail and industrial property construction and development project arm which later became a separate group within the Silva Group Holdings group of companies called Moreland Investments.

2002: Cosira sees the need to develop a fully integrated approach to structural steel detailing and fabrication. Despite the prevailing economic slump in the industry at the time, Cosira strikes out and invests substantially in a draughting facility with

CAD/CAM technology, making it possible to own the process at all stages of the manufacturing cycle.

Cosira handles all aspects of project management, planning, detailing, fabrication, corrosion protection and finishing, site erection, commissioning and construction management, thereby offering turnkey solutions at optimum efficiency.

Cosira also invests in its first CNC (Computer Numerically Controlled) equipment.

Furthermore, in 2002, Cosira acknowledges that, for the company to continue on its successful growth path, it must offer the industry the full range of services, from detailing and fabrication, right through to commissioning of projects. Cosira employs key leaders and skills in site construction and thereby establishes a site construction SMPP arm to the business.

2003: Cosira sees the need to operate as a fully South African company, and to this end initiates negotiations with the TIH Group.

2004: In January 2004, following the conclusion of a black empowerment deal with the TIH Group, the company became the first major black empowered structural steel fabrication, mechanical, platework and piping construction company in South Africa. Now officially, the 'Cosira Group', it is initially accredited by the South African Mining Preferential Procurement Forum (SAMPPF).

The Group has one structural steel shop in operation. Over the next two years, a further three steel shops are opened and become operational, further testimony to Cosira's successful growth trajectory over this time period.

2005: In 2005, the Cosira Group initiates further diversification into related industries with the establishment of Cosira IMS (Industrial and Mining Solutions), which provides solutions and equipment for the industrial and mining sector.

In the same year, Cosira Towers is established as a transmission line and cellular tower business, targeting the tremendous opportunities taking place on the African continent in the cellular and electricity transmission and distribution markets.

2006: The Group wins the Export Category Steel Award for the Dangote Cement Conveyer Project exported to Nigeria.

2007: In response to the significant personnel and skills shortages in South Africa, the Cosira Group concludes a strategic supply partnership with Paradigm HR Solutions in order to secure reliable source of quality, skilled resources.

The Group wins the Export Category Steel Award for the Snap Lake Diamond Recovery project exported to Canada.

2008: Cosira proudly makes a ground breaking investment and starts construction of state-of-the-art facilities, such as the new Vulcania premises – 'Cosira Vulcan'.

Cosira is one of the winners of the overall Steel Award for 2008, for their structural steelwork on Soweto's ground breaking Maponya Mall.

Communications tower supplier, Cosira Towers, grows to the stage where it becomes an independent subsidiary of the Cosira Group, known as Cosira Towers.

A new subsidiary is founded - Cosira Electrical and Instrumentation Projects – to broaden the comprehensive turnkey offering of the Cosira Group.

2009: The Cosira Group celebrates its 21st anniversary, with the launch in October 2009 of Cosira Vulcan, the Group's flagship fabrication investment, a world-class, state-of-the-art facility, which is one of the most technologically-advanced, efficient structural steel fabrication facilities today.

The Group also wins the largest single contract to date, and the first in the all-important South African power generation sector – the Turbine Hall Contract for the Medupi Power Station project by Eskom, managed by Alstom.

Cosira is also awarded ISO9001:2008 accreditation and Level 6 Empowerdex BBBEE certification.

2011: Cosira Manufacturing hit a milestone by producing more than 2500 tonnes in the month of October from its Cosira Vulcan plant and almost 3000 tonnes from all plants and sub-contractors combined.

(Cosira International, 2012)

PROJECT AIM

PROBLEM STATEMENT

Early in 2012 the shareholders and top management of the Cosira Group informed all staff members of the acquisition of Cosira Group by First Tech Group. This handover will be gradual over the following 18 months. The reason for the transaction is not clear at all, however from the inside there is some evidence that Cosira was on the verge of going under. When looking at the five steps of a great company's “death” according to Jim Collins' How the Mighty Fall (Collins, 2009)

:

- Step 1: Hubris born of success – As is evident from Cosira’s background; it is no surprise that Cosira will have a positive attitude about their performance.
- Step 2: Undisciplined pursuit of more – Recent expansions to the workshop were done and brand new equipment was installed to the value of R50’000’000 without considering the current market trends.
- Step 3: Denial of risk and peril – For the past two years Cosira was unsuccessful in being awarded any significant new contracts. However the contracts running at the moment is still enough to keep the company going for a few years and thus the company appears to be doing well.
- Step 4: Grasping for salvation – In 2011 Cosira started the process of looking for a willing buyer with large enough infrastructure and reach to bring in new work to the company.
- Step 5: Capitulation to irrelevance or death – This step is not reached yet by Cosira and according to Jim Collins a company can still survive and prosper when it has not yet reached this step.

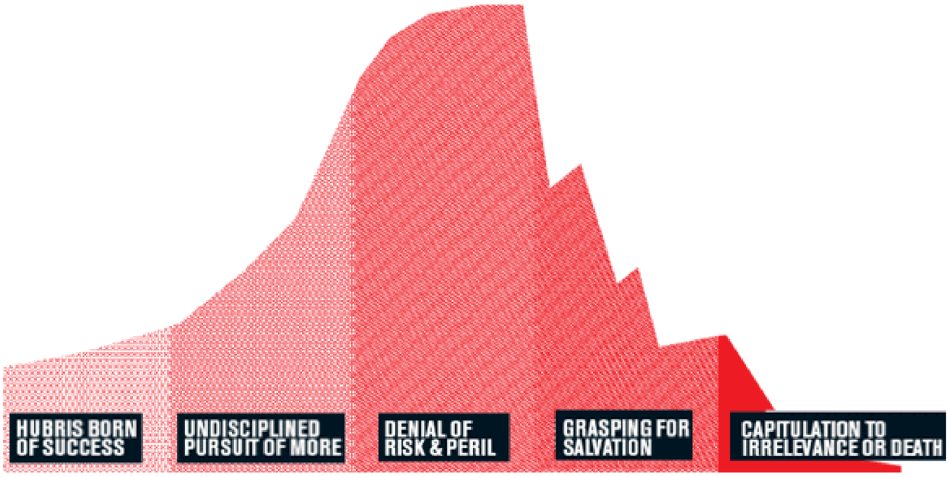


Figure 1 - How the Mighty Fall (5 steps)

The reason why Cosira has not been successful in being awarded contracts is purely financially rooted. Cosira is not able to tender for the same price as the competitors; it is even more cost effective to tender using the fabrication facilities of sub-contractors.

Cosira’s manufacturing division is bulky, non-reactive and ineffective. With the initial analysis showing that the resources are not properly balanced and that there are unwanted bottlenecks in the workshop which may be a result of the layout of the workshop.

PROJECT GOAL

The main goal of this project is improving the profitability of the manufacturing division of Cosira International.

PROJECT OBJECTIVES

The following objectives will contribute to achieving the main goal of the project:

- Determine the real current capacity of the workshop based on the actual operation of the workshop.
- Streamlining the resource balance of the manufacturing division.
- Improving the throughput time of work in the workshop.
- Increasing the potential capacity of the workshop.

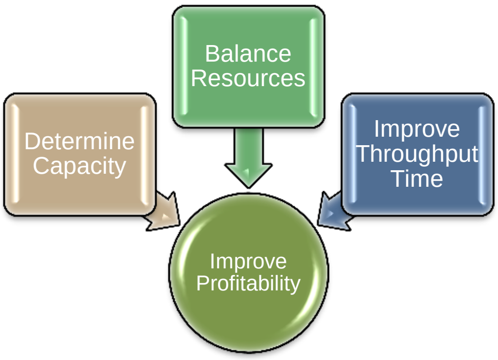


Figure 2 - Project Purpose

PROJECT APPROACH

The first part of the project was to observe and evaluate the manufacturing department of Cosira. Based on this evaluation possible problems were then identified.

The next step was to research, describe and compile a literature review of the problems that were identified. This is followed by the collection and initial analysis of any relevant data that will be used later to confirm the assumptions of the current problems.

Part of the data analysis process is to determine the nature of the processes in terms of process times, material handling speed, time and discipline, resource usage and movements, etc. This information will be used in the next step; which is the development of an Arena Simulation Model that resembles the current status of the Cosira Manufacturing workshop. This model will be used to confirm whether the data collected is accurate, and if the problems identified in the initial stages of the project were correct.

In an attempt to improve the performance of the workshop, and to eliminate to a large extent the problems within the workshop, the simulation model will be adjusted a few time focussing on a specific problem at a time.

These models will then be scrutinised and a single model will then be designed based on the sum of best sections of each of the previous models. This model will then be used to compile a possible performance improvement report, as well as the implementation plan to accomplish the improvements in a sustainable method.

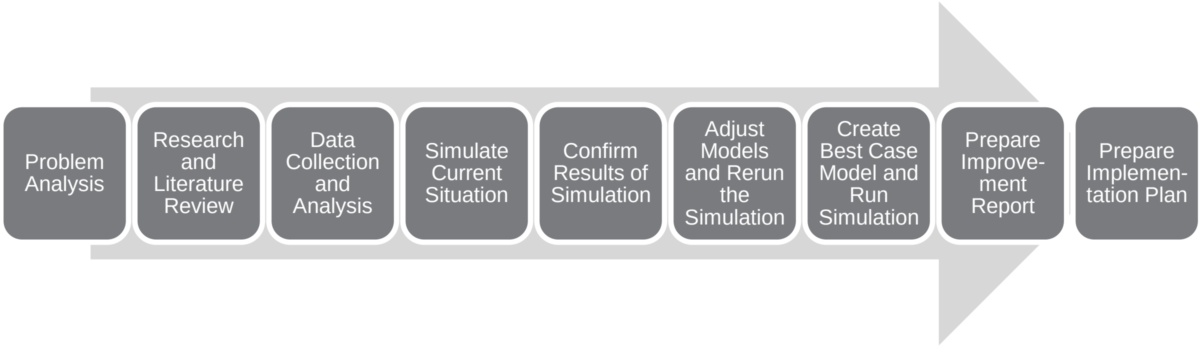


Figure 3 - Project Approach and Implementation

LITERATURE REVIEW

INTRODUCTION TO LITERATURE REVIEW

The literature review will firstly attempt to define the environment of the problem, as well as various technical aspects related to the specific environment. This will be followed by the industrial engineering techniques that are available for addressing issues in the specific environment, as well as the selection of the appropriate techniques for this project.

PROJECT ENVIRONMENT: JOB SHOP

DEFINITION OF A JOB SHOP

The following definition of a job shop is given in (Aquilano, Chase, & Jacobs, 2006):

“Production of small batches of a large number of different products, most of which require a different set or sequence of processing steps.”

The figure below shows the positioning of the job shop relative to other manufacturing environments: (NetMBA.com)

	Project	Job Shop	Batch Process	Assembly Line	Continuous Flow
Flow	None		→		Continuous
Flexibility	High		→		Low
No of Products	High		→		Low
Capital Investment	Low		→		High
Variable Cost	High		→		Low
Labour Content	High		→		Low
Labour Skill	High		→		Low
Volume	Low		→		High

Table 1 - Manufacturing Environment Comparison

Cosira Manufacturing is the perfect example of a job shop with an average of 2’000 tonnes of structural steel assemblies being dispatched every month from the 30’000m^2 workshop. This equates to between 4’500 and 9’000 assemblies (based on work mix for the month) of which 95% are different from any other assembly worked on. Each assembly is made up of a number of parts that need to be produced in the same workshop, this means that the workshop needs to produce up to 40’000 parts, in addition to assembling them, of which more than 80% are different from the rest.

CHARACTERISTICS OF A JOB SHOP

LAYOUT AND ROUTING

In a job shop layout, similar machines and operations are usually grouped together. This means that a part will have to be routed from one area to another according to the processes needed to be performed on the specific part. This might result in a part having to visit a certain area of the workshop more than once. The layout of the workshop needs to be designed to minimise material handling costs and inventory build-up. (Aquilano, Chase, & Jacobs, 2006), (Answers.com)

EMPLOYEES

The employees in a job shop are usually highly skilled employees with the correct training to operate the machines in the workshop. (Answers.com) Job shops also employ more employees than most other manufacturing environments due to the “random” nature of the work being performed.

INFORMATION

Information is the most curtail part of a job shop business. Information is required to do everything in the business; from quoting/tendering, generating works orders, routing, scheduling the project, etc.

Information is gathered using job sheets and time cards in order to perform labour and production cost calculations. The records with this information should be kept up to date to assist with quoting of future jobs. (Answers.com)

SCHEDULING

In a job shop a job is characterised by its route / processing requirements and its priority. In a job shop the job mix determines the routing of the jobs, this means that the jobs will not necessarily be completed in the same order they arrived, but in such an order as to minimise machine set-ups and change-overs. (Answers.com)

PROJECT ENVIRONMENT: FABRICATION SHOP

DEFINITION OF A FABRICATION SHOP

A fabrication shop (like Cosira's manufacturing workshop) is in a sense a specialised job shop.

Fabrication is an industrial term that refers to the building of metal structures by preparing parts (cutting, drilling, punching, shearing, and sawing) and building metal assemblies from these parts (Wikipedia.org). The building of the assemblies always requires a high level of skill with initial assembly being performed by a trained artisan (like a boiler maker).

AVAILABLE INDUSTRIAL ENGINEERING METHODS, TOOLS AND TECHNIQUES

Many industrial engineering techniques and tools are available to investigate and improve the output of fabrication facilities. The following techniques were considered for this project:

LEAN MANUFACTURING

Lean is a production control technique for eliminating waste from the organisation. (Lean Manufacturing Japan.com)

The implementation of lean manufacturing are guided by the following five steps: (Lean.org)

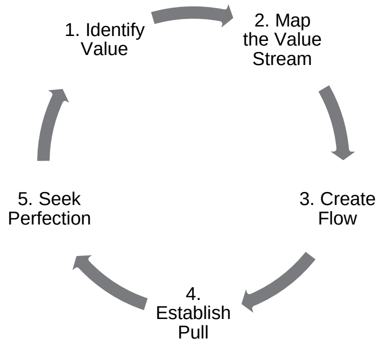


Figure 4 - Principles of Lean

1. Specify the value of the output relative to the end user’s perception of value
2. Identify that value stream of production, and try to eliminate those steps that do not add value, and are not necessary for production
3. Tighten the sequence of occurrence of these steps in order to create smooth flow
4. Allow customers to “pull value” from the upstream activities (this is the value refinement stage)
5. In this step the refined value definition is introduced into the value stream and the process repeats itself into infinity

JUST-IN-TIME MANUFACTURING

Just-In-Time (JIT) manufacturing is one method of achieving lean manufacturing. The aim of JIT manufacturing is to reduce waste. According to (Tompkins, White, Boser, & Tanchoco, 2003) the seven types of waste are:

- Waste arising from overproduction
- Waste arising from time on hand (waiting)
- Waste arising from transporting
- Waste arising from processing itself
- Waste arising from unnecessary stock on hand
- Waste arising from unnecessary motion
- Waste arising from producing defective goods

The reduction of waste is achieved by providing the right amount of the right material, in the right condition (quality), at the right place (routing), at the right time (scheduling), in the right position, in the right sequence (job sheet), and for the right costs (budget), by using the right method. (Tompkins, White, Boser, & Tanchoco, 2003)

LINE/RESOURCE BALANCING

Line balancing is an operations research method of assigning operations to workstations in an assembly line, in such a way that the assignment be optimal in some way (Falkenauer). Line balancing aims at reducing bottlenecks as well as excess capacity (Six Sigma Material).

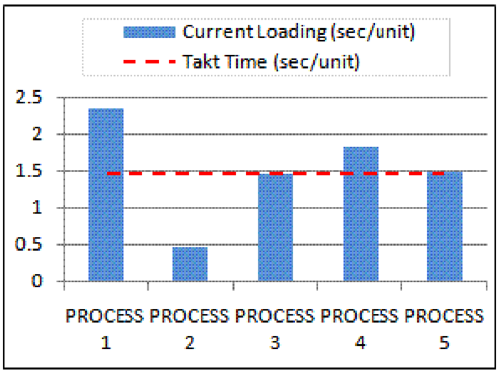


Figure 5 - Unbalanced Line

Figure 5 above shows the processing time of a general 5 process assembly line that has not been balanced. The result of this unbalanced line will cause some form of wastes mentioned in the previous section. Looking at the graph in figure 5, process 2 will wait for material from process 1. If process 2 receives material as and when required it will over supply to process 3, which will in turn create large WIP build-up and another form of waste. Process 3 and 5 are almost in balance and should not cause too much wastage. But process 4 is again taking too long. The idea is to redesign the processes and divide tasks between the processes (or add resources to processes) that will cause the processes to have close to the same duration.

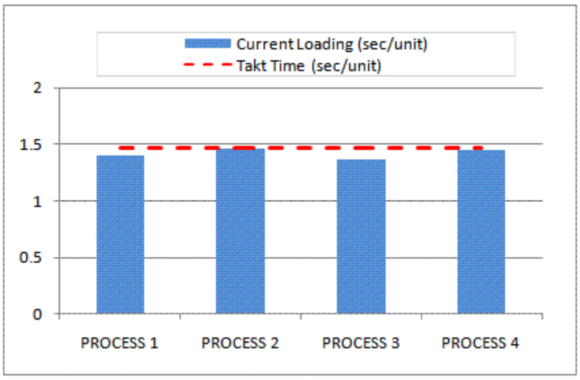


Figure 6 - Balanced Line

Figure 6 above shows the processing time for a newly defined four process assembly line with balanced activity durations.

THEORY OF CONSTRAINTS

"A chain is only as strong as its weakest link."

The theory of constraints (TOC) applied this idiom to processes, divisions and businesses (Wikipedia.org). The TOC are explained very well by Eliyahu M. Goldratt in his book "The Goal". The Goal demonstrates the TOC in an everyday situation in a language that everyone will understand. The following key points are highlighted in this book (Goldratt, 2004):

TOC is also a cycle of on-going improvement as is displayed below.

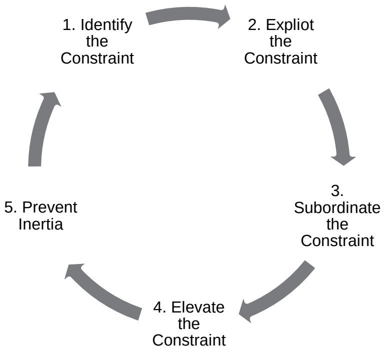


Figure 7 - Process of On-going Improvement (TOC)

1. A practical way to identify a constraint is to look for the largest pile of idle WIP, in most cases the constraint will be the process immediately following the idle WIP.
2. There are various ways to exploit the constraint; the main objective is to have the process constraining the system work as hard as possible with the available resources.
3. The objective here is to find other processes (non-constraints) in the workshop that can assist the constraining process to catch up the production requirements.
4. Here the constraining process should permanently be improved, again there are a few ways to achieve this, some ways are buying new / more equipment that can do the job, reengineer the process, change the layout of the workshop, etc.
5. To prevent inertia there needs to be a system regulating the speed of production. This system is described as the "Drum-Buffer-Rope" system in the book.
    a. The constraint is the drum. It keeps the beat for the rest of the production to follow.
    b. Buffer stock should be maintained just after the constraint in case of a system failure.
    c. The processes following the constraint are the rope, they will indicate when the constraint is failing to produce as required.

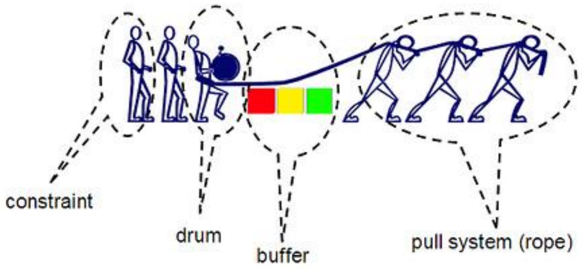


Figure 8 - Drum - Buffer - Rope System

SIMULATION MODELLING

Simulation modelling is an important part of engineering design, used for training purposes, to save time and money, to optimise a system, to predict performance, to enhance understanding of system behaviour, and to examine worst case scenarios (Hewitt).

Simulation also refers to a wide collection of methods and tools to “copy” the behaviour of real systems; simulation is usually done with computer based software (Kelton, Sadowski, & Sturrock, 2004).

Simulation packages, such as Arena and Simio, are good tools to use in the simulation of fabrication facilities, since the simulation model is based on basic flow chart procedures and since most companies have their processes mapped out, it can be imported into the simulation package.

SELECTION OF APPROPRIATE INDUSTRIAL ENGINEERING METHODS, TOOLS AND TECHNIQUES

After evaluating the mentioned techniques, the following techniques were selected for the project:

LINE/RESOURCE BALANCING

Initial investigations have shown that there are a resource balance issue within the assembly department. Line balancing will resolve a lot of in-department throughput problems. Line balancing however would probably not work for the whole workshop.

THEORY OF CONSTRAINTS

In investigating TOC, it became clear that this would be a very convenient production improvement project for the whole manufacturing workshop. The main reason for this is that the constraint can be artificially selected and maintained in order to regulate the effective flow of work through the workshop applying the Drum-Buffer-Rope principal.

SIMULATION MODELING

Since physical experiments in a production shop are very expensive and disruptive to production, and it takes a long time to see results (not yet knowing if the results will be positive or negative), computer based simulation will be the ideal tool to design and evaluate the possible production improvement projects. This project will evaluate the current and possible improvement models of the Cosira manufacturing workshop using Arena simulation software.

DEVELOPMENT OF SUPPLEMENTARY METHODS, TOOLS AND TECHNIQUES

The techniques and tools discussed in the previous section are sufficient for this project, and thus no supplementary methods will be required.

DATA AND INFORMATION GATHERING AND ANALYSIS

MATERIAL FLOW

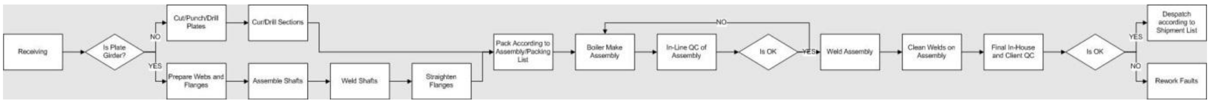


Figure 9 - Material Flow of Cosira Manufacturing (See Appendix A for Larger Image)

The diagram above shows a very simple flow of material through the Cosira Manufacturing plant. A larger (more legible) version of this flow diagram was included in an appendix to this document.

DECISIONS AND ASSUMPTIONS

After looking at the material flow through the workshop, and before doing intensive data analysis, some decisions and assumptions pertaining to the simulation model need to be specified in order to know what data to collect and how to analyse the data. These decisions and assumptions are listed below.

DECISION 1 - ARENA: STUDENT OR FULL VERSION

The first decision regarding the gathering and analysis of data was to decide on the version of Arena that would be used for simulating the manufacturing department of Cosira, and how this would influence the data analysis. There are two versions to be considered, the free student version, and the full version which requires a license dongle to work. The main difference between the versions is the number of entities running in the simulation. The student version allows for 150 entities, and the full version for unlimited entities. After considering the logistical issues in trying to use the full version of the software the decision was taken to simulate using the limitations of the student version. The following step was to determine how to simulate with the restrictions of the student version of Arena while still representing accurate information.

COUNTER DECISION - ARENA: STUDENT OR FULL VERSION

As mentioned in Decision 1, the student version would be used to model. After several attempts to make the simulation work failed the decision was reversed to using the full version. A licence for the full version of the software was borrowed from the University of Pretoria.

DECISION 2 – SIMULATING OVERHEAD CRANES

The standard version of Arena does not allow for the overhead crane as a type of transporter, there are an after-market crane simulation module available from a company in Argentina, this however is not a free version and will not be considered. Since cranage is not considered to be a restraint in Cosira's manufacturing plant, it does not have to be modelled in great detail. Only simple routing will be used for material movement in the workshop.

DECISION 3 – JOB SIZE / COMPLEXITY

Although each contract / job that is processed by Cosira is unique, they can be categorized into a couple of simple work types as the diagram below shows:

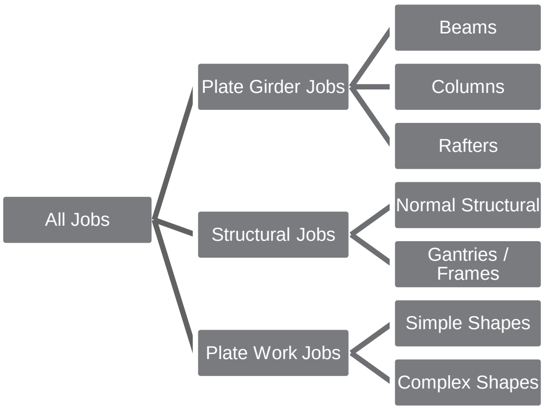


Figure 10 - Cosira Work Types

Each of these seven work types have sub types based on average assembly masses. The decision that needed to be made was how to simulate the workshop using generalisations on work type, but still portray an accurate view of the workshop. The decision was made easier by looking at the order book of Cosira for the foreseeable future with a job mix as in the table below:

Main Work Type	% of Order Book	Work Type	% of Order Book
Plate Girders	5%	Beams	2%
		Columns	2%
		Rafters	1%
Structural	55%	Normal	35%
		Gantries	20%
Plate Work	40%	Simple Shapes	30%
		Complex Shapes	10%

Table 2 - Cosira Work Type Mix

Based on the work type mix the decision was made to only simulate for four types of work; both structural and both Plate Work types.

DECISION 4 – WORKSHOP AREAS TO SIMULATE

The initial plan was to simulate the whole workshop, but based on decision 1 (using the student version of Arena and adapting the model to fit the limitations of the student version) not all areas of the workshop can be simulated. When looking at the layout of the workshop, there are two main departments; prep / supply department and fabrication department.

The prep / supply department again consists of the CNC department with all the machines to cut, punch, drill, and shape material, and a Plate Girder Shaft Assembly department, the latter was not simulated based on Decision 3, but all the CNC machines will be simulated.

The fabrication department consists of four fabrication bays all doing all types of work, but in different ratios. For that reason only one bay was simulated (as a general fabrication bay) where a quarter of all the jobs flowing through the workshop were processed by this bay.

All work not processed by the general fabrication bay was only discarded from the simulation after prep / supply to stay within the limitations of the student version of Arena.

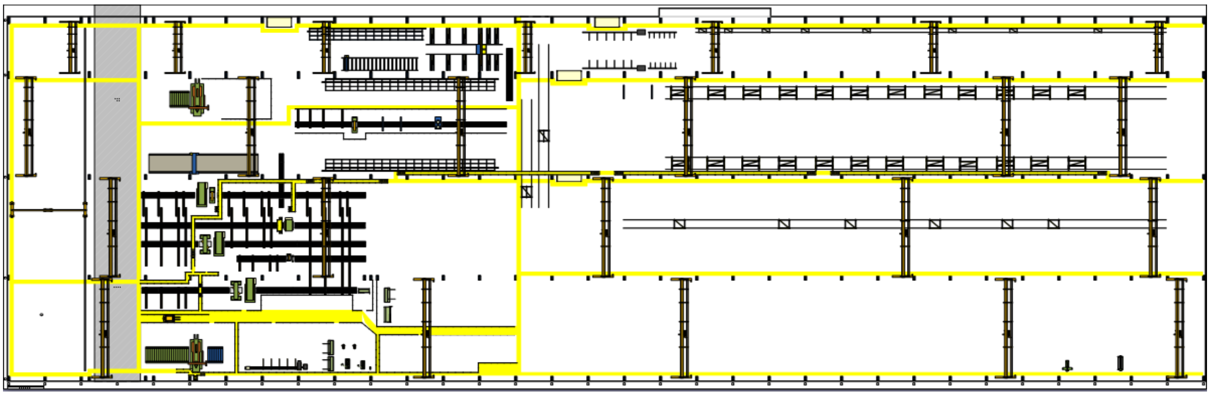


Figure 11 - Cosira Vulcan Workshop Layout

DECISION 5 – ANIMATING THE SIMULATION

Since all the results from the simulation will be analysed and presented in this report, a decision was made to only animate the simulation after all academic parts of the project is completed.

Animation will only be done to improve the aesthetic feel of the simulation and will not be considered a priority.

ASSUMPTION 1 – MATERIAL SUPPLY IS PERFECT

The first major assumption for this project is that the supply of material is “perfect”. In other words all material required for a job is delivered in full and on time. Although this does not reflect reality, partial delivery can be viewed as an assignable cause of variation and should be handled by management.

ASSUMPTION 2 – MATERIAL HANDLING IS EFFECTIVE

As mentioned in Decision 2, the assumption is that material handling can be considered as effective and sufficient. It will not be considered as a constraint and will therefore not form part of the proposed improved solution.

ASSUMPTION 3 – MACHINE BREAKDOWNS ARE NEGLIGIBLE

Although breakdowns do occur currently, the implementation of a scheduled maintenance plan should decrease the possibility of the machines breaking down and causing unplanned down time. Since the aim of the project is to find ways of improving throughput time, the ideal workshop would be simulated and any improvement from there would be carried over to the real world workshop.

ASSUMPTION 4 – ABSENTEEISM IS NEGLIGIBLE

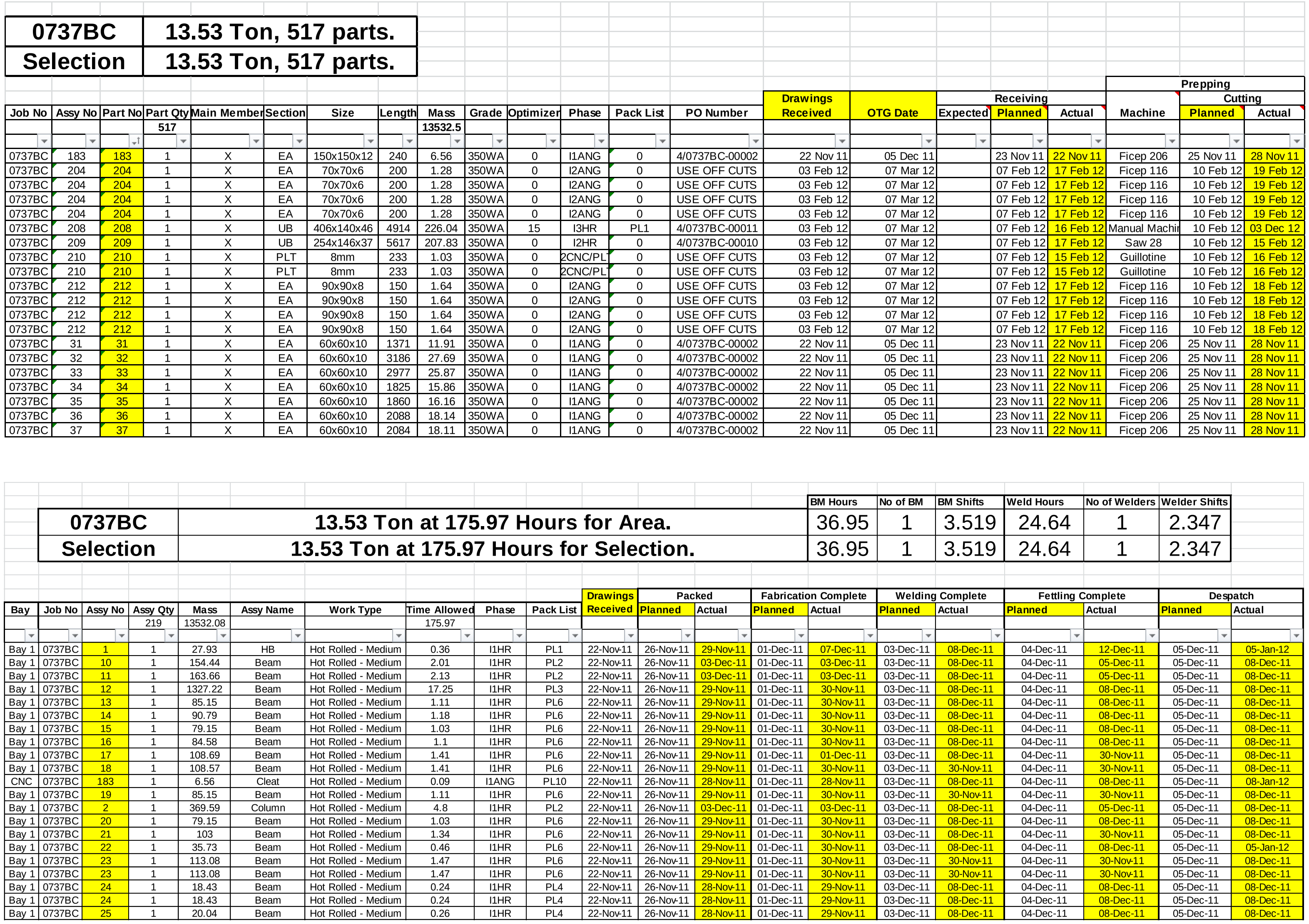
Again as mentioned above, the idea is to simulate the ideal workshop and improve throughput thereof. The assumption of absenteeism is aimed at making the simulation of resources simpler.

DATA GATHERING

PRODUCTION TRACKING SHEETS

A vast amount of raw data has been collected from Cosira's production tracking and MRP systems. This data shows clearly the duration each part/assembly spends at any particular are in the workshop. The images on the next page show a section from the production tracking sheets for the parts up to the staging area, and the assemblies from the staging area up the dispatch (each phase of each contract has a set of sheets like this).

The only problem with these sheets is that the idle time of the material could not be identified, further investigation was needed to determine idle vs. value adding time.



0737BC	**13.53 Ton, 517 parts.**
Selection	**13.53 Ton, 517 parts.**

																			Prepping		
																Receiving				**Cutting**	
Job No	**Assy No**	**Part No**	**Part Qty**	**Main Member**	**Section**	**Size**	**Length**	**Mass**	**Grade**	**Optimizer**	**Phase**	**Pack List**	**PO Number**	**Drawings Received**	**OTG Date**	**Expected**	**Planned**	**Actual**	**Machine**	**Planned**	**Actual**
			517					13532.5													
0737BC	183	183	1	X	EA	150x150x12	240	6.56	350WA	0	I1ANG	0	4/0737BC-00002	22 Nov 11	05 Dec 11		23 Nov 11	22 Nov 11	Ficep 206	25 Nov 11	28 Nov 11
0737BC	204	204	1	X	EA	70x70x6	200	1.28	350WA	0	I2ANG	0	USE OFF CUTS	03 Feb 12	07 Mar 12		07 Feb 12	17 Feb 12	Ficep 116	10 Feb 12	19 Feb 12
0737BC	204	204	1	X	EA	70x70x6	200	1.28	350WA	0	I2ANG	0	USE OFF CUTS	03 Feb 12	07 Mar 12		07 Feb 12	17 Feb 12	Ficep 116	10 Feb 12	19 Feb 12
0737BC	204	204	1	X	EA	70x70x6	200	1.28	350WA	0	I2ANG	0	USE OFF CUTS	03 Feb 12	07 Mar 12		07 Feb 12	17 Feb 12	Ficep 116	10 Feb 12	19 Feb 12
0737BC	204	204	1	X	EA	70x70x6	200	1.28	350WA	0	I2ANG	0	USE OFF CUTS	03 Feb 12	07 Mar 12		07 Feb 12	17 Feb 12	Ficep 116	10 Feb 12	19 Feb 12
0737BC	208	208	1	X	UB	406x140x46	4914	226.04	350WA	15	I3HR	PL1	4/0737BC-00011	03 Feb 12	07 Mar 12		07 Feb 12	16 Feb 12	Manual Machir	10 Feb 12	03 Dec 12
0737BC	209	209	1	X	UB	254x146x37	5617	207.83	350WA	0	I2HR	0	4/0737BC-00010	03 Feb 12	07 Mar 12		07 Feb 12	17 Feb 12	Saw 28	10 Feb 12	15 Feb 12
0737BC	210	210	1	X	PLT	8mm	233	1.03	350WA	0	2CNC/PL	0	USE OFF CUTS	03 Feb 12	07 Mar 12		07 Feb 12	15 Feb 12	Guillotine	10 Feb 12	16 Feb 12
0737BC	210	210	1	X	PLT	8mm	233	1.03	350WA	0	2CNC/PL	0	USE OFF CUTS	03 Feb 12	07 Mar 12		07 Feb 12	15 Feb 12	Guillotine	10 Feb 12	16 Feb 12
0737BC	212	212	1	X	EA	90x90x8	150	1.64	350WA	0	I2ANG	0	USE OFF CUTS	03 Feb 12	07 Mar 12		07 Feb 12	17 Feb 12	Ficep 116	10 Feb 12	18 Feb 12
0737BC	212	212	1	X	EA	90x90x8	150	1.64	350WA	0	I2ANG	0	USE OFF CUTS	03 Feb 12	07 Mar 12		07 Feb 12	17 Feb 12	Ficep 116	10 Feb 12	18 Feb 12
0737BC	212	212	1	X	EA	90x90x8	150	1.64	350WA	0	I2ANG	0	USE OFF CUTS	03 Feb 12	07 Mar 12		07 Feb 12	17 Feb 12	Ficep 116	10 Feb 12	18 Feb 12
0737BC	212	212	1	X	EA	90x90x8	150	1.64	350WA	0	I2ANG	0	USE OFF CUTS	03 Feb 12	07 Mar 12		07 Feb 12	17 Feb 12	Ficep 116	10 Feb 12	18 Feb 12
0737BC	31	31	1	X	EA	60x60x10	1371	11.91	350WA	0	I1ANG	0	4/0737BC-00002	22 Nov 11	05 Dec 11		23 Nov 11	22 Nov 11	Ficep 206	25 Nov 11	28 Nov 11
0737BC	32	32	1	X	EA	60x60x10	3186	27.69	350WA	0	I1ANG	0	4/0737BC-00002	22 Nov 11	05 Dec 11		23 Nov 11	22 Nov 11	Ficep 206	25 Nov 11	28 Nov 11
0737BC	33	33	1	X	EA	60x60x10	2977	25.87	350WA	0	I1ANG	0	4/0737BC-00002	22 Nov 11	05 Dec 11		23 Nov 11	22 Nov 11	Ficep 206	25 Nov 11	28 Nov 11
0737BC	34	34	1	X	EA	60x60x10	1825	15.86	350WA	0	I1ANG	0	4/0737BC-00002	22 Nov 11	05 Dec 11		23 Nov 11	22 Nov 11	Ficep 206	25 Nov 11	28 Nov 11
0737BC	35	35	1	X	EA	60x60x10	1860	16.16	350WA	0	I1ANG	0	4/0737BC-00002	22 Nov 11	05 Dec 11		23 Nov 11	22 Nov 11	Ficep 206	25 Nov 11	28 Nov 11
0737BC	36	36	1	X	EA	60x60x10	2088	18.14	350WA	0	I1ANG	0	4/0737BC-00002	22 Nov 11	05 Dec 11		23 Nov 11	22 Nov 11	Ficep 206	25 Nov 11	28 Nov 11
0737BC	37	37	1	X	EA	60x60x10	2084	18.11	350WA	0	I1ANG	0	4/0737BC-00002	22 Nov 11	05 Dec 11		23 Nov 11	22 Nov 11	Ficep 206	25 Nov 11	28 Nov 11

		BM Hours	No of BM	BM Shifts	Weld Hours	No of Welders	Welder Shifts
0737BC	**13.53 Ton at 175.97 Hours for Area.**	36.95	1	3.519	24.64	1	2.347
Selection	**13.53 Ton at 175.97 Hours for Selection.**	36.95	1	3.519	24.64	1	2.347

										Drawings	**Packed**		**Fabrication Complete**		**Welding Complete**		**Fettling Complete**		**Despatch**	
Bay	**Job No**	**Assy No**	**Assy Qty**	**Mass**	**Assy Name**	**Work Type**	**Time Allowed**	**Phase**	**Pack List**	**Received**	**Planned**	**Actual**	**Planned**	**Actual**	**Planned**	**Actual**	**Planned**	**Actual**	**Planned**	**Actual**
			219	13532.08			175.97													
Bay 1	0737BC	1	1	27.93	HB	Hot Rolled - Medium	0.36	I1HR	PL1	22-Nov-11	26-Nov-11	29-Nov-11	01-Dec-11	07-Dec-11	03-Dec-11	08-Dec-11	04-Dec-11	12-Dec-11	05-Dec-11	05-Jan-12
Bay 1	0737BC	10	1	154.44	Beam	Hot Rolled - Medium	2.01	I1HR	PL2	22-Nov-11	26-Nov-11	03-Dec-11	01-Dec-11	03-Dec-11	03-Dec-11	08-Dec-11	04-Dec-11	05-Dec-11	05-Dec-11	08-Dec-11
Bay 1	0737BC	11	1	163.66	Beam	Hot Rolled - Medium	2.13	I1HR	PL2	22-Nov-11	26-Nov-11	03-Dec-11	01-Dec-11	03-Dec-11	03-Dec-11	08-Dec-11	04-Dec-11	05-Dec-11	05-Dec-11	08-Dec-11
Bay 1	0737BC	12	1	1327.22	Beam	Hot Rolled - Medium	17.25	I1HR	PL3	22-Nov-11	26-Nov-11	29-Nov-11	01-Dec-11	30-Nov-11	03-Dec-11	08-Dec-11	04-Dec-11	08-Dec-11	05-Dec-11	08-Dec-11
Bay 1	0737BC	13	1	85.15	Beam	Hot Rolled - Medium	1.11	I1HR	PL6	22-Nov-11	26-Nov-11	29-Nov-11	01-Dec-11	30-Nov-11	03-Dec-11	08-Dec-11	04-Dec-11	08-Dec-11	05-Dec-11	08-Dec-11
Bay 1	0737BC	14	1	90.79	Beam	Hot Rolled - Medium	1.18	I1HR	PL6	22-Nov-11	26-Nov-11	29-Nov-11	01-Dec-11	30-Nov-11	03-Dec-11	08-Dec-11	04-Dec-11	08-Dec-11	05-Dec-11	08-Dec-11
Bay 1	0737BC	15	1	79.15	Beam	Hot Rolled - Medium	1.03	I1HR	PL6	22-Nov-11	26-Nov-11	29-Nov-11	01-Dec-11	30-Nov-11	03-Dec-11	08-Dec-11	04-Dec-11	08-Dec-11	05-Dec-11	08-Dec-11
Bay 1	0737BC	16	1	84.58	Beam	Hot Rolled - Medium	1.1	I1HR	PL6	22-Nov-11	26-Nov-11	29-Nov-11	01-Dec-11	30-Nov-11	03-Dec-11	08-Dec-11	04-Dec-11	08-Dec-11	05-Dec-11	08-Dec-11
Bay 1	0737BC	17	1	108.69	Beam	Hot Rolled - Medium	1.41	I1HR	PL6	22-Nov-11	26-Nov-11	29-Nov-11	01-Dec-11	01-Dec-11	03-Dec-11	08-Dec-11	04-Dec-11	30-Nov-11	05-Dec-11	08-Dec-11
Bay 1	0737BC	18	1	108.57	Beam	Hot Rolled - Medium	1.41	I1HR	PL6	22-Nov-11	26-Nov-11	29-Nov-11	01-Dec-11	30-Nov-11	03-Dec-11	30-Nov-11	04-Dec-11	30-Nov-11	05-Dec-11	08-Dec-11
CNC	0737BC	183	1	6.56	Cleat	Hot Rolled - Medium	0.09	I1ANG	PL10	22-Nov-11	26-Nov-11	28-Nov-11	01-Dec-11	28-Nov-11	03-Dec-11	08-Dec-11	04-Dec-11	08-Dec-11	05-Dec-11	08-Jan-12
Bay 1	0737BC	19	1	85.15	Beam	Hot Rolled - Medium	1.11	I1HR	PL6	22-Nov-11	26-Nov-11	29-Nov-11	01-Dec-11	30-Nov-11	03-Dec-11	30-Nov-11	04-Dec-11	30-Nov-11	05-Dec-11	08-Dec-11
Bay 1	0737BC	2	1	369.59	Column	Hot Rolled - Medium	4.8	I1HR	PL2	22-Nov-11	26-Nov-11	03-Dec-11	01-Dec-11	03-Dec-11	03-Dec-11	08-Dec-11	04-Dec-11	05-Dec-11	05-Dec-11	08-Dec-11
Bay 1	0737BC	20	1	79.15	Beam	Hot Rolled - Medium	1.03	I1HR	PL6	22-Nov-11	26-Nov-11	29-Nov-11	01-Dec-11	30-Nov-11	03-Dec-11	08-Dec-11	04-Dec-11	08-Dec-11	05-Dec-11	08-Dec-11
Bay 1	0737BC	21	1	103	Beam	Hot Rolled - Medium	1.34	I1HR	PL6	22-Nov-11	26-Nov-11	29-Nov-11	01-Dec-11	30-Nov-11	03-Dec-11	08-Dec-11	04-Dec-11	30-Nov-11	05-Dec-11	08-Dec-11
Bay 1	0737BC	22	1	35.73	Beam	Hot Rolled - Medium	0.46	I1HR	PL6	22-Nov-11	26-Nov-11	29-Nov-11	01-Dec-11	30-Nov-11	03-Dec-11	08-Dec-11	04-Dec-11	08-Dec-11	05-Dec-11	05-Jan-12
Bay 1	0737BC	23	1	113.08	Beam	Hot Rolled - Medium	1.47	I1HR	PL6	22-Nov-11	26-Nov-11	29-Nov-11	01-Dec-11	30-Nov-11	03-Dec-11	30-Nov-11	04-Dec-11	30-Nov-11	05-Dec-11	08-Dec-11
Bay 1	0737BC	23	1	113.08	Beam	Hot Rolled - Medium	1.47	I1HR	PL6	22-Nov-11	26-Nov-11	29-Nov-11	01-Dec-11	30-Nov-11	03-Dec-11	30-Nov-11	04-Dec-11	30-Nov-11	05-Dec-11	08-Dec-11
Bay 1	0737BC	24	1	18.43	Beam	Hot Rolled - Medium	0.24	I1HR	PL4	22-Nov-11	26-Nov-11	28-Nov-11	01-Dec-11	29-Nov-11	03-Dec-11	08-Dec-11	04-Dec-11	08-Dec-11	05-Dec-11	08-Dec-11
Bay 1	0737BC	24	1	18.43	Beam	Hot Rolled - Medium	0.24	I1HR	PL4	22-Nov-11	26-Nov-11	28-Nov-11	01-Dec-11	29-Nov-11	03-Dec-11	08-Dec-11	04-Dec-11	08-Dec-11	05-Dec-11	08-Dec-11
Bay 1	0737BC	25	1	20.04	Beam	Hot Rolled - Medium	0.26	I1HR	PL4	22-Nov-11	26-Nov-11	28-Nov-11	01-Dec-11	29-Nov-11	03-Dec-11	08-Dec-11	04-Dec-11	08-Dec-11	05-Dec-11	08-Dec-11

Figure 12 - Production Tracking/Planning Sheet

CNC PERFORMANCE

The foreman of the CNC department captures each day's performance of each machine in a file that forms part of the monthly management report. From this file, the following CNC machines were analysed to get the part processing time:

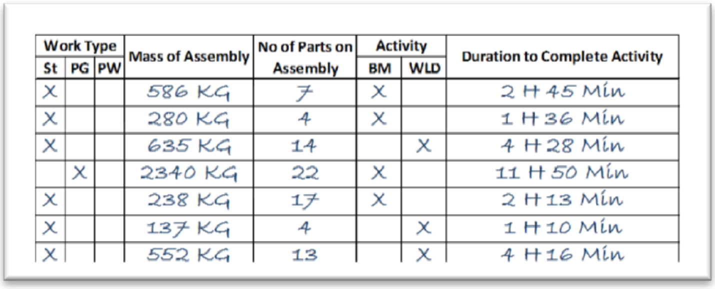
- All CNC Saws
- All CNC Plasma Machines (for plate preparation)
- All Angle- and Flat Bar Machines

This file gives an accurate figure for daily output from each machine.

FABRICATION PERFORMANCE

As mentioned earlier, the production tracking sheets don't indicate the actual value adding time of each discipline vs. the idle time of the material in that section of the workshop. Since batch processing is used in some areas of the workshop, it is inevitable to have material waiting to be processed.

Time studies along with interviews of the artisans and their supervisors yielded the following VA matrices for the boiler making and welding in the fabrication department.



Work Type			Mass of Assembly	No of Parts on Assembly	Activity		Duration to Complete Activity
St	PG	PW			BM	WLD	
X			586 KG	7	X		2 H 45 Min
X			280 KG	4	X		1 H 36 Min
X			635 KG	14		X	4 H 28 Min
	X		2340 KG	22	X		11 H 50 Min
X			238 KG	17	X		2 H 13 Min
X			137 KG	4		X	1 H 10 Min
X			552 KG	13		X	4 H 16 Min

Figure 13 - Time Studies Sheet

Platework Matrix (Hours/Ton) for Artisans			
	UNDERPANS [Incl deckplates, etc]	NORMAL [Head shoots, etc.]	COMPLEX [Conical / rolled / bevelled curves, tubular]
LIGHT P/W [3mm - 5mm plate]	106.25	67.03	76.35
MEDIUM P/W [6mm - 8mm plate]	67.46	33.33	37.50
HEAVY P/W [10mm + plate]	42.83	20.00	24.94

Table 3 – Plate work VA Matrix

Hot Rolled Hours / Ton for All Artisans						
0		1	2	3	4	5
		0 - 0.2 Ton/Assy	0.2 - 0.5 Ton/Assy	0.5 - 1.5 Ton/Assy	1.5 - 4 Ton/Assy	4 + Ton/Assy
W	1 Part/Assy	0.83	0.33	0.25	0.15	0.11
A	2 - 5 Parts/Assy	12.00	4.57	2.80	1.75	0.91
B	6 - 10 Parts/Assy	22.67	10.93	5.95	2.68	1.58
C	11 - 20 Parts/Assy	38.00	19.00	9.03	4.15	2.58
D	20 + Parts/Assy	140.00	48.57	18.50	8.00	5.14

Table 4 - Structural VA Matrix

DATA ANALYSIS

The data analysis was a tedious task, extrapolating information from the planning/tracking sheets, time studies and other production update sheets, and finding a logical work matrix with acceptable duration distributions to use as the inputs and parameters of the model.

CNC MACHINES

The information from the CNC update files were analysed for a period of three months with similar job mix than was decided to use for the simulation, and yielded the following results.

SAWS

Cosira Operates 3 CNC saws, as well as one manually operated saw that forms part of the CNC configuration of saws, the data shows the following items per hour data; where the blue curve shows a normal distribution using the mean and standard deviation obtained from the captured data, and the purple curve shows the actual data gathered. Saw 28 has a much flatter line, and deviates the furthest from the normal curve, the fact that this is the manually operated saw might be the reason for this.

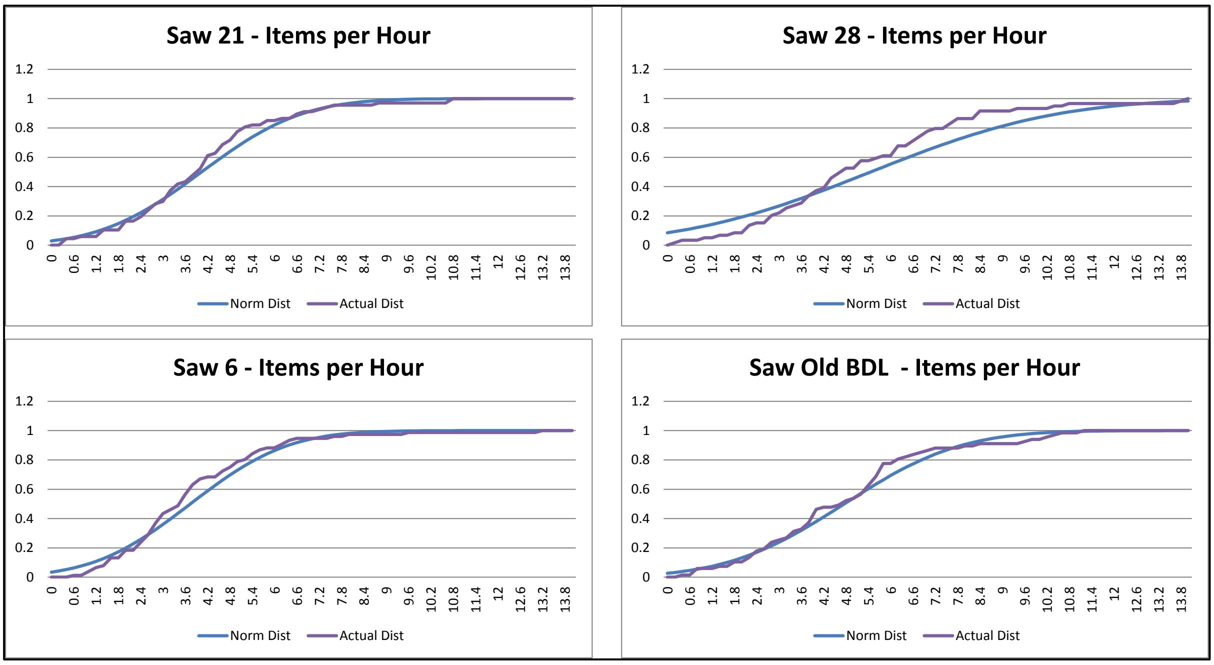


Figure 14 - Individual Saw Performance Curves

Since the data for the saws included cutting of plate girders, which takes a very long time, the simulated jobs will be allocated with a complexity factor to accommodate for the size of the sections being cut.

The data that was used to create the graphs above was sufficient to allocate cutting times to the machines being simulated using the following distributions for each saw:

- Saw 21: Parts leave the machine in a Poisson distribution with a mean of 25.21 minutes per part.
- Saw 6: Parts leave the machine in a Poisson distribution with a mean of 21.92 minutes per part.
- Saw 28: Parts leave the machine in a Poisson distribution with a mean of 22.85 minutes per part.
- Saw Old BDL: Parts leave the machine in a Poisson distribution with a mean of 19.98 minutes per part.

It is important to note that these times include setup times of the machines as well as possible maintenance that were done during the time period, making assumption 3 possible for the simulation.

Saw 28 will however not be used for simulation purposes as was only recently converted to a CNC Saw, and used to be run as a manual saw to cut the odd small part or batch.

CNC PLASMA MACHINES

The following graphs are similar to the graphs for the saw, and were obtained using the data from the same timeframe as for the saws. It is clear that the plasma machines are not as predictable in terms of cutting a part as the saws.

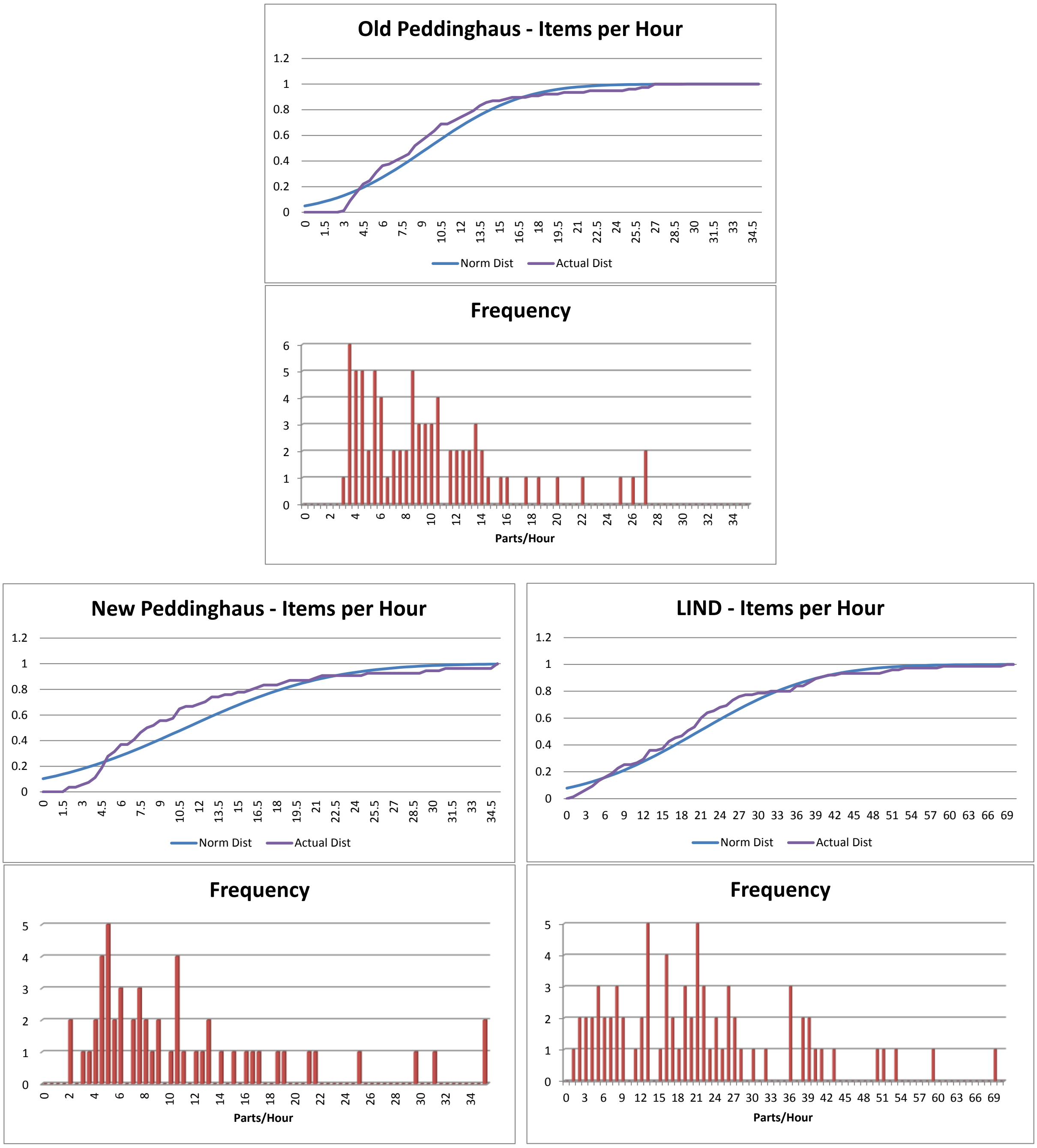


Figure 15 - CNC Plasma Machine Performance Graphs

For the sake of the simulation, the cutting times can be approximated as follows:

- Old Peddinghaus Plasma: Parts leave the machine in a Poisson distribution with a mean of 8.80 minutes per part.
- New Peddinghaus Plasma: Parts leave the machine in a Poisson distribution with a mean of 9.07 minutes per part.
- Lind Plasma: Parts leave the machine in a Poisson distribution with a mean of 7.61 minutes per part.

As with the saws, it is important to note that these times include setup times of the machines as well as possible maintenance that were done during the time period, making assumption 3 possible for the simulation.

ANGLE MACHINES

The angle machines are exclusively used for gantry jobs, and the following graph shows the output of the two machines. Data from the same timeframe was used to get these graphs.

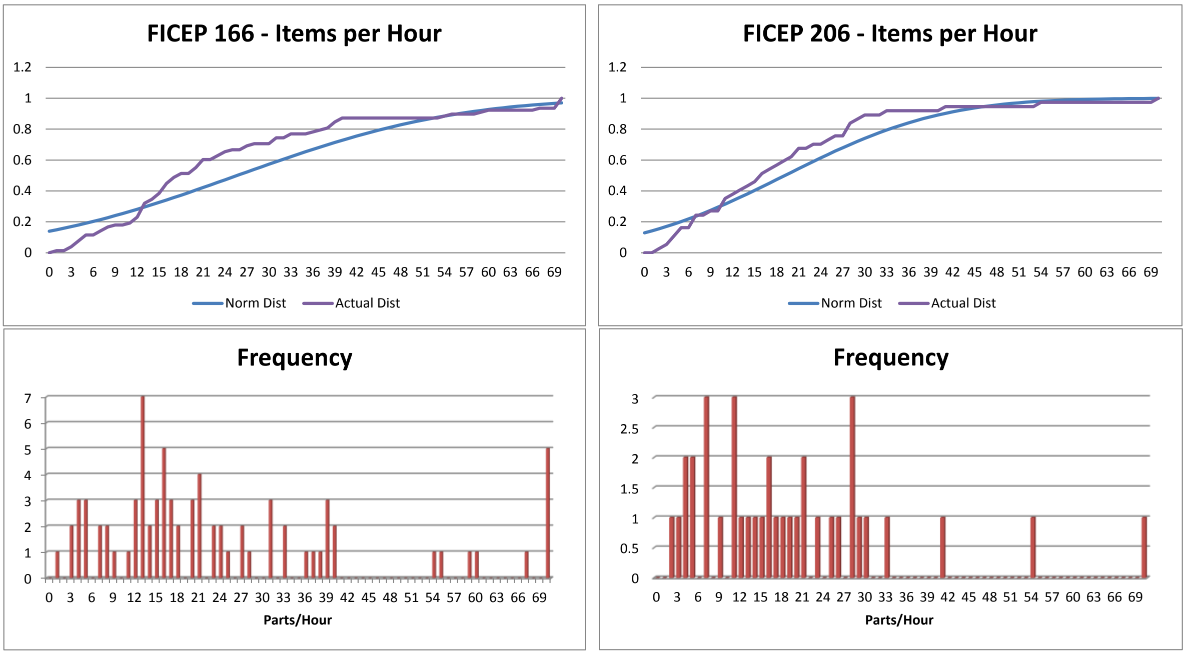


Figure 16 - Angle Machine Performance Graphs

As with the plasma machines, the angle machines does not give the most predictable performance figures, but was also be roughly extrapolated to give the following output distributions that was used in the simulation:

- FICEP 166: Parts leave the machine in a Poisson distribution with a mean of 5.42 minutes per part.
- FICEP 206: Parts leave the machine in a Poisson distribution with a mean of 6.53 minutes per part.

As with the saws and plasma machines, it is important to note that these times include setup times of the machines as well as possible maintenance that were done during the time period, making assumption 3 possible for the simulation.

FABRICATION

As mentioned in a previous section, certain performance matrices were defined for fabrication based on time studies and interviews with artisans as well as their supervisors. Since the decision was made to only simulate four work types, a fabrication time must have been selected for these four work types that would work in the simulation. These times are as follows (for a generic assembly that was simulated):

Work Type	Boiler Maker Time	Welder Time
Structural – Normal	1h45m (Normally Distributed)	2h30m (Normally Distributed)
Structural – Gantries	5h00m (Normally Distributed)	9h00m (Normally Distributed)
Plate Work – Normal	12h00m (Normally Distributed)	24h00m (Normally Distributed)
Plate Work - Complex	28h00m (Normally Distributed)	50h00m (Normally Distributed)

Table 5 - Work type fabrication times

The fact that the times are fluctuating (normal distribution) allows for realistic conditions as not all assemblies are the same, however, most assemblies of a certain job type are similar to a degree.

QUALITY CONTROL

Cosira Manufacturing does 100% inspection at two stages of production, one is just after the boiler maker completed the assembly, and the next is just before despatch, the latter might include client inspection as the contract requires.

According to the data analysed, the first in-line inspection rejects an average of 5% of assemblies. When a reject occurs the boiler maker needs to redo his work at 150% of the original duration to complete the assembly.

It was calculated that about 1% of assemblies inspected at the final inspection stage are rejected for welding mistakes. This work must be redone by the welder at the same duration as he originally worked to complete the job.

DESIGN AND PROBLEM SOLVING

BASE MODEL

Using all the data collected and defined in the previous section of this report, the base model was simulated. The results from this model were then used to determine where to improve the “process” and to compare the results from the improved model to the base model.

After running ten replications of one month each the average throughput time for work scheduled for bay 2, was 195.6 hours, as can be seen in Appendix 4A, from being loaded onto the machines up to the point where the jobs were ready to be dispatched. This result made a lot of sense since this had been accomplished before. It is however not the current norm in the workshop.

SUPRISING RESULTS

Although visual inspection of the workshop would suggest that the major problem was the time it took the artisans to do their work, the model painted a different picture where not all artisans could be kept busy all the time. The model showed that as soon as work was packed into packing list for fabrication it flowed relatively smooth through the rest of the workshop, with occasional delays between boiler making and welding, and between welding and cleaning. The graph below was taken from the report generated by Arena and shows the value-add times for the various processes over a period of one month. Please note that the first eight bars indicate the eight boilermakers (each assigned to his own workstation).

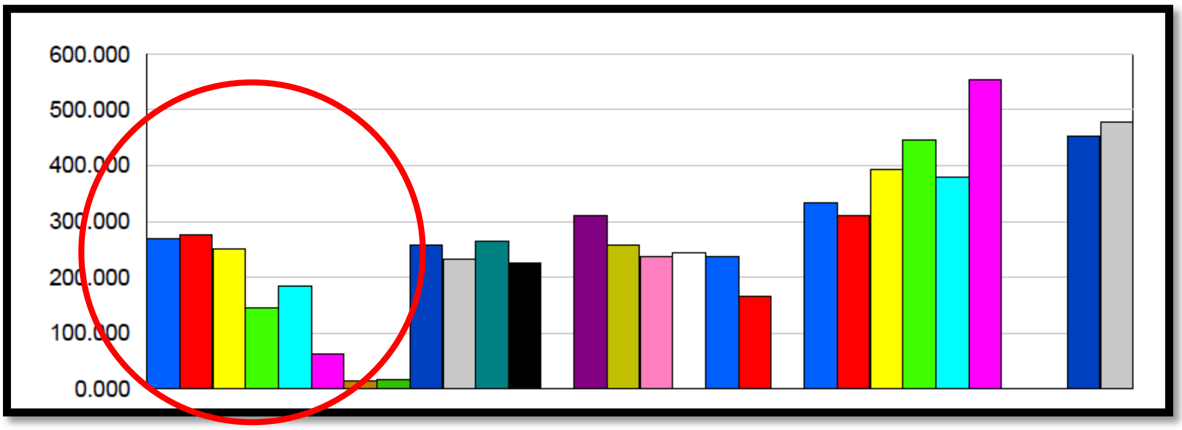


Figure 17 - VA Time for Workshop Processes

The simulation assigned work to the first available resource looking sequentially at the options, that is why they are not equally busy all the time.

The reason for this discrepancy is discussed in the next section.

PRODUCTIVITY ANALYSIS

In 2009 Mr Gavin Smith, an industrial engineer working for Cosira, conducted productivity studies by randomly walking through the workshop, and noting how many people were adding value (busy actually working), and how many people were not adding value.

The numbers that were generated by this study was shocking and revealed that on average only about 40% of the artisans were busy adding value at any time of day. This experiment was repeated in 2012 after the management of Cosira announced that the company had been sold. This experiment yielded even lower value-add time than before. More people were having small informal “meetings” rather than working/adding value.

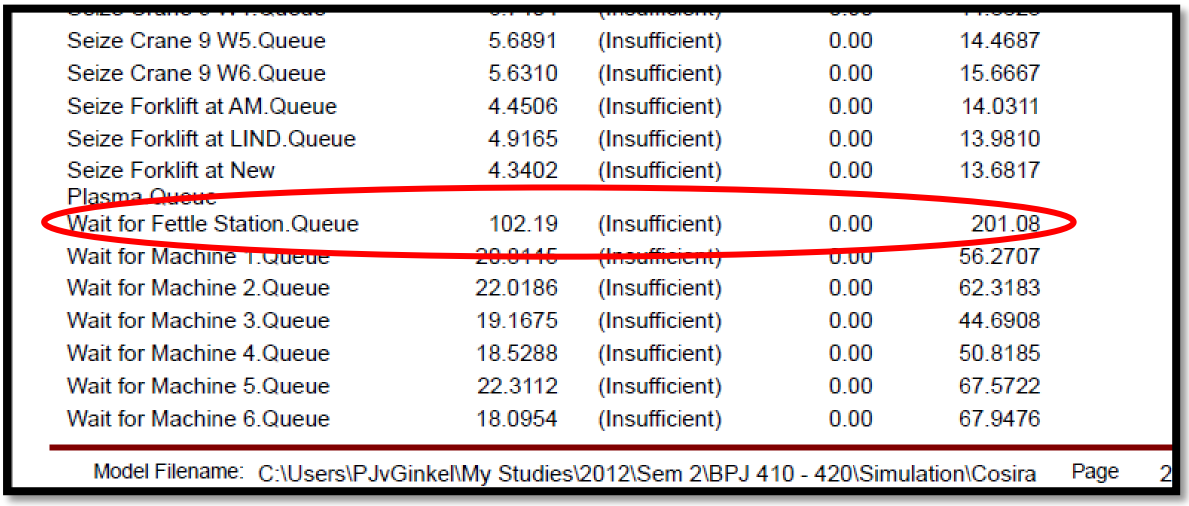
COULD IT BE BETTER

The results from the simulation were a true revelation as to the inherent potential that there still is to improve the throughput time of the workshop, and ultimately improving the profitability of the organisation.

The improved models are discussed in more detail in the next sections of this report.

IMPROVED MODEL – LINE BALANCING

The following picture shows part of the report that was generated by Arena for Queues (All reports relating to queues are included as Appendices to this report) in front of processes, and one place where there was a serious bottleneck or delay was in the laydown are between welding and fettling, as seen in the report.



Seize Crane 9 W5.Queue	5.6891	(Insufficient)	0.00	14.4687
Seize Crane 9 W6.Queue	5.6310	(Insufficient)	0.00	15.6667
Seize Forklift at AM.Queue	4.4506	(Insufficient)	0.00	14.0311
Seize Forklift at LIND.Queue	4.9165	(Insufficient)	0.00	13.9810
Seize Forklift at New Plasma.Queue	4.3402	(Insufficient)	0.00	13.6817
Wait for Fettle Station.Queue	102.19	(Insufficient)	0.00	201.08
Wait for Machine 1.Queue	20.8145	(Insufficient)	0.00	56.2707
Wait for Machine 2.Queue	22.0186	(Insufficient)	0.00	62.3183
Wait for Machine 3.Queue	19.1675	(Insufficient)	0.00	44.6908
Wait for Machine 4.Queue	18.5288	(Insufficient)	0.00	50.8185
Wait for Machine 5.Queue	22.3112	(Insufficient)	0.00	67.5722
Wait for Machine 6.Queue	18.0954	(Insufficient)	0.00	67.9476

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 2

Figure 18 - Part of Arena Generated Report 01

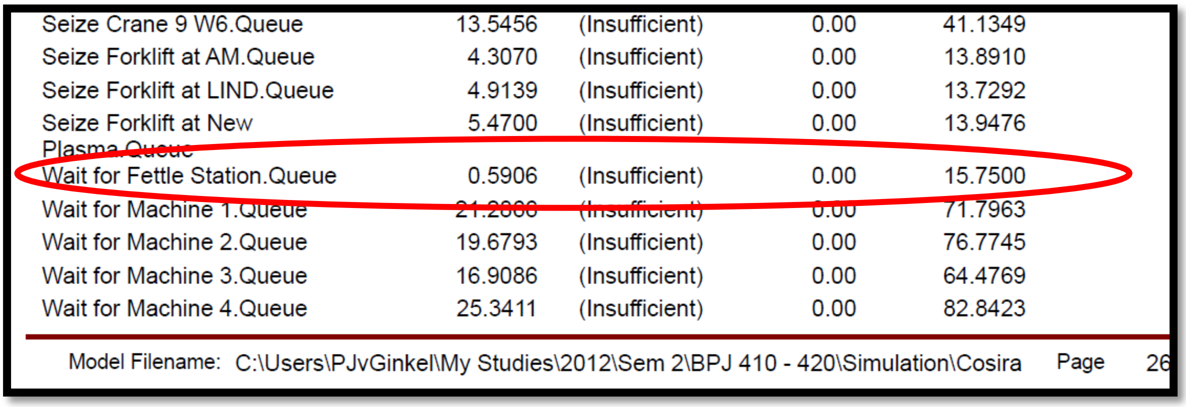
This clearly stood out as an area that could benefit if the resources were more balanced. This however was not the only problem, cranes operators are not trained to recognise what movements are more critical than others. For example, material moved from a laydown are to a production area is more important than material moving into a laydown area.

The reason why this investigation focussed on the queues in the laydown areas is because this is where things go wrong very easily. Steel assemblies are big and heavy, which causes these laydown areas to become piles of steel, where the new work gets stacked on the old work, and thus results in the new work being lifted off first as well, leaving the old work sometimes for months without moving from the same laydown area. This fact was not modelled, but would dramatically affect the throughput time of some of the jobs.

LINE BALANCING MODEL 1

The first change that was made towards balancing the line was to add one more fettling area and one more fettler to the line, as this also is the cheapest resource in the workshop. Another change was to change the priority of the movement by the crane as mentioned above, achieving this only requires some training in operating procedures.

Appendix 4B shows the results of this change on throughput time. Again ten replications of one month each was run. This simulation yielded a throughput time of 184.6 hours, an improvement of about 6%. This also had a tremendous impact on the time work waited in the laydown area before fettling as can be seen in the image taken from the simulation report.



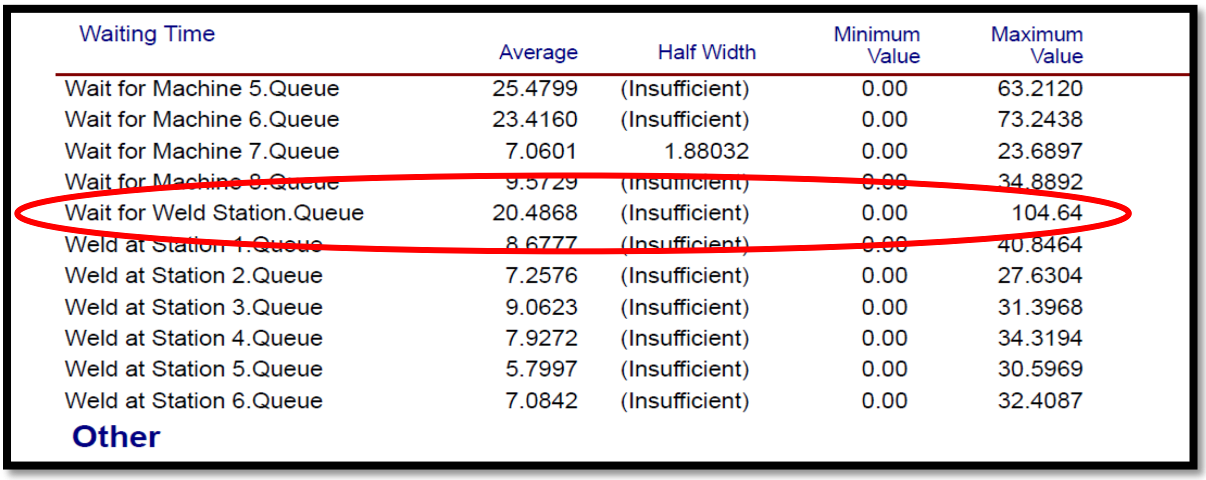
```
Seize Crane 9 W6.Queue            13.5456   (Insufficient)     0.00       41.1349
Seize Forklift at AM.Queue         4.3070   (Insufficient)     0.00       13.8910
Seize Forklift at LIND.Queue       4.9139   (Insufficient)     0.00       13.7292
Seize Forklift at New              5.4700   (Insufficient)     0.00       13.9476
Plasma.Queue
Wait for Fettle Station.Queue      0.5906   (Insufficient)     0.00       15.7500
Wait for Machine 1.Queue          21.2860   (Insufficient)     0.00       71.7963
Wait for Machine 2.Queue          19.6793   (Insufficient)     0.00       76.7745
Wait for Machine 3.Queue          16.9086   (Insufficient)     0.00       64.4769
Wait for Machine 4.Queue          25.3411   (Insufficient)     0.00       82.8423

  Model Filename:  C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira     Page    26
```

Figure 19 - Part of Arena Generated Report 02

This change in the crane behaviour did have a negative effect on the time material had to wait to be moved from the welding area to the fettling laydown area. But as can be seen by the results, the overall result is an improvement of the throughput time of the workshop.

This change did not affect the boiler making in any sense, and the utilisation of the boiler makers remained unchanged.

The next area of concern was the laydown area before the welders, looking as the image below, it does only have an average waiting time of 20 hours, the maximum waiting time for the simulation was over 100 hours, and material waiting that long only costs the company money.



Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Wait for Machine 5.Queue	25.4799	(Insufficient)	0.00	63.2120
Wait for Machine 6.Queue	23.4160	(Insufficient)	0.00	73.2438
Wait for Machine 7.Queue	7.0601	1.88032	0.00	23.6897
Wait for Machine 8.Queue	9.5729	(Insufficient)	0.00	34.8892
Wait for Weld Station.Queue	20.4868	(Insufficient)	0.00	104.64
Weld at Station 1.Queue	8.6777	(Insufficient)	0.00	40.8464
Weld at Station 2.Queue	7.2576	(Insufficient)	0.00	27.6304
Weld at Station 3.Queue	9.0623	(Insufficient)	0.00	31.3968
Weld at Station 4.Queue	7.9272	(Insufficient)	0.00	34.3194
Weld at Station 5.Queue	5.7997	(Insufficient)	0.00	30.5969
Weld at Station 6.Queue	7.0842	(Insufficient)	0.00	32.4087

Other

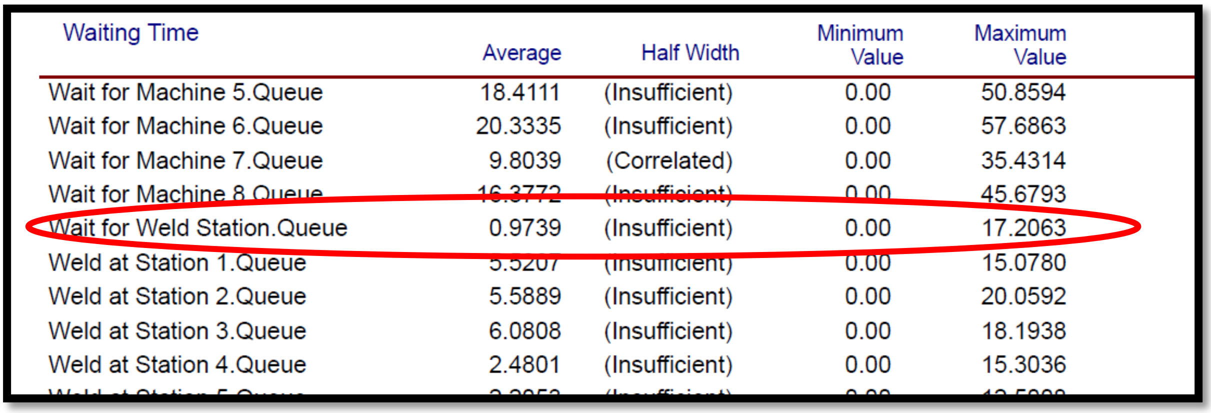
Figure 20 - Part of Arena Generated Report 03

LINE BALANCING – MODEL 2

The numbers shown in Figure 20 above regarding the wait time for jobs to go to the welding indicated yet another resource imbalance. This resulted in another improved line balancing model, where one welder was added, and the rules for the crane movements as explained for the first line balancing model was expanded for the crane moving steel between the boiler makers and the welders. The changes that were made in the line balancing 1 model remained the same for this model.

As can be seen in Appendix 4C, this change resulted in further improvement of the throughput time from 195.6 for the base model, and 184.6 hours for the first line balancing model to 164.3 hours, which translates to an improvement of about 16% in throughput time.

This also reduced waiting time in the laydown area for welding by a large degree, as can be seen in the next image, as taken from the report for the simulation.



Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Wait for Machine 5.Queue	18.4111	(Insufficient)	0.00	50.8594
Wait for Machine 6.Queue	20.3335	(Insufficient)	0.00	57.6863
Wait for Machine 7.Queue	9.8039	(Correlated)	0.00	35.4314
Wait for Machine 8.Queue	16.3772	(Insufficient)	0.00	45.6793
Wait for Weld Station.Queue	0.9739	(Insufficient)	0.00	17.2063
Weld at Station 1.Queue	5.5207	(Insufficient)	0.00	15.0780
Weld at Station 2.Queue	5.5889	(Insufficient)	0.00	20.0592
Weld at Station 3.Queue	6.0808	(Insufficient)	0.00	18.1938
Weld at Station 4.Queue	2.4801	(Insufficient)	0.00	15.3036

Figure 21 - Part of Arena Generated Report 04

These changes still did not address the imbalance when it comes to the utilisation of the boiler makers as can be seen in Figure 22, showing the VA times for the various processes in the workshop, with the first eight columns representing the times for the boiler makers. Form this it is almost justifiable to let go one or two boiler makers is exchange for the additional labour introduced at welding and fettling, but it is also to be noted that the next section will focus on improving the delivery of work to the boilermakers and might yet result in much better utilisation of the boiler maker (the most expensive worker in the workshop).

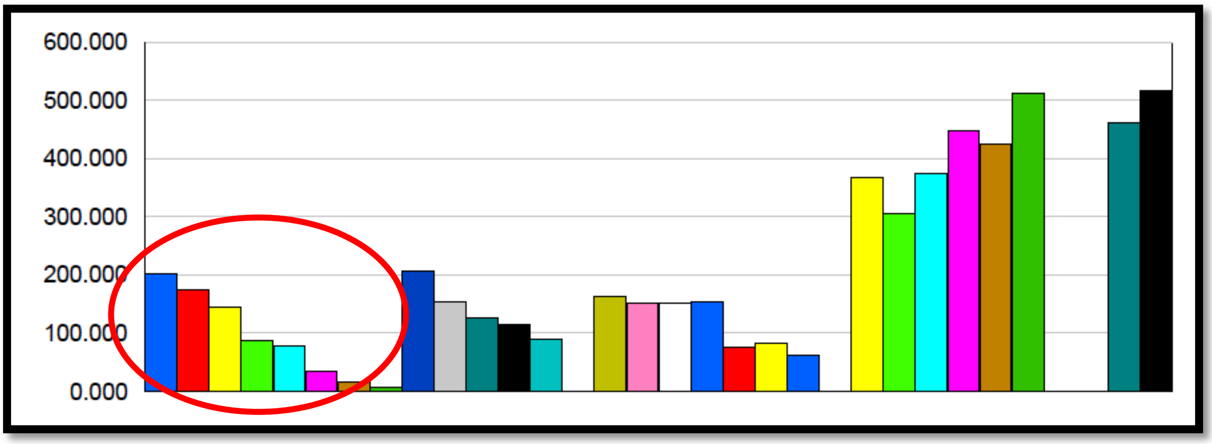


Figure 22 - VA Time for Workshop Processes 02

IMPROVED MODEL – TOC

One clear constraint in the workshop is the packing since it is the area with the largest amount of work waiting to be processed. This however is only half accurate, since the packing department rely on different parts coming from different machines, they can only pack what they have available to pack. It is clear from this statement that the synchronisation between the machines (planning of the machines) is a problem. Line balancing will not be feasible in this case as this would influence the number of machines (high capital items). TOC seems to be a good method to apply here.

TOC – MODEL 1

Currently the general rule is to send one job to one machine (e.g. all the plates of the job to New Plasma, all the angles to Ficep A166, and all the sections to Saw 6) which results in all parts waiting in a line to be processed, this created long queues of raw steel as some machines and much shorter queues at other machines. The first idea to be simulated was to distribute the job between all the machines, thus reducing the time a job needs to wait for a machine to be processed.

Using the initial base model as the base for this model, and ignoring the changes that were made when using line balancing, this simulation yielded the following results:

As per Appendix 4D, throughput time improved from 195.6 hours for the base model to 185 hours for the TOC 1 model, this translates to an improvement of about 5% on throughput time. This however did not improve the situation in the packing area; it only resulted in a shorter wait for the machines and more effective utilisation of the machines.

TOC – MODEL 2

The problem with TOC 1 model was that it did not address the real constraint in the part preparation are, namely the synchronisation of the parts. To understand this better, one needs to understand the rules of planning the current workshop processes; work is being set out for specific machines in advance, and all processes in the preparation area are performed in the same sequence. This means then some jobs are scheduled for a machine that is busy processing a very time consuming job, and as a result the planned job needs to wait a long time for the machine to finish its current job. It also means that some jobs plates will be cut way in advance to the sections or angles (as an example).This next model looked at the time each machine would take to prepare a job and based on this, each job's preparation operation sequence will be different, always starting the preparation of the job at the process with the longest lead time. The following table shows the calculation for the different jobs' preparation lead times per operation:

Job Type	**Structural**	**Gantries**	**Plate Work - Simple**	**Plate Work - Complex**
No of Plates	4	8	10	10
Parts per Plate	20	13	4	4
Time to Process Plate Part	00:08:30	00:08:30	00:08:30	00:08:30
Total Prep Time for all Plate Parts	**11:20:00**	**14:44:00**	**05:40:00**	**05:40:00**
No of Sections	15	8	5	5
Parts per Section	5	2	4	4
Time to Process Section Part	0:15:40	0:13:25	0:13:25	0:13:25
Total Prep Time for all Section Parts	**19:35:00**	**3:34:40**	**4:28:20**	**4:28:20**
No of Angles	0	16	10	10
Parts per Angle	0	4	8	8
Time to Process Angle Part	0:05:59	0:05:59	0:05:59	0:05:59
Total Prep time for all Angle Parts	**0:00:00**	**6:22:56**	**7:58:40**	**7:58:40**

Table 6 - Preparation Times per Operation

The table shows that the sequence for the preparation operations for the different job types are as follows:

- Structural: Saw Sections → Cut Plates
- Gantries: Cut Plates → Cut Angles → Saw Sections
- Plate Work (Both): Cut Angles → Cut Plates → Saw Sections

These sequences are based on the average job selection for the simulation, and in reality each job's sequence should be individually determined.

Another change to the planning rule would be that no job's preparation would start before the process with the longest lead time does not have a machine available to process this job. This means that all the jobs (job cards) will be queued in front of its slowest process, and will only be started as soon as there is space on a machine for that process. The job cards for the subsequent processes will be added to the queues of that process as soon as the slowest process has started. This ensures that work will be distributed equally between machines and will suffer the shortest possible waiting time before being processed.

These rules were applied to the base model, again ignoring any previous changes to the model and according to Appendix 4E yielded an improvement in throughput time from 195.6 hours for the base model to 184.1 hours for this improved model; which translates to an improvement of 6% in throughput time.

Although some parts still waited a long time to be packed, it did decrease the amount of material in the CNC area (waiting on the conveyors) and increased the control over material being prepared.

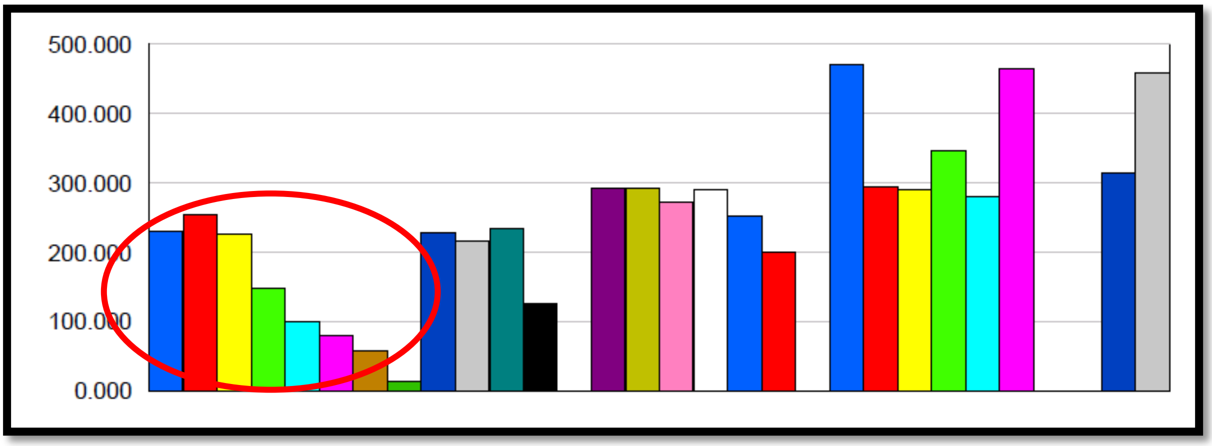


Figure 23 - VA Time for Workshop Processes 03

Figure 23 above also shows some improvement in the utilisation of the boiler makers when compared to Figure 22.

FINAL MODEL – A HOLISTIC IMPROVEMENT

For the final model, the TOC 2 model, which focussed on the synchronisation of preparation functions were combined with the Line Balancing 2 Model, which focussed on reducing the laydown/wait times after boiler making and welding.

Appendix 4F shows the resulting average throughput time for the ten replications over a one month period and yields an average throughput time for work scheduled for bay 2 of 154.4 hours. Which is a 21% improvement from the base model's 195.6 hours.

DESIGN AND SOLUTION EVALUATION

The final model as discussed above included the following operational changes:

- Operational Rule Changes:
    - Crane operators to focus on moving work towards waiting processes, before moving work from processes to laydown areas
    - Preparation process sequence to be changed to start with sequence with longest lead time, and end with process with shortest lead time, to be calculated per job
    - Job cards to be queued before each process and sent to the first available machine for that process to ensure faster processing times and better distribution of workload to machines
- Operation Structure Changes:
    - One additional welder and one additional fettler per workshop fabrication bay

Most of the changes are operating procedure changes and can be implemented through some basic training.

PROJECT IMPLEMENATION AND BENEFITS

IMPLEMENTATION

The implementation of this proposal will be very simple and could include the following activities:

- Training of Crane Operators: This should not take more than 2 to 3 hours per crane operator and can be done with a group of crane operators at once, depending on operational needs of the manufacturing department.
- Training of Preparation Programmer: This training is more involved as it would include the calculations of lead times for each job, and then how to create and queue the job cards for the new procedure. This would take about one week per programmer and should be done one-on-one and not in a group
- Employing of Extra Staff: This part of the improvement is the only part that will cost the company money, the improvement gained from this would definitely be worth it. Since there are many people looking for employment in the sector, finding the correct candidate should not take long.

IMPROVEMENT EXPECTATION

Like any new procedure, results will not be evident overnight, but if these changes are implemented, the throughput time for jobs in the workshop could increase by as much as 21% creating the opportunity to introduce more work into the workshop, improving customer satisfaction and improving possible profitability.

CONCLUSION

This report showed the results of simulation models of Cosira’s manufacturing facility and the possible improvements that can be seen within the facility by implementing small yet effective changes in the operation. It however remains to be said that these are not the only ways Cosira could improve throughput and production figures and that these changes will only result in improvements if it is supported by top management and effectively “enforced” to the general worker level.

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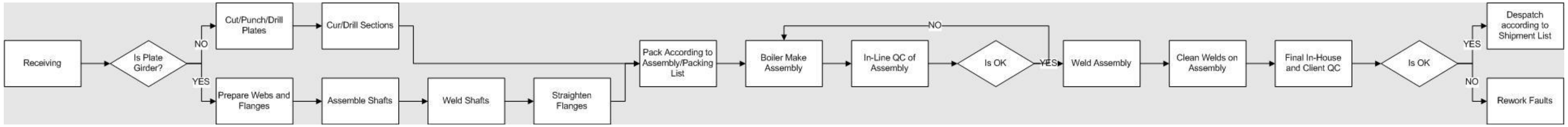
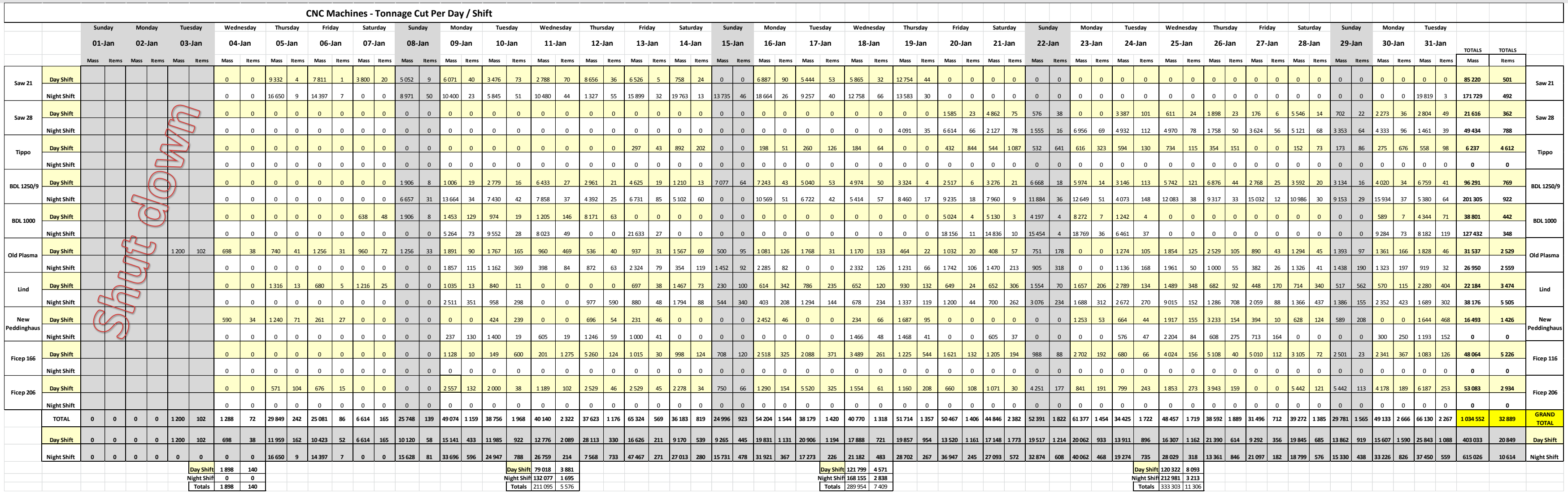
APPENDICES

APPENDIX 1 – MATERIAL FLOW DIAGRAM



APPENDIX 2 – CNC UPDATE FILES



CNC Machines - Tonnage Cut Per Day / Shift

		Sunday		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		Sunday	
		01-Jan		02-Jan		03-Jan		04-Jan		05-Jan		06-Jan		07-Jan		08-Jan	
		Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items
Saw 21	Day Shift							0	0	9 332	4	7 811	1	3 800	20	5 052	9
	Night Shift							0	0	16 650	9	14 397	7	0	0	8 971	50
Saw 28	Day Shift							0	0	0	0	0	0	0	0	0	0
	Night Shift							0	0	0	0	0	0	0	0	0	0
Tippo	Day Shift							0	0	0	0	0	0	0	0	0	0
	Night Shift							0	0	0	0	0	0	0	0	0	0
BDL 1250/9	Day Shift							0	0	0	0	0	0	0	0	1 906	8
	Night Shift							0	0	0	0	0	0	0	0	6 657	31
BDL 1000	Day Shift							0	0	0	0	0	0	638	48	1 906	8
	Night Shift							0	0	0	0	0	0	0	0	0	0
Old Plasma	Day Shift					1 200	102	698	38	740	41	1 256	31	960	72	1 256	33
	Night Shift							0	0	0	0	0	0	0	0	0	0
Lind	Day Shift							0	0	1 316	13	680	5	1 216	25	0	0
	Night Shift							0	0	0	0	0	0	0	0	0	0
New Peddinghaus	Day Shift							590	34	1 240	71	261	27	0	0	0	0
	Night Shift							0	0	0	0	0	0	0	0	0	0
Ficep 166	Day Shift							0	0	0	0	0	0	0	0	0	0
	Night Shift							0	0	0	0	0	0	0	0	0	0
Ficep 206	Day Shift							0	0	571	104	676	15	0	0	0	0
	Night Shift							0	0	0	0	0	0	0	0	0	0
	TOTAL	0	0	0	0	1 200	102	1 288	72	29 849	242	25 081	86	6 614	165	25 748	139
	Day Shift	0	0	0	0	1 200	102	698	38	11 959	162	10 423	52	6 614	165	10 120	58
	Night Shift	0	0	0	0	0	0	0	0	16 650	9	14 397	7	0	0	15 628	81

		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		Sunday		Monday	
		09-Jan		10-Jan		11-Jan		12-Jan		13-Jan		14-Jan		15-Jan		16-Jan	
		Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items
Saw 21	Day Shift	6 071	40	3 476	73	2 788	70	8 656	36	6 526	5	758	24	0	0	6 887	90
	Night Shift	10 400	23	5 845	51	10 480	44	1 327	55	15 899	32	19 763	13	13 735	46	18 664	26
Saw 28	Day Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tippo	Day Shift	0	0	0	0	0	0	0	0	297	43	892	202	0	0	198	51
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDL 1250/9	Day Shift	1 006	19	2 779	16	6 433	27	2 961	21	4 625	19	1 210	13	7 077	64	7 243	43
	Night Shift	13 664	34	7 430	42	7 858	37	4 392	25	6 731	85	5 102	60	0	0	10 569	51
BDL 1000	Day Shift	1 453	129	974	19	1 205	146	8 171	63	0	0	0	0	0	0	0	0
	Night Shift	5 264	73	9 552	28	8 023	49	0	0	21 633	27	0	0	0	0	0	0
Old Plasma	Day Shift	1 891	90	1 767	165	960	469	536	40	937	31	1 567	69	500	95	1 081	126
	Night Shift	1 857	115	1 162	369	398	84	872	63	2 324	79	354	119	1 452	92	2 285	82
Lind	Day Shift	1 035	13	840	11	0	0	0	0	697	38	1 467	73	230	100	614	342
	Night Shift	2 511	351	958	298	0	0	977	590	880	48	1 794	88	544	340	403	208
New Peddinghaus	Day Shift	0	0	424	239	0	0	696	54	231	46	0	0	0	0	2 452	46
	Night Shift	237	130	1 400	19	605	19	1 246	59	1 000	41	0	0	0	0	0	0
Ficep 166	Day Shift	1 128	10	149	600	201	1 275	5 260	124	1 015	30	998	124	708	120	2 518	325
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ficep 206	Day Shift	2 557	132	2 000	38	1 189	102	2 529	46	2 529	45	2 278	34	750	66	1 290	154
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	49 074	1 159	38 756	1 968	40 140	2 322	37 623	1 176	65 324	569	36 183	819	24 996	923	54 204	1 544
	Day Shift	15 141	433	11 985	922	12 776	2 089	28 113	330	16 626	211	9 170	539	9 265	445	19 831	1 131
	Night Shift	33 696	596	24 947	788	26 759	214	7 568	733	47 467	271	27 013	280	15 731	478	31 921	367

		Tuesday		Wednesday		Thursday		Friday		Saturday		Sunday		Monday		Tuesday	
		17-Jan		18-Jan		19-Jan		20-Jan		21-Jan		22-Jan		23-Jan		24-Jan	
		Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items
Saw 21	Day Shift	5 444	53	5 865	32	12 754	44	0	0	0	0	0	0	0	0	0	0
	Night Shift	9 257	40	12 758	66	13 583	30	0	0	0	0	0	0	0	0	0	0
Saw 28	Day Shift	0	0	0	0	0	0	1 585	23	4 862	75	576	38	0	0	3 387	101
	Night Shift	0	0	0	0	4 091	35	6 614	66	2 127	78	1 555	16	6 956	69	4 932	112
Tippo	Day Shift	260	126	184	64	0	0	432	844	544	1 087	532	641	616	323	594	130
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDL 1250/9	Day Shift	5 040	53	4 974	50	3 324	4	2 517	6	3 276	21	6 668	18	5 974	14	3 146	113
	Night Shift	6 722	42	5 414	57	8 460	17	9 235	18	7 960	9	11 884	36	12 649	51	4 073	148
BDL 1000	Day Shift	0	0	0	0	0	0	5 024	4	5 130	3	4 197	4	8 272	7	1 242	4
	Night Shift	0	0	0	0	0	0	18 156	11	14 836	10	15 454	4	18 769	36	6 461	37
Old Plasma	Day Shift	1 768	31	1 170	133	464	22	1 032	20	408	57	751	178	0	0	1 274	105
	Night Shift	0	0	2 332	126	1 231	66	1 742	106	1 470	213	905	318	0	0	1 136	168
Lind	Day Shift	786	235	652	120	930	132	649	24	652	306	1 554	70	1 657	206	2 789	134
	Night Shift	1 294	144	678	234	1 337	119	1 200	44	700	262	3 076	234	1 688	312	2 672	270
New Peddinghaus	Day Shift	0	0	234	66	1 687	95	0	0	0	0	0	0	1 253	53	664	44
	Night Shift	0	0	1 466	48	1 468	41	0	0	605	37	0	0	0	0	576	47
Ficep 166	Day Shift	2 088	371	3 489	261	1 225	544	1 621	132	1 205	194	988	88	2 702	192	680	66
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ficep 206	Day Shift	5 520	325	1 554	61	1 160	208	660	108	1 071	30	4 251	177	841	191	799	243
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	38 179	1 420	40 770	1 318	51 714	1 357	50 467	1 406	44 846	2 382	52 391	1 822	61 377	1 454	34 425	1 722
	Day Shift	20 906	1 194	17 888	721	19 857	954	13 520	1 161	17 148	1 773	19 517	1 214	20 062	933	13 911	896
	Night Shift	17 273	226	21 182	483	28 702	267	36 947	245	27 093	572	32 874	608	40 062	468	19 274	735

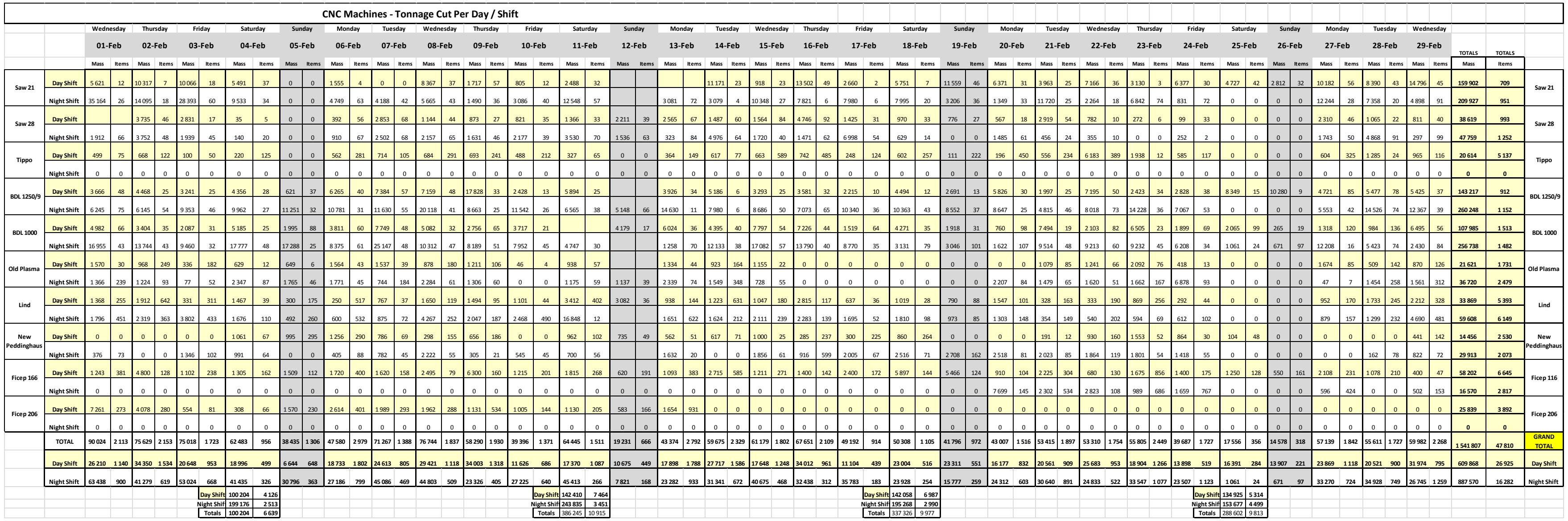
		Wednesday		Thursday		Friday		Saturday		Sunday		Monday		Tuesday				
		25-Jan		26-Jan		27-Jan		28-Jan		29-Jan		30-Jan		31-Jan		TOTALS	TOTALS	
		Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	
Saw 21	Day Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0	85 220	501	Saw 21
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	19 819	3	171 729	492	
Saw 28	Day Shift	611	24	1 898	23	176	6	5 546	14	702	22	2 273	36	2 804	49	21 616	362	Saw 28
	Night Shift	4 970	78	1 758	50	3 624	56	5 121	68	3 353	64	4 333	96	1 461	39	49 434	788	
Tippo	Day Shift	734	115	354	151	0	0	152	73	173	86	275	676	558	98	6 237	4 612	Tippo
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
BDL 1250/9	Day Shift	5 742	121	6 876	44	2 768	25	3 592	20	3 134	16	4 020	34	6 759	41	96 291	769	BDL 1250/9
	Night Shift	12 083	38	9 317	33	15 032	12	10 986	30	9 153	29	15 934	37	5 380	64	201 305	922	
BDL 1000	Day Shift	0	0	0	0	0	0	0	0	0	0	589	7	4 344	71	38 801	442	BDL 1000
	Night Shift	0	0	0	0	0	0	0	0	0	0	9 284	73	8 182	119	127 432	348	
Old Plasma	Day Shift	1 854	125	2 529	105	890	43	1 294	45	1 393	97	1 361	166	1 828	46	31 537	2 529	Old Plasma
	Night Shift	1 961	50	1 000	55	382	26	1 326	41	1 438	190	1 323	197	919	32	26 950	2 559	
Lind	Day Shift	1 489	348	682	92	448	170	714	340	517	562	570	115	2 280	404	22 184	3 474	Lind
	Night Shift	9 015	152	1 286	708	2 059	88	1 366	437	1 386	155	2 352	423	1 689	302	38 176	5 505	
New Peddinghaus	Day Shift	1 917	155	3 233	154	394	10	628	124	589	208	0	0	1 644	468	16 493	1 426	New Peddinghaus
	Night Shift	2 204	84	608	275	713	164	0	0	0	0	300	250	1 193	152	0	0	
Ficep 166	Day Shift	4 024	156	5 108	40	5 010	112	3 105	72	2 501	23	2 341	367	1 083	126	48 064	5 226	Ficep 116
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Ficep 206	Day Shift	1 853	273	3 943	159	0	0	5 442	121	5 442	113	4 178	189	6 187	253	53 083	2 934	Ficep 206
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	TOTAL	48 457	1 719	38 592	1 889	31 496	712	39 272	1 385	29 781	1 565	49 133	2 666	66 130	2 267	1 034 552	32 889	GRAND TOTAL
	Day Shift	16 307	1 162	21 390	614	9 292	356	19 845	685	13 862	919	15 607	1 590	25 843	1 088	403 033	20 849	Day Shift
	Night Shift	28 029	318	13 361	846	21 097	182	18 799	576	15 330	438	33 226	826	37 450	559	615 026	10 614	Night Shift

Day Shift	1 898	140
Night Shif	0	0
Totals	1 898	140

Day Shift	79 018	3 881
Night Shif	132 077	1 695
Totals	211 095	5 576

Day Shift	121 799	4 571
Night Shif	168 155	2 838
Totals	289 954	7 409

Day Shift	120 322	8 093
Night Shif	212 981	3 213
Totals	333 303	11 306



CNC Machines - Tonnage Cut Per Day / Shift

		Wednesday		Thursday		Friday		Saturday		Sunday		Monday		Tuesday		Wednesday	
		01-Feb		02-Feb		03-Feb		04-Feb		05-Feb		06-Feb		07-Feb		08-Feb	
		Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items
Saw 21	Day Shift	5 621	12	10 317	7	10 066	18	5 491	37	0	0	1 555	4	0	0	8 367	37
	Night Shift	35 164	26	14 095	18	28 393	60	9 533	34	0	0	4 749	63	4 188	42	5 665	43
Saw 28	Day Shift			3 735	46	2 831	17	35	5	0	0	392	56	2 853	68	1 144	44
	Night Shift	1 912	66	3 752	48	1 939	45	140	20	0	0	910	67	2 502	68	2 157	65
Tippo	Day Shift	499	75	668	122	100	50	220	125	0	0	562	281	714	105	684	291
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDL 1250/9	Day Shift	3 666	48	4 468	25	3 241	25	4 356	28	621	37	6 265	40	7 384	57	7 159	48
	Night Shift	6 245	75	6 145	54	9 353	46	9 962	27	11 251	32	10 781	31	11 630	55	20 118	41
BDL 1000	Day Shift	4 982	66	3 404	35	2 087	31	5 185	25	1 995	88	3 811	60	7 749	48	5 082	32
	Night Shift	16 955	43	13 744	43	9 460	32	17 777	48	17 288	25	8 375	61	25 147	48	10 312	47
Old Plasma	Day Shift	1 570	30	968	249	336	182	629	12	649	6	1 564	43	1 537	39	878	180
	Night Shift	1 366	239	1 224	93	77	52	2 347	87	1 765	46	1 771	45	744	184	2 284	61
Lind	Day Shift	1 368	255	1 912	642	331	311	1 467	39	300	175	250	517	767	37	1 650	119
	Night Shift	1 796	451	2 319	363	3 802	433	1 676	110	492	260	600	532	875	72	4 267	252
New Peddinghaus	Day Shift	0	0	0	0	0	0	1 061	67	995	295	1 256	290	786	69	298	155
	Night Shift	376	73	0	0	1 346	102	991	64	0	0	405	88	782	45	2 222	55
Ficep 166	Day Shift	1 243	381	4 800	128	1 102	238	1 305	162	1 509	112	1 720	400	1 620	158	2 495	79
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ficep 206	Day Shift	7 261	273	4 078	280	554	81	308	66	1 570	230	2 614	401	1 989	293	1 962	288
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	90 024	2 113	75 629	2 153	75 018	1 723	62 483	956	38 435	1 306	47 580	2 979	71 267	1 388	76 744	1 837
	Day Shift	26 210	1 140	34 350	1 534	20 648	953	18 996	499	6 644	648	18 733	1 802	24 613	805	29 421	1 118
	Night Shift	63 438	900	41 279	619	53 024	668	41 435	326	30 796	363	27 186	799	45 086	469	44 803	509

		Thursday		Friday		Saturday		Sunday		Monday		Tuesday		Wednesday		Thursday	
		09-Feb		10-Feb		11-Feb		12-Feb		13-Feb		14-Feb		15-Feb		16-Feb	
		Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items
Saw 21	Day Shift	1 717	57	805	12	2 488	32					11 171	23	918	23	13 502	49
	Night Shift	1 490	36	3 086	40	12 548	57			3 081	72	3 079	4	10 348	27	7 821	6
Saw 28	Day Shift	873	27	821	35	1 366	33	2 211	39	2 565	67	1 487	60	1 564	84	4 746	92
	Night Shift	1 631	46	2 177	39	3 530	70	1 536	63	323	84	4 976	64	1 720	40	1 471	62
Tippo	Day Shift	693	241	488	212	327	65	0	0	364	149	617	77	663	589	742	485
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDL 1250/9	Day Shift	17 828	33	2 428	13	5 894	25			3 926	34	5 186	6	3 293	25	3 581	32
	Night Shift	8 663	25	11 542	26	6 565	38	5 148	66	14 630	11	7 980	6	8 686	50	7 073	65
BDL 1000	Day Shift	2 756	65	3 717	21			4 179	17	6 024	36	4 395	40	7 797	54	7 226	44
	Night Shift	8 189	51	7 952	45	4 747	30			1 258	70	12 133	38	17 082	57	13 790	40
Old Plasma	Day Shift	1 211	106	46	4	938	57			1 334	44	923	164	1 155	22	0	0
	Night Shift	1 306	60	0	0	1 175	59	1 137	39	2 339	74	1 549	348	728	55	0	0
Lind	Day Shift	1 494	95	1 101	44	3 412	402	3 082	36	938	144	1 223	631	1 047	180	2 815	117
	Night Shift	2 047	187	2 468	490	16 848	12			1 651	622	1 624	212	2 111	239	2 283	139
New Peddinghaus	Day Shift	656	186	0	0	962	102	735	49	562	51	617	71	1 000	25	285	237
	Night Shift	305	21	545	45	700	56			1 632	20	0	0	1 856	61	916	599
Ficep 166	Day Shift	6 300	160	1 215	201	1 815	268	620	191	1 093	383	2 715	585	1 211	271	1 400	142
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ficep 206	Day Shift	1 131	534	1 005	144	1 130	205	583	166	1 654	931	0	0	0	0	0	0
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	58 290	1 930	39 396	1 371	64 445	1 511	19 231	666	43 374	2 792	59 675	2 329	61 179	1 802	67 651	2 109
	Day Shift	34 003	1 318	11 626	686	17 370	1 087	10 675	449	17 898	1 788	27 717	1 586	17 648	1 248	34 012	961
	Night Shift	23 326	405	27 225	640	45 413	266	7 821	168	23 282	933	31 341	672	40 675	468	32 438	312

		Friday		Saturday		Sunday		Monday		Tuesday		Wednesday		Thursday		Friday	
		17-Feb		18-Feb		19-Feb		20-Feb		21-Feb		22-Feb		23-Feb		24-Feb	
		Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items
Saw 21	Day Shift	2 660	2	5 751	7	11 559	46	6 371	31	3 963	25	7 166	36	3 130	3	6 377	30
	Night Shift	7 980	6	7 995	20	3 206	36	1 349	33	11 720	25	2 264	18	6 842	74	831	72
Saw 28	Day Shift	1 425	31	970	33	776	27	567	18	2 919	54	782	10	272	6	99	33
	Night Shift	6 998	54	629	14	0	0	1 485	61	456	24	355	10	0	0	252	2
Tippo	Day Shift	248	124	602	257	111	222	196	450	556	234	6 183	389	1 938	12	585	117
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDL 1250/9	Day Shift	2 215	10	4 494	12	2 691	13	5 826	30	1 997	25	7 195	50	2 423	34	2 828	38
	Night Shift	10 340	36	10 363	43	8 552	37	8 647	25	4 815	46	8 018	73	14 228	36	7 067	53
BDL 1000	Day Shift	1 519	64	4 271	35	1 918	31	760	98	7 494	19	2 103	82	6 505	23	1 899	69
	Night Shift	8 770	35	3 131	79	3 046	101	1 622	107	9 514	48	9 213	60	9 232	45	6 208	34
Old Plasma	Day Shift	0	0	0	0	0	0	0	0	1 079	85	1 241	66	2 092	76	418	13
	Night Shift	0	0	0	0	0	0	2 207	84	1 479	65	1 620	51	1 662	167	6 878	93
Lind	Day Shift	637	36	1 019	28	790	88	1 547	101	328	163	333	190	869	256	292	44
	Night Shift	1 695	52	1 810	98	973	85	1 303	148	354	149	540	202	594	69	612	102
New Peddinghaus	Day Shift	300	225	860	264	0	0	0	0	191	12	930	160	1 553	52	864	30
	Night Shift	2 005	67	2 516	71	2 708	162	2 518	81	2 023	85	1 864	119	1 801	54	1 418	55
Ficep 166	Day Shift	2 400	172	5 897	144	5 466	124	910	104	2 225	304	680	130	1 675	856	1 400	175
	Night Shift	0	0	0	0	0	0	7 699	145	2 302	534	2 823	108	989	686	1 659	767
Ficep 206	Day Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	49 192	914	50 308	1 105	41 796	972	43 007	1 516	53 415	1 897	53 310	1 754	55 805	2 449	39 687	1 727
	Day Shift	11 104	439	23 004	516	23 311	551	16 177	832	20 561	909	25 683	953	18 904	1 266	13 898	519
	Night Shift	35 783	183	23 928	254	15 777	259	24 312	603	30 640	891	24 833	522	33 547	1 077	23 507	1 123

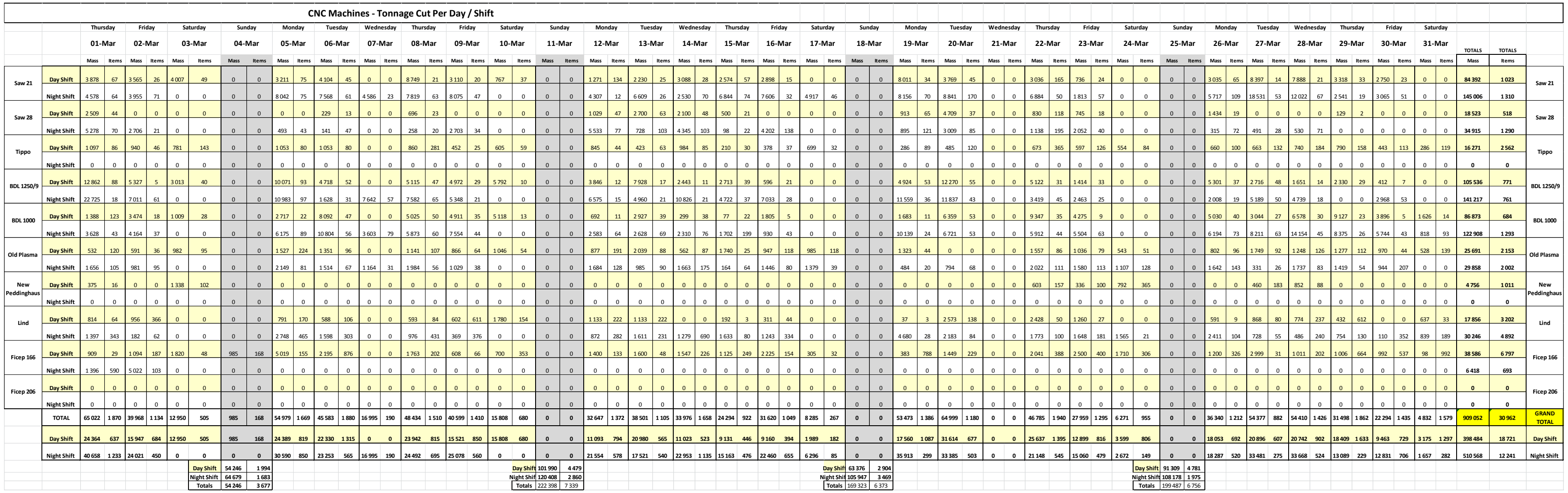
		Saturday		Sunday		Monday		Tuesday		Wednesday				
		25-Feb		26-Feb		27-Feb		28-Feb		29-Feb		TOTALS	TOTALS	
		Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	
Saw 21	Day Shift	4 727	42	2 812	32	10 182	56	8 390	43	14 796	45	159 902	709	Saw 21
	Night Shift	0	0	0	0	12 244	28	7 358	20	4 898	91	209 927	951	
Saw 28	Day Shift	0	0	0	0	2 310	46	1 065	22	811	40	38 619	993	Saw 28
	Night Shift	0	0	0	0	1 743	50	4 868	91	297	99	47 759	1 252	
Tippo	Day Shift	0	0	0	0	604	325	1 285	24	965	116	20 614	5 137	Tippo
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	
BDL 1250/9	Day Shift	8 349	15	10 280	9	4 721	85	5 477	78	5 425	37	143 217	912	BDL 1250/9
	Night Shift	0	0	0	0	5 553	42	14 526	74	12 367	39	260 248	1 152	
BDL 1000	Day Shift	2 065	99	265	19	1 318	120	984	136	6 495	56	107 985	1 513	BDL 1000
	Night Shift	1 061	24	671	97	12 208	16	5 423	74	2 430	84	256 738	1 482	
Old Plasma	Day Shift	0	0	0	0	1 674	85	509	142	870	126	21 621	1 731	Old Plasma
	Night Shift	0	0	0	0	47	7	1 454	258	1 561	312	36 720	2 479	
Lind	Day Shift	0	0	0	0	952	170	1 733	245	2 212	328	33 869	5 393	Lind
	Night Shift	0	0	0	0	879	157	1 299	232	4 690	481	59 608	6 149	
New Peddinghaus	Day Shift	104	48	0	0	0	0	0	0	441	142	14 456	2 530	New Peddinghaus
	Night Shift	0	0	0	0	0	0	162	78	822	72	29 913	2 073	
Ficep 166	Day Shift	1 250	128	550	161	2 108	231	1 078	210	400	47	58 202	6 645	Ficep 116
	Night Shift	0	0	0	0	596	424	0	0	502	153	16 570	2 817	
Ficep 206	Day Shift	0	0	0	0	0	0	0	0	0	0	25 839	3 892	Ficep 206
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	
	TOTAL	17 556	356	14 578	318	57 139	1 842	55 611	1 727	59 982	2 268	1 541 807	47 810	GRAND TOTAL
	Day Shift	16 391	284	13 907	221	23 869	1 118	20 521	900	31 974	795	609 868	26 925	Day Shift
	Night Shift	1 061	24	671	97	33 270	724	34 928	749	26 745	1 259	887 570	16 282	Night Shift

Day Shift	100 204	4 126
Night Shift	199 176	2 513
Totals	100 204	6 639

Day Shift	142 410	7 464
Night Shif	243 835	3 451
Totals	386 245	10 915

Day Shift	142 058	6 987
Night Shif	195 268	2 990
Totals	337 326	9 977

Day Shift	134 925	5 314
Night Shif	153 677	4 499
Totals	288 602	9 813



CNC Machines - Tonnage Cut Per Day / Shift

		Thursday 01-Mar		Friday 02-Mar		Saturday 03-Mar		Sunday 04-Mar		Monday 05-Mar		Tuesday 06-Mar		Wednesday 07-Mar	
		Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items
Saw 21	Day Shift	3 878	67	3 565	26	4 007	49	0	0	3 211	75	4 104	45	0	0
	Night Shift	4 578	64	3 955	71	0	0	0	0	8 042	75	7 568	61	4 586	23
Saw 28	Day Shift	2 509	44	0	0	0	0	0	0	0	0	229	13	0	0
	Night Shift	5 278	70	2 706	21	0	0	0	0	493	43	141	47	0	0
Tippo	Day Shift	1 097	86	940	46	781	143	0	0	1 053	80	1 053	80	0	0
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDL 1250/9	Day Shift	12 862	88	5 327	5	3 013	40	0	0	10 071	93	4 718	52	0	0
	Night Shift	22 725	18	7 011	61	0	0	0	0	10 983	97	1 628	31	7 642	57
BDL 1000	Day Shift	1 388	123	3 474	18	1 009	28	0	0	2 717	22	8 092	47	0	0
	Night Shift	3 628	43	4 164	37	0	0	0	0	6 175	89	10 804	56	3 603	79
Old Plasma	Day Shift	532	120	591	36	982	95	0	0	1 527	224	1 351	96	0	0
	Night Shift	1 656	105	981	95	0	0	0	0	2 149	81	1 514	67	1 164	31
New Peddinghaus	Day Shift	375	16	0	0	1 338	102	0	0	0	0	0	0	0	0
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lind	Day Shift	814	64	956	366	0	0	0	0	791	170	588	106	0	0
	Night Shift	1 397	343	182	62	0	0	0	0	2 748	465	1 598	303	0	0
Ficep 166	Day Shift	909	29	1 094	187	1 820	48	985	168	5 019	155	2 195	876	0	0
	Night Shift	1 396	590	5 022	103	0	0	0	0	0	0	0	0	0	0
Ficep 206	Day Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	65 022	1 870	39 968	1 134	12 950	505	985	168	54 979	1 669	45 583	1 880	16 995	190
	Day Shift	24 364	637	15 947	684	12 950	505	985	168	24 389	819	22 330	1 315	0	0
	Night Shift	40 658	1 233	24 021	450	0	0	0	0	30 590	850	23 253	565	16 995	190
							Day Shift	54 246	1 994						
							Night Shift	64 679	1 683						
							Totals	54 246	3 677						

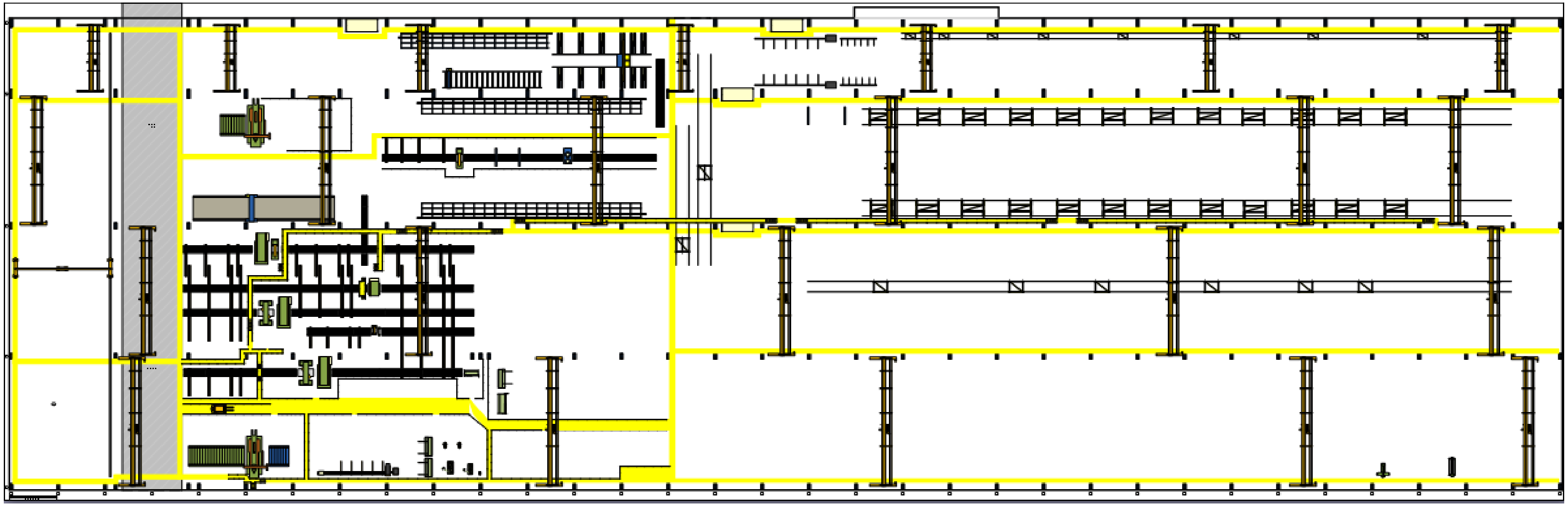
		Thursday 08-Mar		Friday 09-Mar		Saturday 10-Mar		Sunday 11-Mar		Monday 12-Mar		Tuesday 13-Mar		Wednesday 14-Mar	
		Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items
Saw 21	Day Shift	8 749	21	3 110	20	767	37	0	0	1 271	134	2 230	25	3 088	28
	Night Shift	7 819	63	8 075	47	0	0	0	0	4 307	12	6 609	26	2 530	70
Saw 28	Day Shift	696	23	0	0	0	0	0	0	1 029	47	2 700	63	2 100	48
	Night Shift	258	20	2 703	34	0	0	0	0	5 533	77	728	103	4 345	103
Tippo	Day Shift	860	281	452	25	605	59	0	0	845	44	423	63	984	85
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDL 1250/9	Day Shift	5 115	47	4 972	29	5 792	10	0	0	3 846	12	7 928	17	2 443	11
	Night Shift	7 582	65	5 348	21	0	0	0	0	6 575	15	4 960	21	10 826	21
BDL 1000	Day Shift	5 025	50	4 911	35	5 118	13	0	0	692	11	2 927	39	299	38
	Night Shift	5 873	60	7 554	44	0	0	0	0	2 583	64	2 628	69	2 310	76
Old Plasma	Day Shift	1 141	107	866	64	1 046	54	0	0	877	191	2 039	88	562	87
	Night Shift	1 984	56	1 029	38	0	0	0	0	1 684	128	985	90	1 663	175
New Peddinghaus	Day Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lind	Day Shift	593	84	602	611	1 780	154	0	0	1 133	222	1 133	222	0	0
	Night Shift	976	431	369	376	0	0	0	0	872	282	1 611	231	1 279	690
Ficep 166	Day Shift	1 763	202	608	66	700	353	0	0	1 400	133	1 600	48	1 547	226
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ficep 206	Day Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	48 434	1 510	40 599	1 410	15 808	680	0	0	32 647	1 372	38 501	1 105	33 976	1 658
	Day Shift	23 942	815	15 521	850	15 808	680	0	0	11 093	794	20 980	565	11 023	523
	Night Shift	24 492	695	25 078	560	0	0	0	0	21 554	578	17 521	540	22 953	1 135
							Day Shift	101 990	4 479						
							Night Shif	120 408	2 860						
							Totals	222 398	7 339						

		Thursday 15-Mar		Friday 16-Mar		Saturday 17-Mar		Sunday 18-Mar		Monday 19-Mar		Tuesday 20-Mar		Wednesday 21-Mar	
		Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items
Saw 21	Day Shift	2 574	57	2 898	15	0	0	0	0	8 011	34	3 769	45	0	0
	Night Shift	6 844	74	7 606	32	4 917	46	0	0	8 156	70	8 841	170	0	0
Saw 28	Day Shift	500	21	0	0	0	0	0	0	913	65	4 709	37	0	0
	Night Shift	98	22	4 202	138	0	0	0	0	895	121	3 009	85	0	0
Tippo	Day Shift	210	30	378	37	699	32	0	0	286	89	485	120	0	0
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDL 1250/9	Day Shift	2 713	39	596	21	0	0	0	0	4 924	53	12 270	55	0	0
	Night Shift	4 722	37	7 033	28	0	0	0	0	11 559	36	11 837	43	0	0
BDL 1000	Day Shift	77	22	1 805	5	0	0	0	0	1 683	11	6 359	53	0	0
	Night Shift	1 702	199	930	43	0	0	0	0	10 139	24	6 721	53	0	0
Old Plasma	Day Shift	1 740	25	947	118	985	118	0	0	1 323	44	0	0	0	0
	Night Shift	164	64	1 446	80	1 379	39	0	0	484	20	794	68	0	0
New Peddinghaus	Day Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lind	Day Shift	192	3	311	44	0	0	0	0	37	3	2 573	138	0	0
	Night Shift	1 633	80	1 243	334	0	0	0	0	4 680	28	2 183	84	0	0
Ficep 166	Day Shift	1 125	249	2 225	154	305	32	0	0	383	788	1 449	229	0	0
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ficep 206	Day Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	24 294	922	31 620	1 049	8 285	267	0	0	53 473	1 386	64 999	1 180	0	0
	Day Shift	9 131	446	9 160	394	1 989	182	0	0	17 560	1 087	31 614	677	0	0
	Night Shift	15 163	476	22 460	655	6 296	85	0	0	35 913	299	33 385	503	0	0
							Day Shif	63 376	2 904						
							Night Shif	105 947	3 469						
							Totals	169 323	6 373						

		Thursday 22-Mar		Friday 23-Mar		Saturday 24-Mar		Sunday 25-Mar		Monday 26-Mar		Tuesday 27-Mar		Wednesday 28-Mar	
		Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items	Mass	Items
Saw 21	Day Shift	3 036	165	736	24	0	0	0	0	3 035	65	8 397	14	7 888	21
	Night Shift	6 884	50	1 813	57	0	0	0	0	5 717	109	18 531	53	12 022	67
Saw 28	Day Shift	830	118	745	18	0	0	0	0	1 434	19	0	0	0	0
	Night Shift	1 138	195	2 052	40	0	0	0	0	315	72	491	28	530	71
Tippo	Day Shift	673	365	597	126	554	84	0	0	660	100	663	132	740	184
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BDL 1250/9	Day Shift	5 122	31	1 414	33	0	0	0	0	5 301	37	2 716	48	1 651	14
	Night Shift	3 419	45	2 463	25	0	0	0	0	2 008	19	5 189	50	4 739	18
BDL 1000	Day Shift	9 347	35	4 275	9	0	0	0	0	5 030	40	3 044	27	6 578	30
	Night Shift	5 912	44	5 504	63	0	0	0	0	6 194	73	8 211	63	14 154	45
Old Plasma	Day Shift	1 557	86	1 036	79	543	51	0	0	802	96	1 749	92	1 248	126
	Night Shift	2 022	111	1 580	113	1 107	128	0	0	1 642	143	331	26	1 737	83
New Peddinghaus	Day Shift	603	157	336	100	792	365	0	0	0	0	460	183	852	88
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lind	Day Shift	2 428	50	1 260	27	0	0	0	0	591	9	868	80	774	237
	Night Shift	1 773	100	1 648	181	1 565	21	0	0	2 411	104	728	55	486	240
Ficep 166	Day Shift	2 041	388	2 500	400	1 710	306	0	0	1 200	326	2 999	31	1 011	202
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ficep 206	Day Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Night Shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	46 785	1 940	27 959	1 295	6 271	955	0	0	36 340	1 212	54 377	882	54 410	1 426
	Day Shift	25 637	1 395	12 899	816	3 599	806	0	0	18 053	692	20 896	607	20 742	902
	Night Shift	21 148	545	15 060	479	2 672	149	0	0	18 287	520	33 481	275	33 668	524
							Day Shift	91 309	4 781						
							Night Shift	108 178	1 975						
							Totals	199 487	6 756						

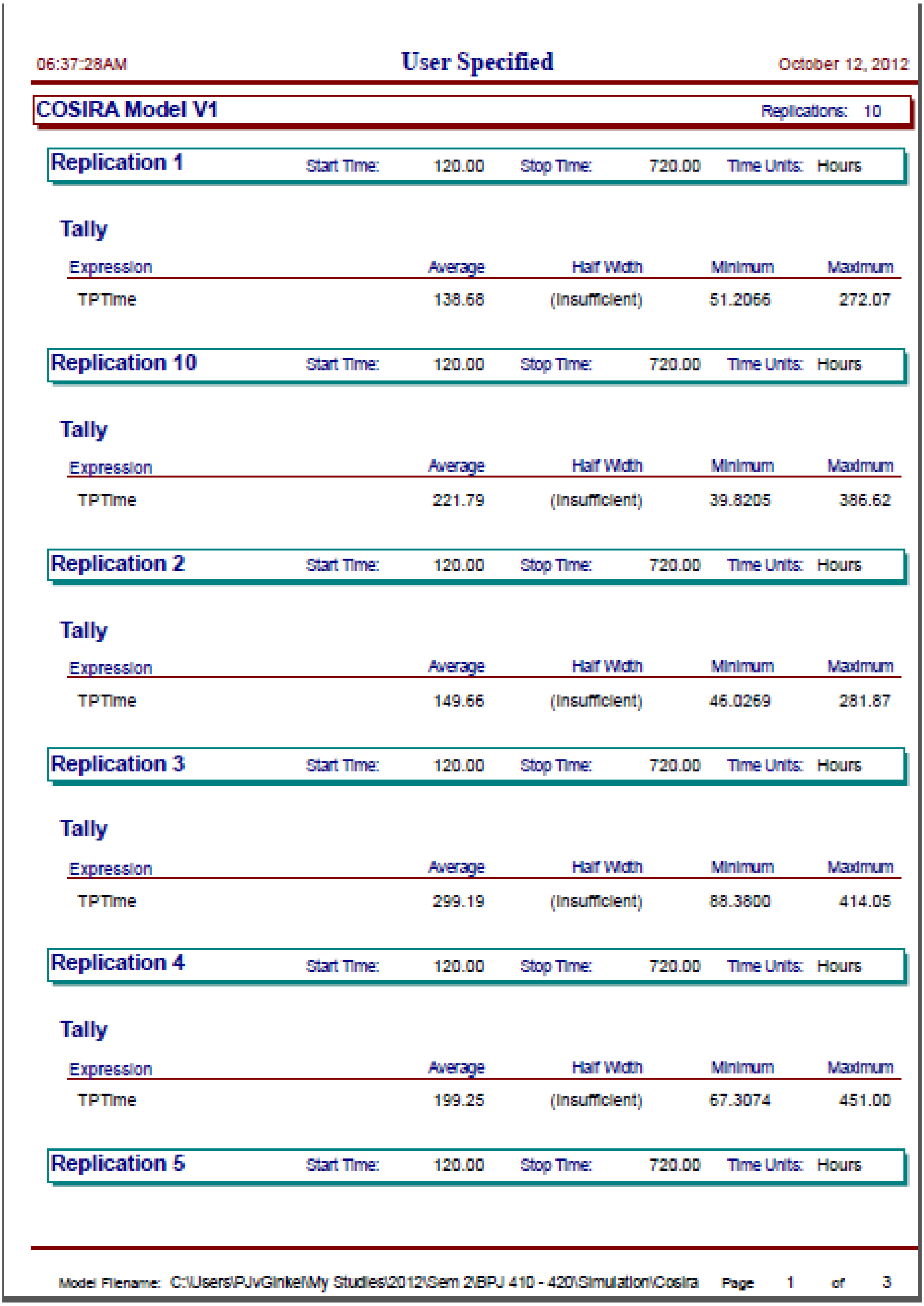
		Thursday 29-Mar		Friday 30-Mar		Saturday 31-Mar		TOTALS	TOTALS	
		Mass	Items	Mass	Items	Mass	Items	Mass	Items	
Saw 21	Day Shift	3 318	33	2 750	23	0	0	84 392	1 023	Saw 21
	Night Shift	2 541	19	3 065	51	0	0	145 006	1 310	
Saw 28	Day Shift	129	2	0	0	0	0	18 523	518	Saw 28
	Night Shift	0	0	0	0	0	0	34 915	1 290	
Tippo	Day Shift	790	158	443	113	286	119	16 271	2 562	Tippo
	Night Shift	0	0	0	0	0	0	0	0	
BDL 1250/9	Day Shift	2 330	29	412	7	0	0	105 536	771	BDL 1250/9
	Night Shift	0	0	2 968	53	0	0	141 217	761	
BDL 1000	Day Shift	9 127	23	3 896	5	1 626	14	86 873	684	BDL 1000
	Night Shift	8 375	26	5 744	43	818	93	122 908	1 293	
Old Plasma	Day Shift	1 277	112	970	44	528	139	25 691	2 153	Old Plasma
	Night Shift	1 419	54	944	207	0	0	29 858	2 002	
New Peddinghaus	Day Shift	0	0	0	0	0	0	4 756	1 011	New Peddinghaus
	Night Shift	0	0	0	0	0	0	0	0	
Lind	Day Shift	432	612	0	0	637	33	17 856	3 202	Lind
	Night Shift	754	130	110	352	839	189	30 246	4 892	
Ficep 166	Day Shift	1 006	664	992	537	98	992	38 586	6 797	Ficep 166
	Night Shift	0	0	0	0	0	0	6 418	693	
Ficep 206	Day Shift	0	0	0	0	0	0	0	0	Ficep 206
	Night Shift	0	0	0	0	0	0	0	0	
	TOTAL	31 498	1 862	22 294	1 435	4 832	1 579	909 052	30 962	GRAND TOTAL
	Day Shift	18 409	1 633	9 463	729	3 175	1 297	398 484	18 721	Day Shift
	Night Shift	13 089	229	12 831	706	1 657	282	510 568	12 241	Night Shift

APPENDIX 3 – COSIRA VULCAN WORKSHOP LAYOUT



APPENDIX 4 – THROUGHPUT TIME REPORTS FROM SIMULATIONS

APPENDIX 4A – BASE MODEL SIMULATION



06:37:28AM **User Specified** October 12, 2012

COSIRA Model V1 Replications: 10

Replication 1 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	138.68	(Insufficient)	51.2066	272.07

Replication 10 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	221.79	(Insufficient)	39.8205	386.62

Replication 2 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	149.66	(Insufficient)	46.0269	281.87

Replication 3 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	299.19	(Insufficient)	88.3800	414.05

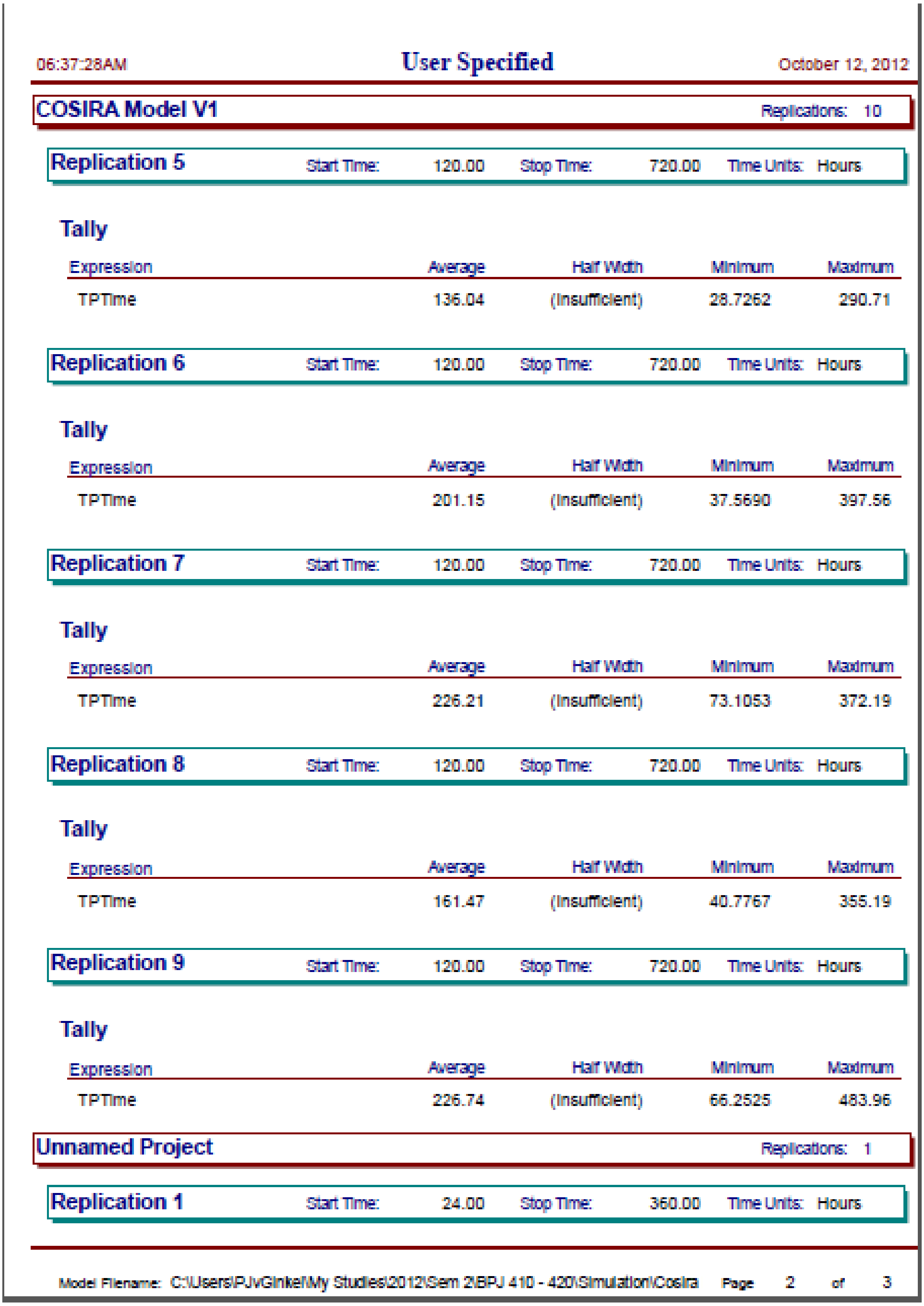
Replication 4 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	199.25	(Insufficient)	67.3074	451.00

Replication 5 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 1 of 3



06:37:28AM **User Specified** October 12, 2012

COSIRA Model V1 Replications: 10

Replication 5 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	136.04	(Insufficient)	28.7262	290.71

Replication 6 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	201.15	(Insufficient)	37.5690	397.56

Replication 7 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	226.21	(Insufficient)	73.1053	372.19

Replication 8 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	161.47	(Insufficient)	40.7767	355.19

Replication 9 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	226.74	(Insufficient)	66.2525	483.96

Unnamed Project Replications: 1

Replication 1 Start Time: 24.00 Stop Time: 360.00 Time Units: Hours

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 2 of 3

APPENDIX 4B – LINE BALANCING MODEL 1 SIMULATION

01:33:23 PM

User Specified

October 12, 2012

COSIRA Model V2_1

Replications: 10

Replication 1

Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	154.33	(Insufficient)	49.1500	302.26

Replication 10

Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	181.27	(Insufficient)	30.5454	473.29

Replication 2

Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	190.69	(Insufficient)	49.5147	407.74

Replication 3

Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	237.77	(Correlated)	54.0300	432.63

Replication 4

Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

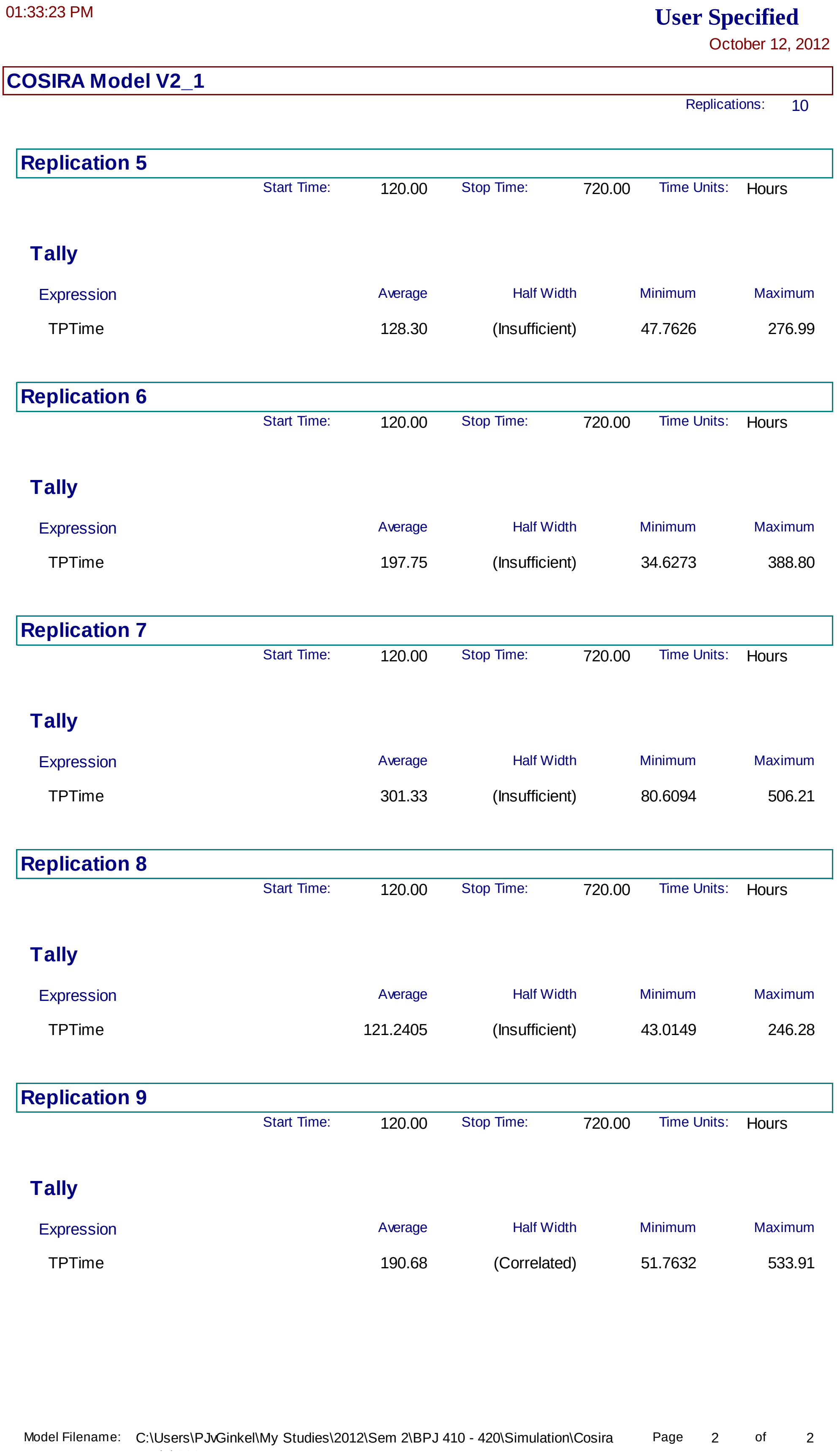
Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	147.13	(Correlated)	62.7205	254.99

Replication 5

Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 1 of 2



01:33:23 PM

User Specified

October 12, 2012

COSIRA Model V2_1

Replications: 10

Replication 5

Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	128.30	(Insufficient)	47.7626	276.99

Replication 6

Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	197.75	(Insufficient)	34.6273	388.80

Replication 7

Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	301.33	(Insufficient)	80.6094	506.21

Replication 8

Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	121.2405	(Insufficient)	43.0149	246.28

Replication 9

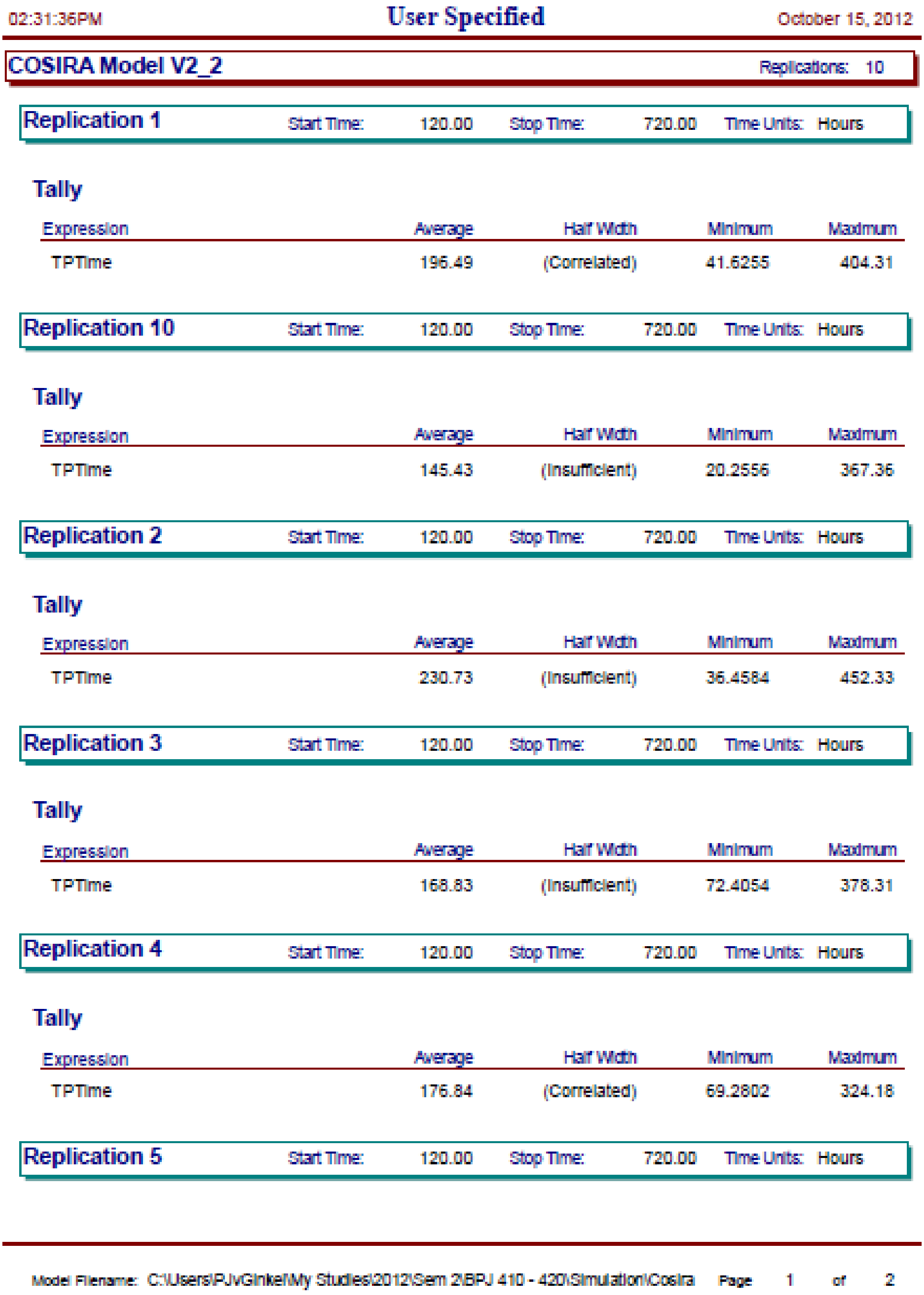
Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	190.68	(Correlated)	51.7632	533.91

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 2 of 2

APPENDIX 4C – LINE BALANCING MODEL 2 SIMULATION



02:31:36PM **User Specified** October 15, 2012

COSIRA Model V2_2 Replications: 10

Replication 1 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	196.49	(Correlated)	41.6255	404.31

Replication 10 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	145.43	(Insufficient)	20.2556	367.36

Replication 2 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	230.73	(Insufficient)	36.4584	452.33

Replication 3 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	168.83	(Insufficient)	72.4054	378.31

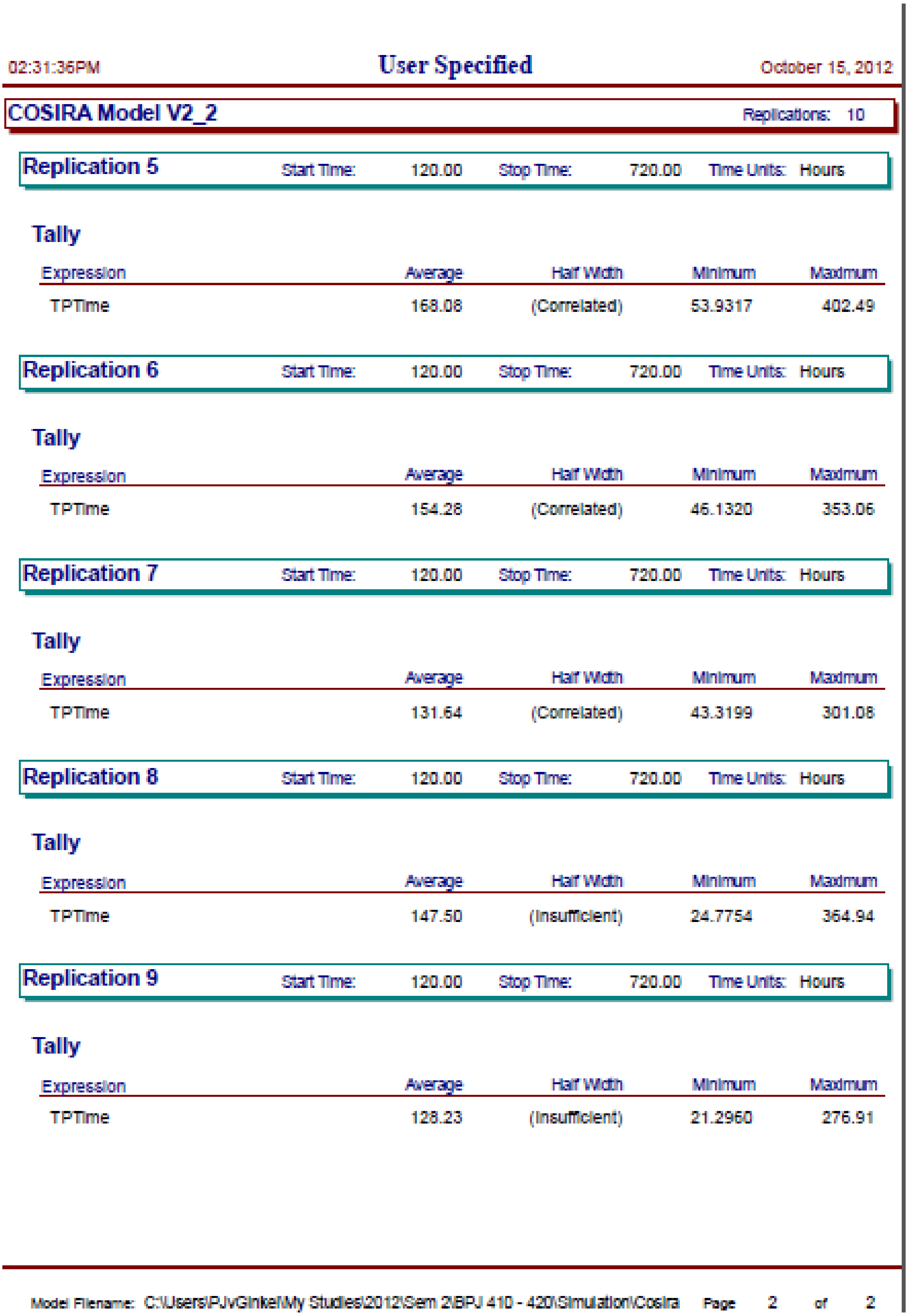
Replication 4 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	176.84	(Correlated)	69.2802	324.18

Replication 5 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 1 of 2



02:31:36PM **User Specified** October 15, 2012

COSIRA Model V2_2 Replications: 10

Replication 5 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	168.08	(Correlated)	53.9317	402.49

Replication 6 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	154.28	(Correlated)	46.1320	353.06

Replication 7 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	131.64	(Correlated)	43.3199	301.08

Replication 8 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	147.50	(Insufficient)	24.7754	364.94

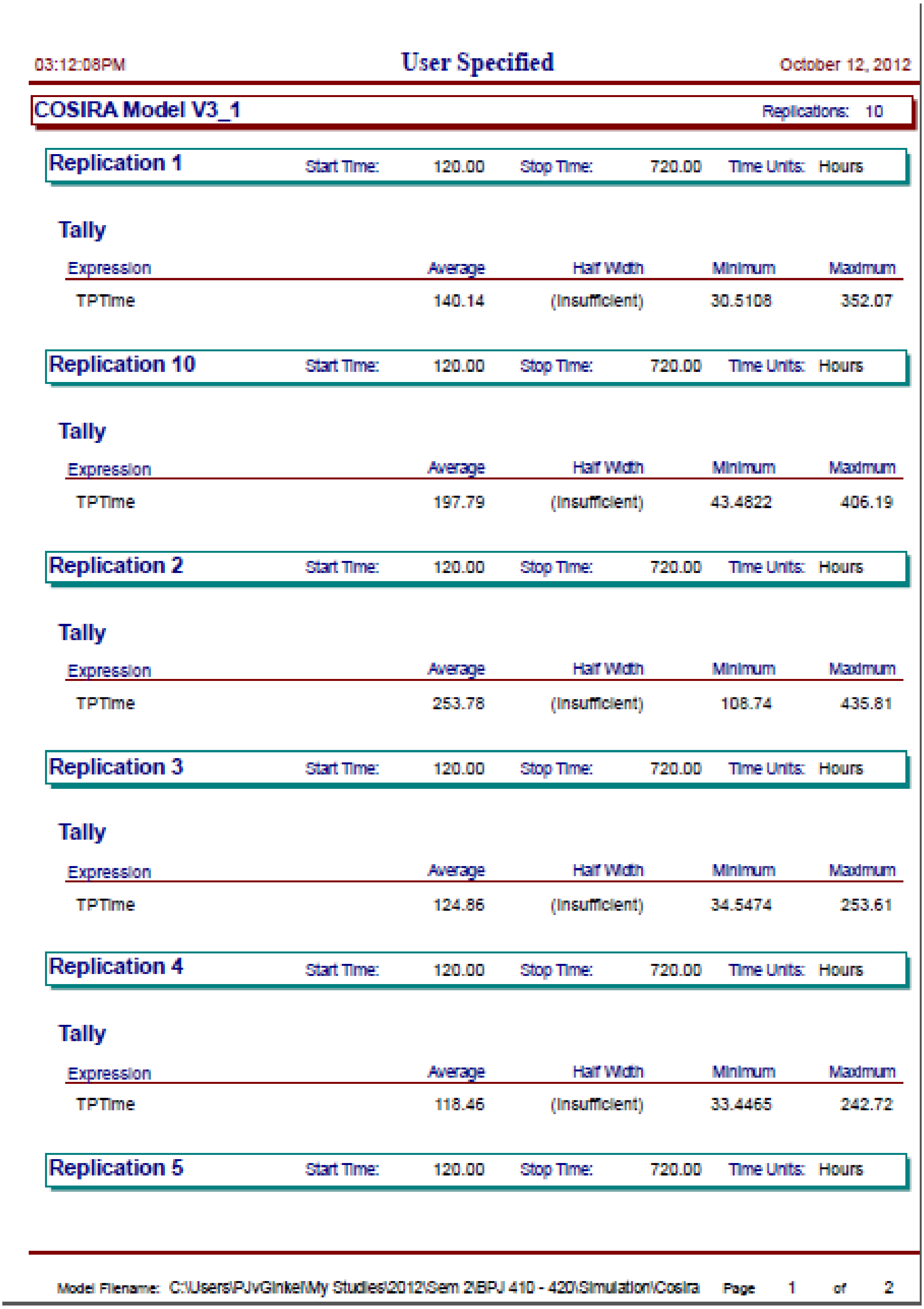
Replication 9 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	128.23	(Insufficient)	21.2960	276.91

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 2 of 2

APPENDIX 4D – TOC MODEL 1 SIMULATION



03:12:08PM **User Specified** October 12, 2012

COSIRA Model V3_1 Replications: 10

Replication 1 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	140.14	(Insufficient)	30.5108	352.07

Replication 10 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	197.79	(Insufficient)	43.4822	406.19

Replication 2 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	253.78	(Insufficient)	108.74	435.81

Replication 3 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	124.86	(Insufficient)	34.5474	253.61

Replication 4 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	118.46	(Insufficient)	33.4465	242.72

Replication 5 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 1 of 2

03:12:08PM **User Specified** October 12, 2012

COSIRA Model V3_1 Replications: 10

Replication 5 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	199.44	(Insufficient)	39.6610	370.44

Replication 6 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	137.69	(Insufficient)	60.8736	289.94

Replication 7 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	294.85	(Insufficient)	63.1063	426.09

Replication 8 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	183.81	(Insufficient)	39.7924	334.69

Replication 9 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	205.74	(Insufficient)	51.0286	430.46

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 2 of 2

APPENDIX 4E – TOC MODEL 2 SIMULATION

01:30:16PM **User Specified** October 15, 2012

COSIRA Model V3_3 Replications: 10

Replication 1

Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	191.84	(Insufficient)	67.2022	347.09

Replication 10

Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	189.01	(Insufficient)	21.6827	446.04

Replication 2

Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	178.98	(Insufficient)	69.2969	335.11

Replication 3

Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	164.89	(Insufficient)	65.0383	362.19

Replication 4

Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	160.87	(Insufficient)	39.7846	397.48

Replication 5

Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 1 of 2

01:30:16PM **User Specified** October 15, 2012

COSIRA Model V3_3

Replications: 10

Replication 5

Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	204.31	(Insufficient)	44.4015	347.23

Replication 6

Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	208.08	(Insufficient)	52.3904	403.56

Replication 7

Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	202.61	(Insufficient)	46.1461	460.29

Replication 8

Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	202.46	(Insufficient)	28.0153	424.93

Replication 9

Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	143.41	(Insufficient)	41.2275	288.39

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 2 of 2

APPENDIX 4F – FINAL MODEL SIMULATION

02:22:17PM **User Specified** October 15, 2012

COSIRA Model V4_1 Replications: 10

Replication 1 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	176.27	(Insufficient)	47.8209	316.92

Replication 10 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	128.58	(Insufficient)	34.7394	260.58

Replication 2 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	190.16	(Insufficient)	54.6595	427.95

Replication 3 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	195.80	(Insufficient)	48.0831	501.64

Replication 4 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	178.53	(Insufficient)	29.6128	435.18

Replication 5 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 1 of 2

02:22:17PM **User Specified** October 15, 2012

COSIRA Model V4_1 Replications: 10

Replication 5 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	116.63	(Insufficient)	42.7647	290.30

Replication 6 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	117.61	(Insufficient)	31.8794	293.29

Replication 7 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	181.64	(Insufficient)	43.0967	350.24

Replication 8 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	129.06	(Insufficient)	49.4433	275.38

Replication 9 Start Time: 120.00 Stop Time: 720.00 Time Units: Hours

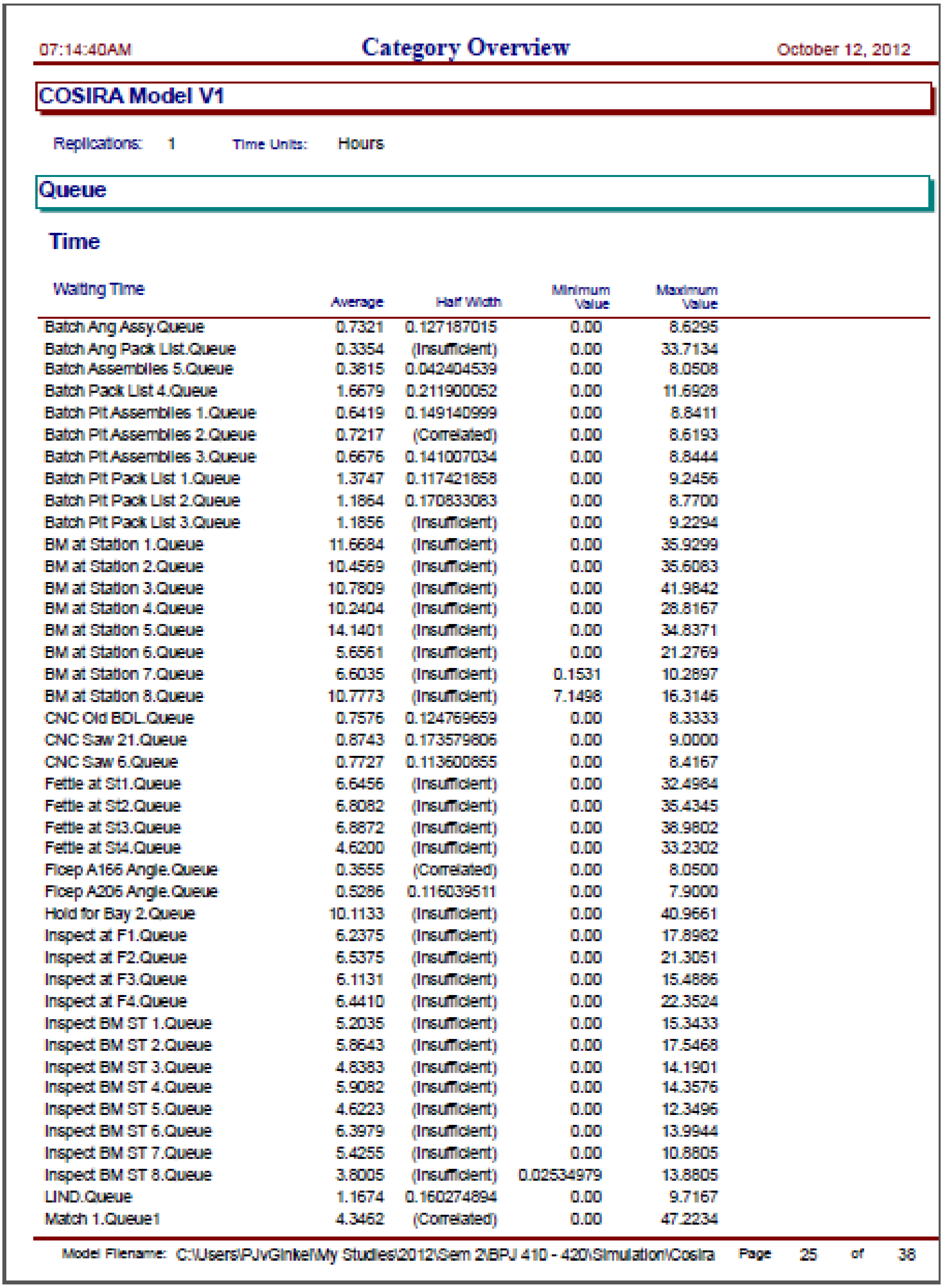
Tally

Expression	Average	Half Width	Minimum	Maximum
TPTime	134.52	(Insufficient)	43.9613	326.77

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 2 of 2

APPENDIX 5 – QUEUES OVERVIEW REPORTS FOR SIMULATIONS

APPENDIX 5A – BASE MODEL SIMULATION



07:14:40AM **Category Overview** October 12, 2012

COSIRA Model V1

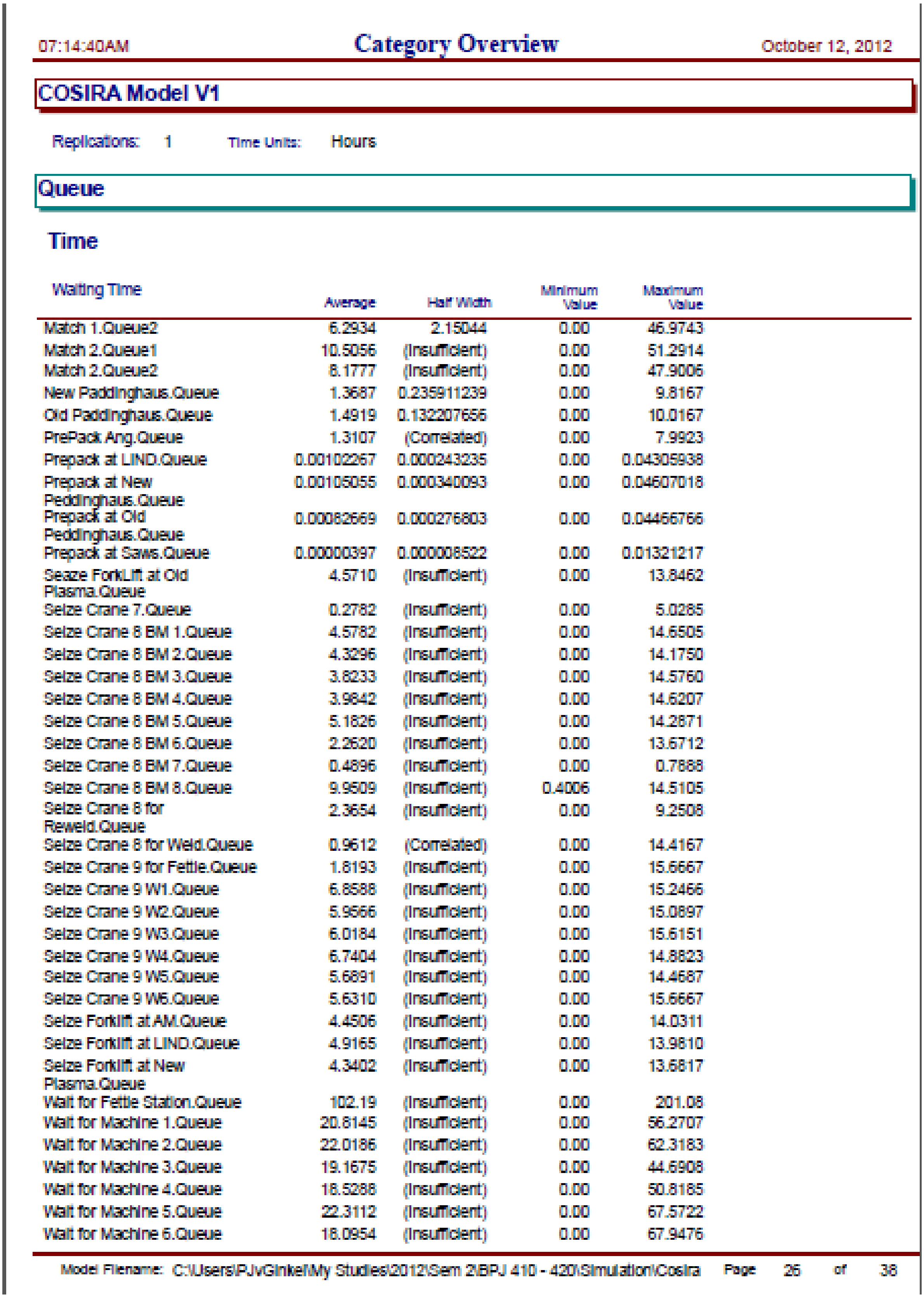
Replications: 1 Time Units: Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Batch Ang Assy.Queue	0.7321	0.127187015	0.00	8.6295
Batch Ang Pack List.Queue	0.3354	(Insufficient)	0.00	33.7134
Batch Assemblies 5.Queue	0.3815	0.042404539	0.00	8.0508
Batch Pack List 4.Queue	1.6679	0.211900052	0.00	11.6928
Batch Pit.Assemblies 1.Queue	0.6419	0.149140999	0.00	8.8411
Batch Pit.Assemblies 2.Queue	0.7217	(Correlated)	0.00	8.6193
Batch Pit.Assemblies 3.Queue	0.6676	0.141007034	0.00	8.8444
Batch Pit Pack List 1.Queue	1.3747	0.117421858	0.00	9.2456
Batch Pit Pack List 2.Queue	1.1864	0.170833083	0.00	8.7700
Batch Pit Pack List 3.Queue	1.1856	(Insufficient)	0.00	9.2294
BM at Station 1.Queue	11.6684	(Insufficient)	0.00	35.9299
BM at Station 2.Queue	10.4569	(Insufficient)	0.00	35.6083
BM at Station 3.Queue	10.7809	(Insufficient)	0.00	41.9842
BM at Station 4.Queue	10.2404	(Insufficient)	0.00	28.8167
BM at Station 5.Queue	14.1401	(Insufficient)	0.00	34.8371
BM at Station 6.Queue	5.6561	(Insufficient)	0.00	21.2769
BM at Station 7.Queue	6.6035	(Insufficient)	0.1531	10.2897
BM at Station 8.Queue	10.7773	(Insufficient)	7.1498	16.3146
CNC Old BDL.Queue	0.7576	0.124769659	0.00	8.3333
CNC Saw 21.Queue	0.8743	0.173579806	0.00	9.0000
CNC Saw 6.Queue	0.7727	0.113600855	0.00	8.4167
Fettle at St1.Queue	6.6456	(Insufficient)	0.00	32.4984
Fettle at St2.Queue	6.8082	(Insufficient)	0.00	35.4345
Fettle at St3.Queue	6.8872	(Insufficient)	0.00	38.9802
Fettle at St4.Queue	4.6200	(Insufficient)	0.00	33.2302
Ficep A166 Angle.Queue	0.3555	(Correlated)	0.00	8.0500
Ficep A206 Angle.Queue	0.5286	0.116039511	0.00	7.9000
Hold for Bay 2.Queue	10.1133	(Insufficient)	0.00	40.9661
Inspect at F1.Queue	6.2375	(Insufficient)	0.00	17.8982
Inspect at F2.Queue	6.5375	(Insufficient)	0.00	21.3051
Inspect at F3.Queue	6.1131	(Insufficient)	0.00	15.4886
Inspect at F4.Queue	6.4410	(Insufficient)	0.00	22.3524
Inspect BM ST 1.Queue	5.2035	(Insufficient)	0.00	15.3433
Inspect BM ST 2.Queue	5.8643	(Insufficient)	0.00	17.5468
Inspect BM ST 3.Queue	4.8383	(Insufficient)	0.00	14.1901
Inspect BM ST 4.Queue	5.9082	(Insufficient)	0.00	14.3576
Inspect BM ST 5.Queue	4.6223	(Insufficient)	0.00	12.3496
Inspect BM ST 6.Queue	6.3979	(Insufficient)	0.00	13.9944
Inspect BM ST 7.Queue	5.4255	(Insufficient)	0.00	10.8805
Inspect BM ST 8.Queue	3.8005	(Insufficient)	0.02534979	13.8805
LIND.Queue	1.1674	0.160274894	0.00	9.7167
Match 1.Queue1	4.3462	(Correlated)	0.00	47.2234

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 25 of 38



07:14:40AM **Category Overview** October 12, 2012

COSIRA Model V1

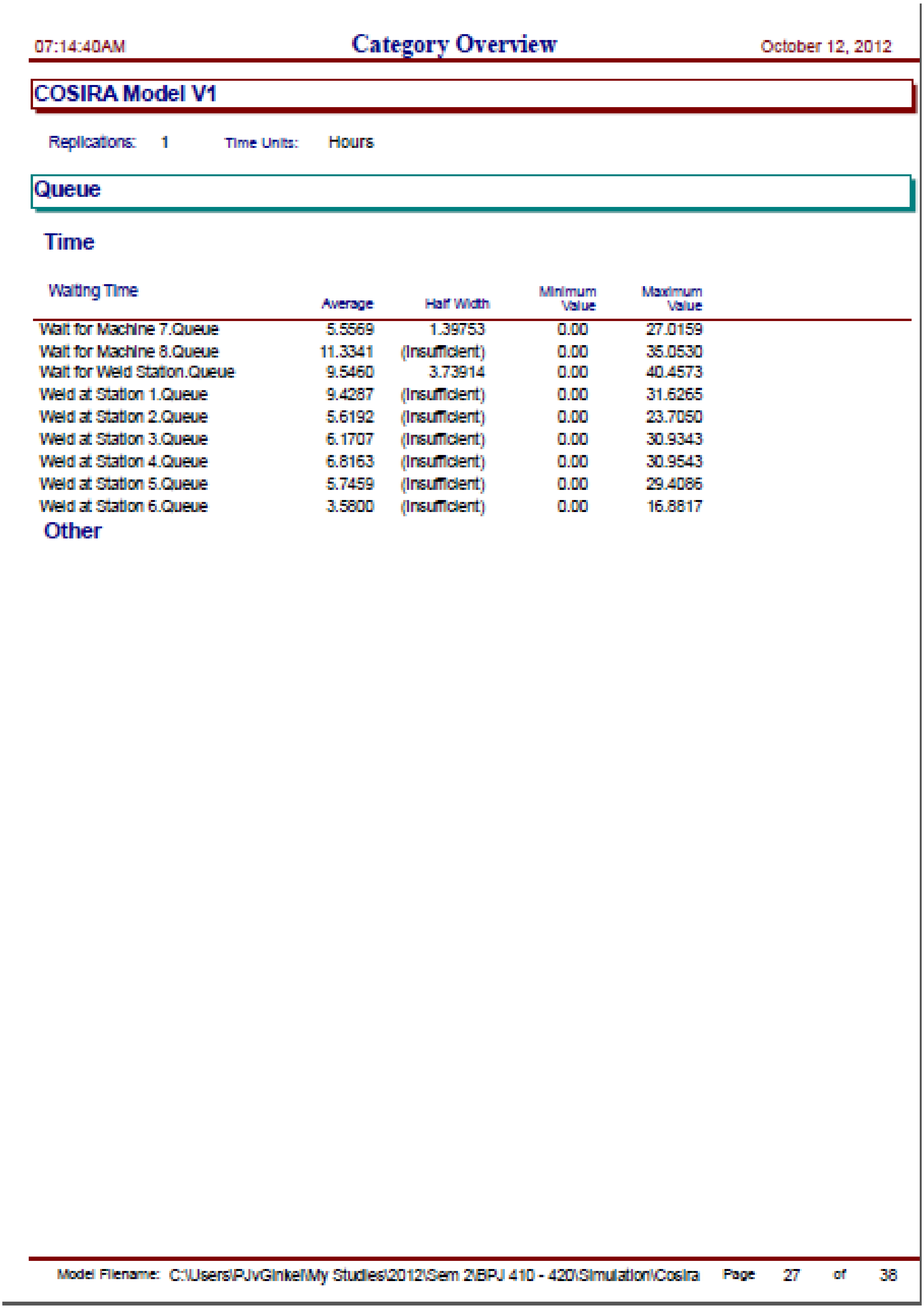
Replications: 1 Time Units: Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Match 1.Queue2	6.2934	2.15044	0.00	46.9743
Match 2.Queue1	10.5056	(Insufficient)	0.00	51.2914
Match 2.Queue2	8.1777	(Insufficient)	0.00	47.9006
New Paddinghaus.Queue	1.3687	0.235911239	0.00	9.8167
Old Paddinghaus.Queue	1.4919	0.132207656	0.00	10.0167
PrePack Ang.Queue	1.3107	(Correlated)	0.00	7.9923
Prepack at LIND.Queue	0.00102267	0.000243235	0.00	0.04305938
Prepack at New Peddinghaus.Queue	0.00105055	0.000340093	0.00	0.04607018
Prepack at Old Peddinghaus.Queue	0.00082669	0.000276803	0.00	0.04466766
Prepack at Saws.Queue	0.00000397	0.000008522	0.00	0.01321217
Seaze ForkLift at Old Plasma.Queue	4.5710	(Insufficient)	0.00	13.8462
Seize Crane 7.Queue	0.2782	(Insufficient)	0.00	5.0285
Seize Crane 8 BM 1.Queue	4.5782	(Insufficient)	0.00	14.6505
Seize Crane 8 BM 2.Queue	4.3296	(Insufficient)	0.00	14.1750
Seize Crane 8 BM 3.Queue	3.8233	(Insufficient)	0.00	14.5760
Seize Crane 8 BM 4.Queue	3.9842	(Insufficient)	0.00	14.6207
Seize Crane 8 BM 5.Queue	5.1826	(Insufficient)	0.00	14.2871
Seize Crane 8 BM 6.Queue	2.2620	(Insufficient)	0.00	13.6712
Seize Crane 8 BM 7.Queue	0.4896	(Insufficient)	0.00	0.7888
Seize Crane 8 BM 8.Queue	9.9509	(Insufficient)	0.4006	14.5105
Seize Crane 8 for Reweld.Queue	2.3654	(Insufficient)	0.00	9.2508
Seize Crane 8 for Weld.Queue	0.9612	(Correlated)	0.00	14.4167
Seize Crane 9 for Fettle.Queue	1.8193	(Insufficient)	0.00	15.6667
Seize Crane 9 W1.Queue	6.8588	(Insufficient)	0.00	15.2466
Seize Crane 9 W2.Queue	5.9566	(Insufficient)	0.00	15.0897
Seize Crane 9 W3.Queue	6.0184	(Insufficient)	0.00	15.6151
Seize Crane 9 W4.Queue	6.7404	(Insufficient)	0.00	14.8823
Seize Crane 9 W5.Queue	5.6891	(Insufficient)	0.00	14.4687
Seize Crane 9 W6.Queue	5.6310	(Insufficient)	0.00	15.6667
Seize Forklift at AM.Queue	4.4506	(Insufficient)	0.00	14.0311
Seize Forklift at LIND.Queue	4.9165	(Insufficient)	0.00	13.9810
Seize Forklift at New Plasma.Queue	4.3402	(Insufficient)	0.00	13.6817
Wait for Fettle Station.Queue	102.19	(Insufficient)	0.00	201.08
Wait for Machine 1.Queue	20.8145	(Insufficient)	0.00	56.2707
Wait for Machine 2.Queue	22.0186	(Insufficient)	0.00	62.3183
Wait for Machine 3.Queue	19.1675	(Insufficient)	0.00	44.6908
Wait for Machine 4.Queue	18.5288	(Insufficient)	0.00	50.8185
Wait for Machine 5.Queue	22.3112	(Insufficient)	0.00	67.5722
Wait for Machine 6.Queue	18.0954	(Insufficient)	0.00	67.9476

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 26 of 38



07:14:40AM **Category Overview** October 12, 2012

COSIRA Model V1

Replications: 1 Time Units: Hours

Queue

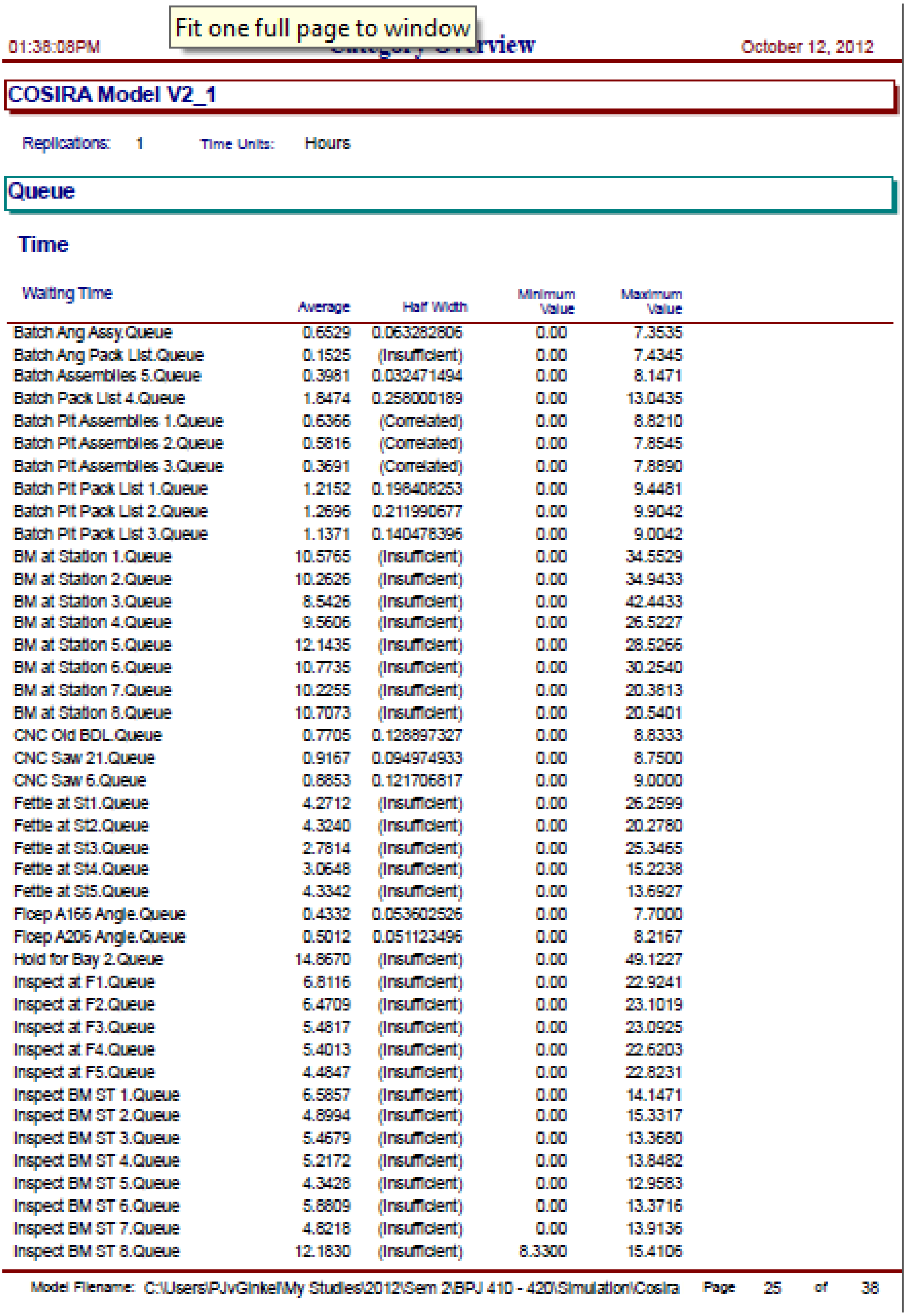
Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Wait for Machine 7.Queue	5.5569	1.39753	0.00	27.0159
Wait for Machine 8.Queue	11.3341	(Insufficient)	0.00	35.0530
Wait for Weld Station.Queue	9.5460	3.73914	0.00	40.4573
Weld at Station 1.Queue	9.4287	(Insufficient)	0.00	31.6265
Weld at Station 2.Queue	5.6192	(Insufficient)	0.00	23.7050
Weld at Station 3.Queue	6.1707	(Insufficient)	0.00	30.9343
Weld at Station 4.Queue	6.8163	(Insufficient)	0.00	30.9543
Weld at Station 5.Queue	5.7459	(Insufficient)	0.00	29.4086
Weld at Station 6.Queue	3.5800	(Insufficient)	0.00	16.8817

Other

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 27 of 38

APPENDIX 5B - LINE BALANCING MODEL 1 SIMULATION



01:38:08PM October 12, 2012

COSIRA Model V2_1

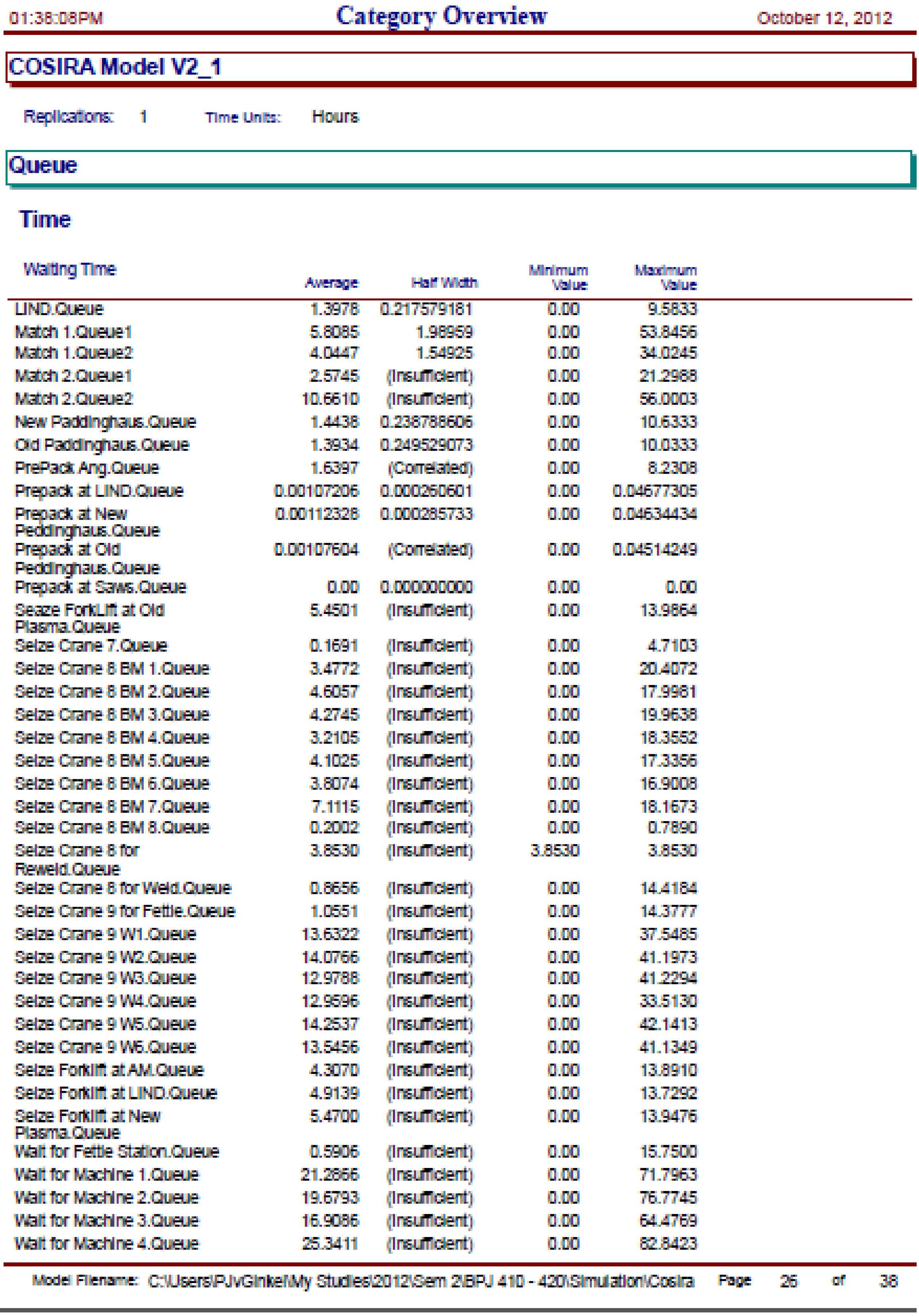
Replications: 1 Time Units: Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Batch Ang Assy.Queue	0.6529	0.063282806	0.00	7.3535
Batch Ang Pack List.Queue	0.1525	(Insufficient)	0.00	7.4345
Batch Assemblies 5.Queue	0.3981	0.032471494	0.00	8.1471
Batch Pack List 4.Queue	1.8474	0.258000189	0.00	13.0435
Batch Pit Assemblies 1.Queue	0.6366	(Correlated)	0.00	8.8210
Batch Pit Assemblies 2.Queue	0.5816	(Correlated)	0.00	7.8545
Batch Pit Assemblies 3.Queue	0.3691	(Correlated)	0.00	7.8890
Batch Pit Pack List 1.Queue	1.2152	0.198408253	0.00	9.4481
Batch Pit Pack List 2.Queue	1.2696	0.211990677	0.00	9.9042
Batch Pit Pack List 3.Queue	1.1371	0.140478396	0.00	9.0042
BM at Station 1.Queue	10.5765	(Insufficient)	0.00	34.5529
BM at Station 2.Queue	10.2626	(Insufficient)	0.00	34.9433
BM at Station 3.Queue	8.5426	(Insufficient)	0.00	42.4433
BM at Station 4.Queue	9.5606	(Insufficient)	0.00	26.5227
BM at Station 5.Queue	12.1435	(Insufficient)	0.00	28.5266
BM at Station 6.Queue	10.7735	(Insufficient)	0.00	30.2540
BM at Station 7.Queue	10.2255	(Insufficient)	0.00	20.3813
BM at Station 8.Queue	10.7073	(Insufficient)	0.00	20.5401
CNC Old BDL.Queue	0.7705	0.128897327	0.00	8.8333
CNC Saw 21.Queue	0.9167	0.094974933	0.00	8.7500
CNC Saw 6.Queue	0.8853	0.121706817	0.00	9.0000
Fettle at St1.Queue	4.2712	(Insufficient)	0.00	26.2599
Fettle at St2.Queue	4.3240	(Insufficient)	0.00	20.2780
Fettle at St3.Queue	2.7814	(Insufficient)	0.00	25.3465
Fettle at St4.Queue	3.0648	(Insufficient)	0.00	15.2238
Fettle at St5.Queue	4.3342	(Insufficient)	0.00	13.6927
Ficep A166 Angle.Queue	0.4332	0.053602526	0.00	7.7000
Ficep A206 Angle.Queue	0.5012	0.051123496	0.00	8.2167
Hold for Bay 2.Queue	14.8670	(Insufficient)	0.00	49.1227
Inspect at F1.Queue	6.8116	(Insufficient)	0.00	22.9241
Inspect at F2.Queue	6.4709	(Insufficient)	0.00	23.1019
Inspect at F3.Queue	5.4817	(Insufficient)	0.00	23.0925
Inspect at F4.Queue	5.4013	(Insufficient)	0.00	22.6203
Inspect at F5.Queue	4.4847	(Insufficient)	0.00	22.8231
Inspect BM ST 1.Queue	6.5857	(Insufficient)	0.00	14.1471
Inspect BM ST 2.Queue	4.8994	(Insufficient)	0.00	15.3317
Inspect BM ST 3.Queue	5.4679	(Insufficient)	0.00	13.3680
Inspect BM ST 4.Queue	5.2172	(Insufficient)	0.00	13.8482
Inspect BM ST 5.Queue	4.3428	(Insufficient)	0.00	12.9583
Inspect BM ST 6.Queue	5.8809	(Insufficient)	0.00	13.3716
Inspect BM ST 7.Queue	4.8218	(Insufficient)	0.00	13.9136
Inspect BM ST 8.Queue	12.1830	(Insufficient)	8.3300	15.4106

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 25 of 38



01:38:08PM **Category Overview** October 12, 2012

COSIRA Model V2_1

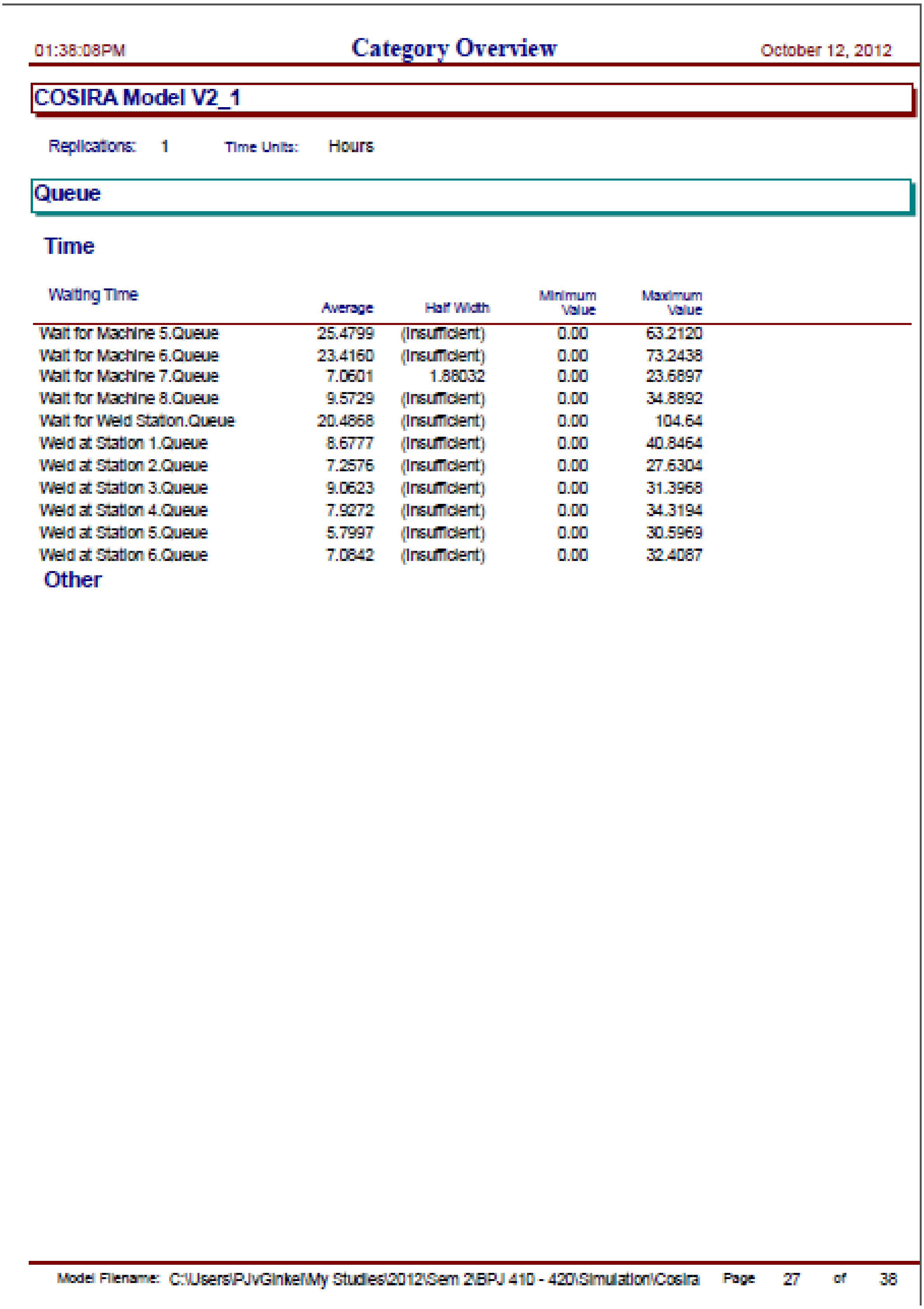
Replications: 1 Time Units: Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
LIND.Queue	1.3978	0.217579181	0.00	9.5833
Match 1.Queue1	5.8085	1.98959	0.00	53.8456
Match 1.Queue2	4.0447	1.54925	0.00	34.0245
Match 2.Queue1	2.5745	(Insufficient)	0.00	21.2988
Match 2.Queue2	10.6610	(Insufficient)	0.00	56.0003
New Paddinghaus.Queue	1.4438	0.238788606	0.00	10.6333
Old Paddinghaus.Queue	1.3934	0.249529073	0.00	10.0333
PrePack Ang.Queue	1.6397	(Correlated)	0.00	8.2308
Prepack at LIND.Queue	0.00107206	0.000260601	0.00	0.04677305
Prepack at New Peddinghaus.Queue	0.00112328	0.000285733	0.00	0.04634434
Prepack at Old Peddinghaus.Queue	0.00107604	(Correlated)	0.00	0.04514249
Prepack at Saws.Queue	0.00	0.000000000	0.00	0.00
Seaze ForkLift at Old Plasma.Queue	5.4501	(Insufficient)	0.00	13.9864
Seize Crane 7.Queue	0.1691	(Insufficient)	0.00	4.7103
Seize Crane 8 BM 1.Queue	3.4772	(Insufficient)	0.00	20.4072
Seize Crane 8 BM 2.Queue	4.6057	(Insufficient)	0.00	17.9981
Seize Crane 8 BM 3.Queue	4.2745	(Insufficient)	0.00	19.9638
Seize Crane 8 BM 4.Queue	3.2105	(Insufficient)	0.00	18.3552
Seize Crane 8 BM 5.Queue	4.1025	(Insufficient)	0.00	17.3356
Seize Crane 8 BM 6.Queue	3.8074	(Insufficient)	0.00	16.9008
Seize Crane 8 BM 7.Queue	7.1115	(Insufficient)	0.00	18.1673
Seize Crane 8 BM 8.Queue	0.2002	(Insufficient)	0.00	0.7890
Seize Crane 8 for Reweld.Queue	3.8530	(Insufficient)	3.8530	3.8530
Seize Crane 8 for Weld.Queue	0.8656	(Insufficient)	0.00	14.4184
Seize Crane 9 for Fettle.Queue	1.0551	(Insufficient)	0.00	14.3777
Seize Crane 9 W1.Queue	13.6322	(Insufficient)	0.00	37.5485
Seize Crane 9 W2.Queue	14.0766	(Insufficient)	0.00	41.1973
Seize Crane 9 W3.Queue	12.9788	(Insufficient)	0.00	41.2294
Seize Crane 9 W4.Queue	12.9596	(Insufficient)	0.00	33.5130
Seize Crane 9 W5.Queue	14.2537	(Insufficient)	0.00	42.1413
Seize Crane 9 W6.Queue	13.5456	(Insufficient)	0.00	41.1349
Seize Forklift at AM.Queue	4.3070	(Insufficient)	0.00	13.8910
Seize Forklift at LIND.Queue	4.9139	(Insufficient)	0.00	13.7292
Seize Forklift at New Plasma.Queue	5.4700	(Insufficient)	0.00	13.9476
Wait for Fettle Station.Queue	0.5906	(Insufficient)	0.00	15.7500
Wait for Machine 1.Queue	21.2866	(Insufficient)	0.00	71.7963
Wait for Machine 2.Queue	19.6793	(Insufficient)	0.00	76.7745
Wait for Machine 3.Queue	16.9086	(Insufficient)	0.00	64.4769
Wait for Machine 4.Queue	25.3411	(Insufficient)	0.00	82.8423

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 26 of 38



01:38:08PM

Category Overview

October 12, 2012

COSIRA Model V2_1

Replications: 1 Time Units: Hours

Queue

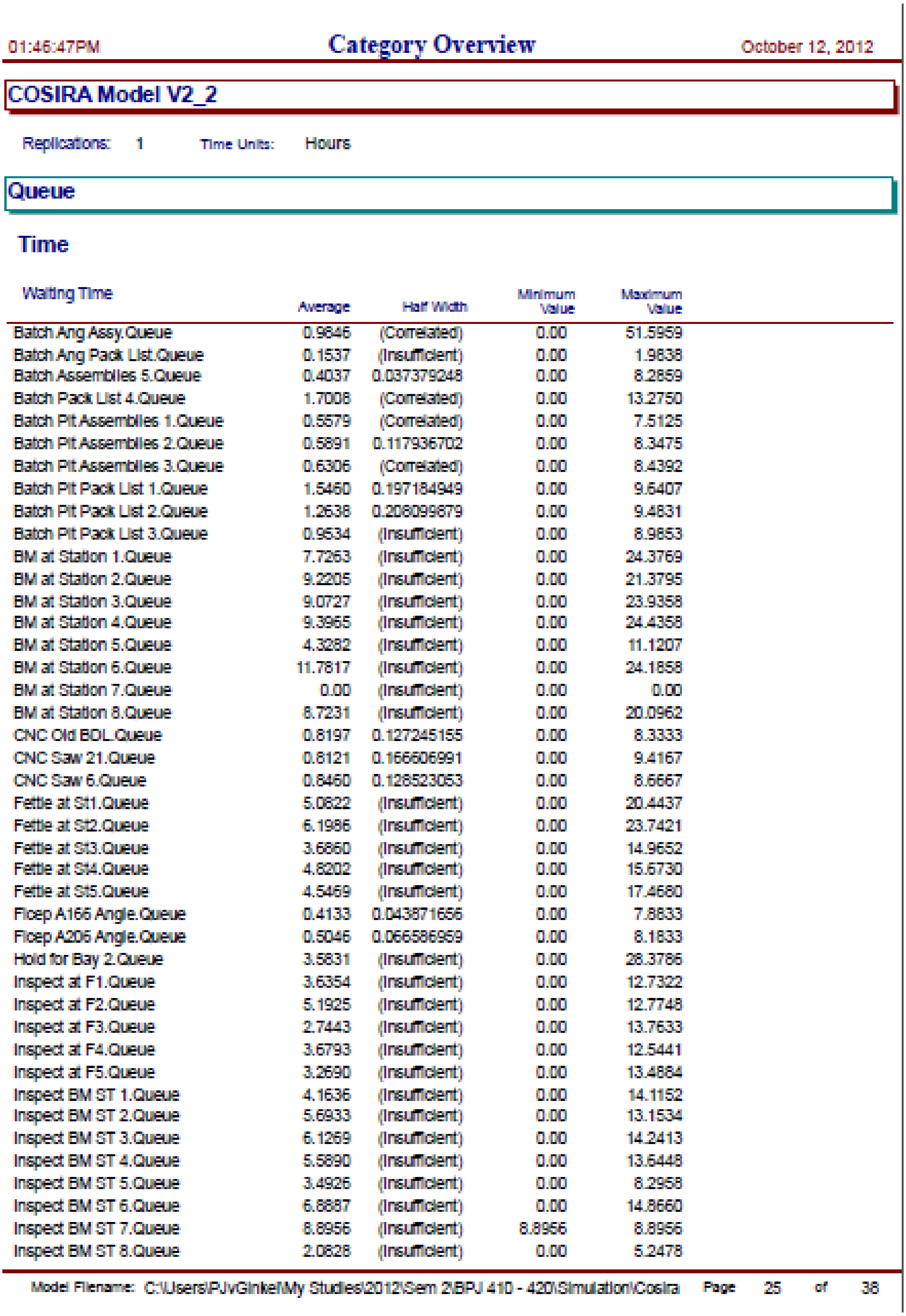
Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Wait for Machine 5.Queue	25.4799	(Insufficient)	0.00	63.2120
Wait for Machine 6.Queue	23.4160	(Insufficient)	0.00	73.2438
Wait for Machine 7.Queue	7.0601	1.88032	0.00	23.6897
Wait for Machine 8.Queue	9.5729	(Insufficient)	0.00	34.8892
Wait for Weld Station.Queue	20.4868	(Insufficient)	0.00	104.64
Weld at Station 1.Queue	8.6777	(Insufficient)	0.00	40.8464
Weld at Station 2.Queue	7.2576	(Insufficient)	0.00	27.6304
Weld at Station 3.Queue	9.0623	(Insufficient)	0.00	31.3968
Weld at Station 4.Queue	7.9272	(Insufficient)	0.00	34.3194
Weld at Station 5.Queue	5.7997	(Insufficient)	0.00	30.5969
Weld at Station 6.Queue	7.0842	(Insufficient)	0.00	32.4087

Other

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 27 of 38

APPENDIX 5C - LINE BALANCING MODEL 2 SIMULATION



01:46:47PM **Category Overview** October 12, 2012

COSIRA Model V2_2

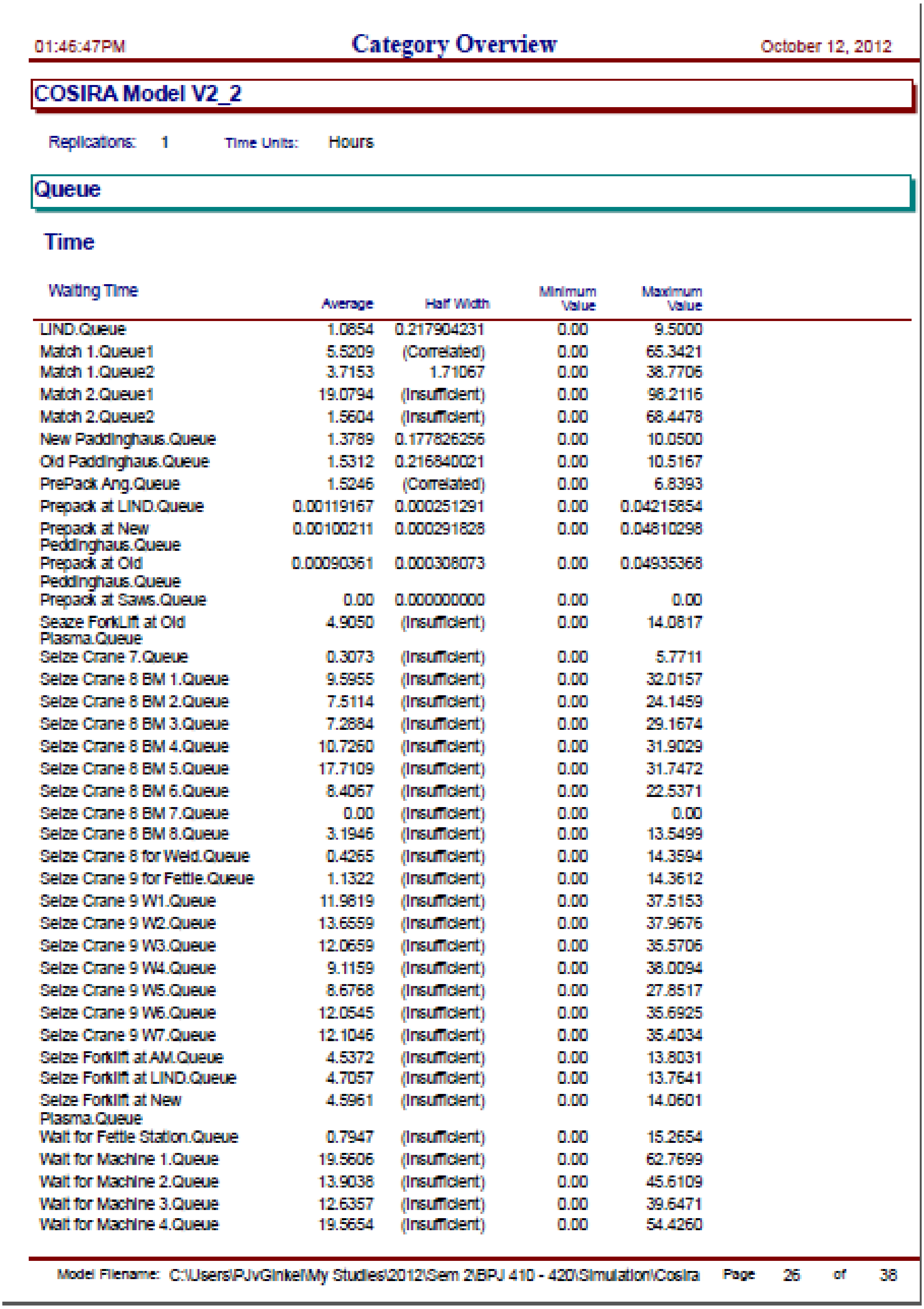
Replications: 1 Time Units: Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Batch Ang Assy.Queue	0.9846	(Correlated)	0.00	51.5959
Batch Ang Pack List.Queue	0.1537	(Insufficient)	0.00	1.9838
Batch Assemblies 5.Queue	0.4037	0.037379248	0.00	8.2859
Batch Pack List 4.Queue	1.7008	(Correlated)	0.00	13.2750
Batch Plt Assemblies 1.Queue	0.5579	(Correlated)	0.00	7.5125
Batch Plt Assemblies 2.Queue	0.5891	0.117936702	0.00	8.3475
Batch Plt Assemblies 3.Queue	0.6306	(Correlated)	0.00	8.4392
Batch Plt Pack List 1.Queue	1.5460	0.197184949	0.00	9.6407
Batch Plt Pack List 2.Queue	1.2638	0.208099879	0.00	9.4831
Batch Plt Pack List 3.Queue	0.9534	(Insufficient)	0.00	8.9853
BM at Station 1.Queue	7.7263	(Insufficient)	0.00	24.3769
BM at Station 2.Queue	9.2205	(Insufficient)	0.00	21.3795
BM at Station 3.Queue	9.0727	(Insufficient)	0.00	23.9358
BM at Station 4.Queue	9.3965	(Insufficient)	0.00	24.4358
BM at Station 5.Queue	4.3282	(Insufficient)	0.00	11.1207
BM at Station 6.Queue	11.7817	(Insufficient)	0.00	24.1858
BM at Station 7.Queue	0.00	(Insufficient)	0.00	0.00
BM at Station 8.Queue	8.7231	(Insufficient)	0.00	20.0962
CNC Old BDL.Queue	0.8197	0.127245155	0.00	8.3333
CNC Saw 21.Queue	0.8121	0.166606991	0.00	9.4167
CNC Saw 6.Queue	0.8460	0.128523053	0.00	8.6667
Fettle at St1.Queue	5.0822	(Insufficient)	0.00	20.4437
Fettle at St2.Queue	6.1986	(Insufficient)	0.00	23.7421
Fettle at St3.Queue	3.6860	(Insufficient)	0.00	14.9652
Fettle at St4.Queue	4.8202	(Insufficient)	0.00	15.6730
Fettle at St5.Queue	4.5469	(Insufficient)	0.00	17.4680
Ficep A166 Angle.Queue	0.4133	0.043871656	0.00	7.8833
Ficep A206 Angle.Queue	0.5046	0.066586959	0.00	8.1833
Hold for Bay 2.Queue	3.5831	(Insufficient)	0.00	28.3786
Inspect at F1.Queue	3.6354	(Insufficient)	0.00	12.7322
Inspect at F2.Queue	5.1925	(Insufficient)	0.00	12.7748
Inspect at F3.Queue	2.7443	(Insufficient)	0.00	13.7633
Inspect at F4.Queue	3.6793	(Insufficient)	0.00	12.5441
Inspect at F5.Queue	3.2690	(Insufficient)	0.00	13.4884
Inspect BM ST 1.Queue	4.1636	(Insufficient)	0.00	14.1152
Inspect BM ST 2.Queue	5.6933	(Insufficient)	0.00	13.1534
Inspect BM ST 3.Queue	6.1269	(Insufficient)	0.00	14.2413
Inspect BM ST 4.Queue	5.5890	(Insufficient)	0.00	13.6448
Inspect BM ST 5.Queue	3.4926	(Insufficient)	0.00	8.2958
Inspect BM ST 6.Queue	6.8887	(Insufficient)	0.00	14.8660
Inspect BM ST 7.Queue	8.8956	(Insufficient)	8.8956	8.8956
Inspect BM ST 8.Queue	2.0828	(Insufficient)	0.00	5.2478

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 25 of 38



01:46:47PM **Category Overview** October 12, 2012

COSIRA Model V2_2

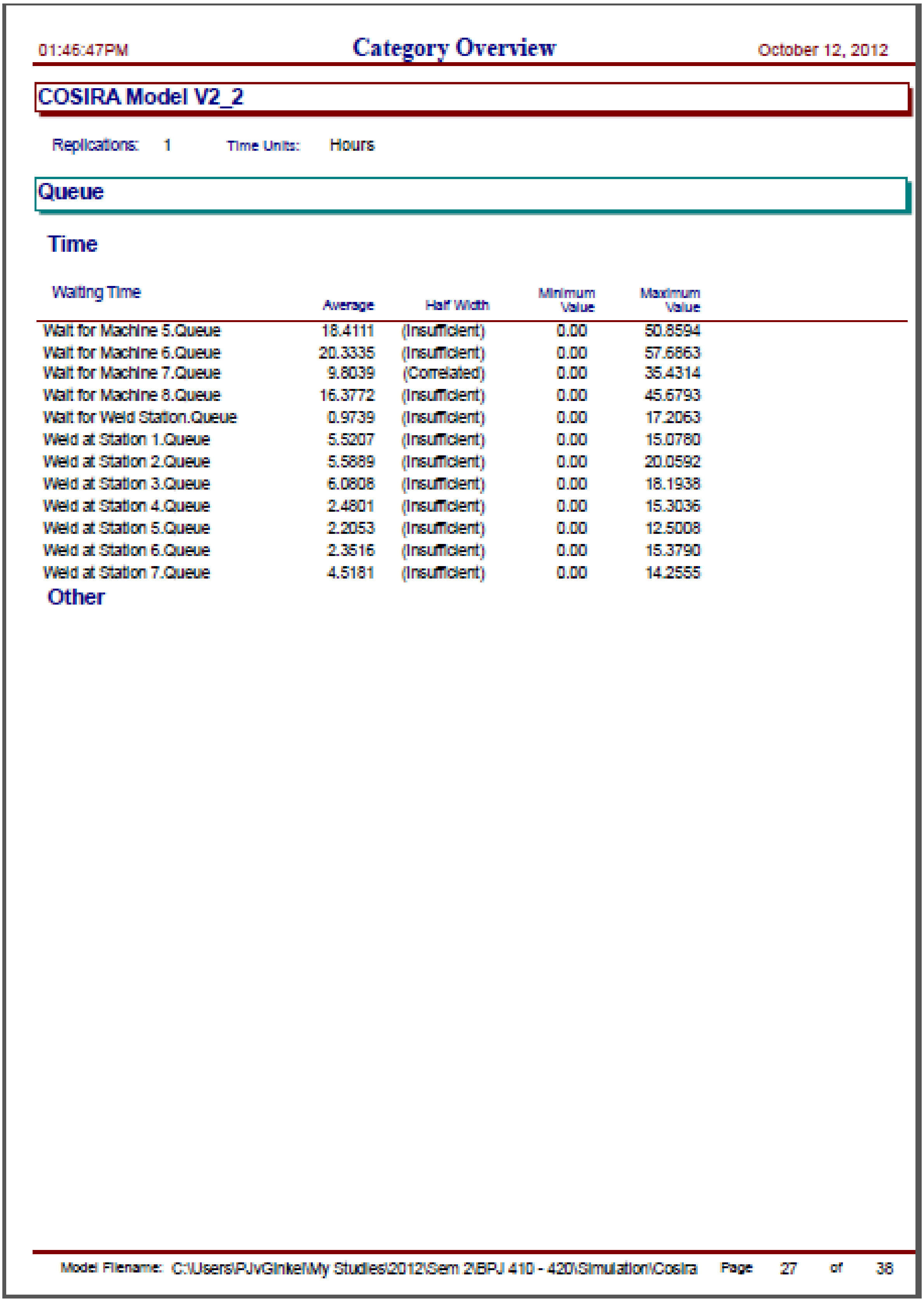
Replications: 1 Time Units: Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
LIND.Queue	1.0854	0.217904231	0.00	9.5000
Match 1.Queue1	5.5209	(Correlated)	0.00	65.3421
Match 1.Queue2	3.7153	1.71067	0.00	38.7706
Match 2.Queue1	19.0794	(Insufficient)	0.00	98.2116
Match 2.Queue2	1.5604	(Insufficient)	0.00	68.4478
New Paddinghaus.Queue	1.3789	0.177826256	0.00	10.0500
Old Paddinghaus.Queue	1.5312	0.216840021	0.00	10.5167
PrePack Ang.Queue	1.5246	(Correlated)	0.00	6.8393
Prepack at LIND.Queue	0.00119167	0.000251291	0.00	0.04215854
Prepack at New Peddinghaus.Queue	0.00100211	0.000291828	0.00	0.04810298
Prepack at Old Peddinghaus.Queue	0.00090361	0.000308073	0.00	0.04935368
Prepack at Saws.Queue	0.00	0.000000000	0.00	0.00
Seaze ForkLift at Old Plasma.Queue	4.9050	(Insufficient)	0.00	14.0817
Seize Crane 7.Queue	0.3073	(Insufficient)	0.00	5.7711
Seize Crane 8 BM 1.Queue	9.5955	(Insufficient)	0.00	32.0157
Seize Crane 8 BM 2.Queue	7.5114	(Insufficient)	0.00	24.1459
Seize Crane 8 BM 3.Queue	7.2884	(Insufficient)	0.00	29.1674
Seize Crane 8 BM 4.Queue	10.7260	(Insufficient)	0.00	31.9029
Seize Crane 8 BM 5.Queue	17.7109	(Insufficient)	0.00	31.7472
Seize Crane 8 BM 6.Queue	8.4067	(Insufficient)	0.00	22.5371
Seize Crane 8 BM 7.Queue	0.00	(Insufficient)	0.00	0.00
Seize Crane 8 BM 8.Queue	3.1946	(Insufficient)	0.00	13.5499
Seize Crane 8 for Weld.Queue	0.4265	(Insufficient)	0.00	14.3594
Seize Crane 9 for Fettle.Queue	1.1322	(Insufficient)	0.00	14.3612
Seize Crane 9 W1.Queue	11.9819	(Insufficient)	0.00	37.5153
Seize Crane 9 W2.Queue	13.6559	(Insufficient)	0.00	37.9676
Seize Crane 9 W3.Queue	12.0659	(Insufficient)	0.00	35.5706
Seize Crane 9 W4.Queue	9.1159	(Insufficient)	0.00	38.0094
Seize Crane 9 W5.Queue	8.6768	(Insufficient)	0.00	27.8517
Seize Crane 9 W6.Queue	12.0545	(Insufficient)	0.00	35.6925
Seize Crane 9 W7.Queue	12.1046	(Insufficient)	0.00	35.4034
Seize Forklift at AM.Queue	4.5372	(Insufficient)	0.00	13.8031
Seize Forklift at LIND.Queue	4.7057	(Insufficient)	0.00	13.7641
Seize Forklift at New Plasma.Queue	4.5961	(Insufficient)	0.00	14.0601
Wait for Fettle Station.Queue	0.7947	(Insufficient)	0.00	15.2654
Wait for Machine 1.Queue	19.5606	(Insufficient)	0.00	62.7699
Wait for Machine 2.Queue	13.9038	(Insufficient)	0.00	45.6109
Wait for Machine 3.Queue	12.6357	(Insufficient)	0.00	39.6471
Wait for Machine 4.Queue	19.5654	(Insufficient)	0.00	54.4260

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 26 of 38



01:46:47PM

Category Overview

October 12, 2012

COSIRA Model V2_2

Replications: 1 Time Units: Hours

Queue

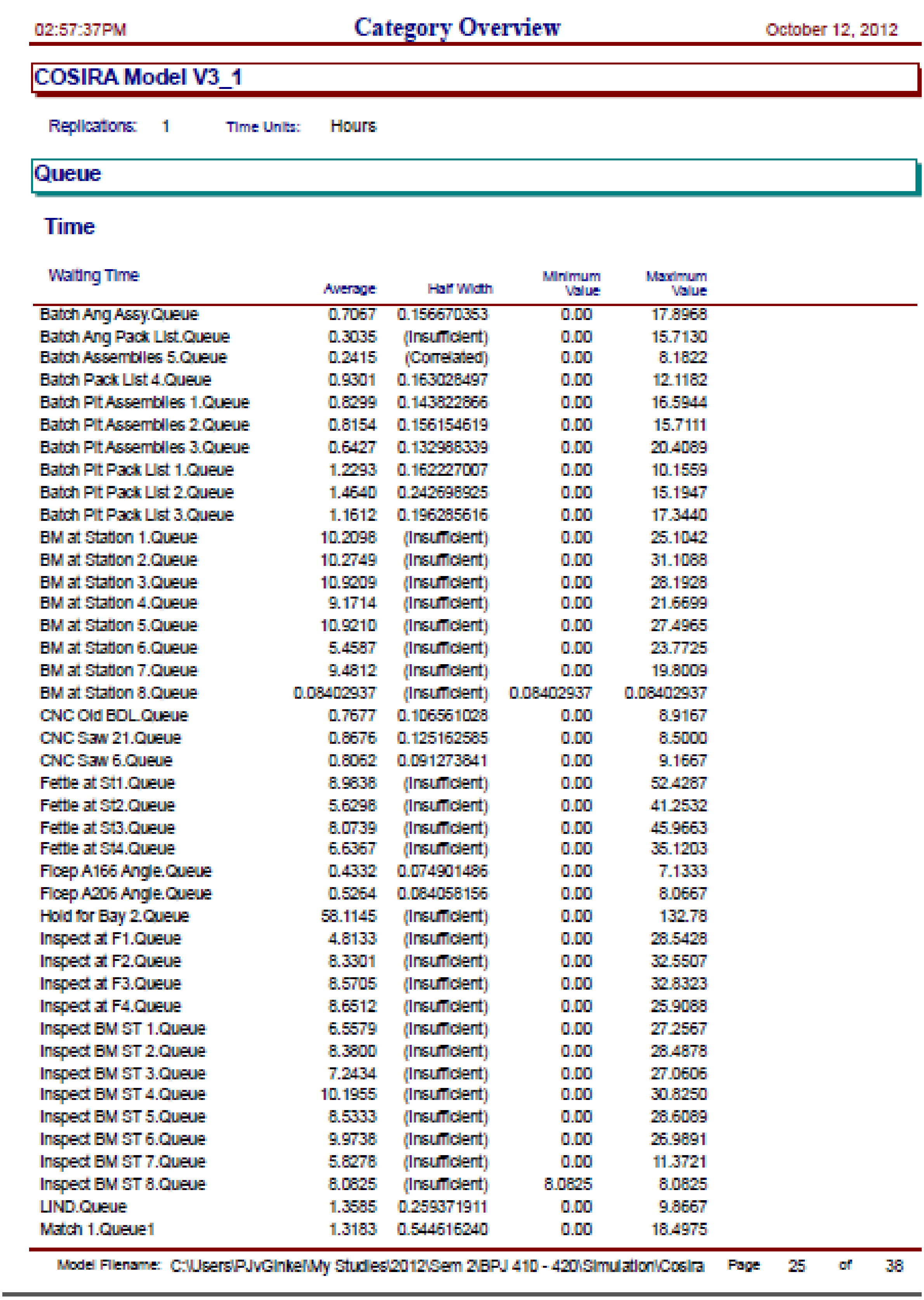
Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Wait for Machine 5.Queue	18.4111	(Insufficient)	0.00	50.8594
Wait for Machine 6.Queue	20.3335	(Insufficient)	0.00	57.6863
Wait for Machine 7.Queue	9.8039	(Correlated)	0.00	35.4314
Wait for Machine 8.Queue	16.3772	(Insufficient)	0.00	45.6793
Wait for Weld Station.Queue	0.9739	(Insufficient)	0.00	17.2063
Weld at Station 1.Queue	5.5207	(Insufficient)	0.00	15.0780
Weld at Station 2.Queue	5.5889	(Insufficient)	0.00	20.0592
Weld at Station 3.Queue	6.0808	(Insufficient)	0.00	18.1938
Weld at Station 4.Queue	2.4801	(Insufficient)	0.00	15.3036
Weld at Station 5.Queue	2.2053	(Insufficient)	0.00	12.5008
Weld at Station 6.Queue	2.3516	(Insufficient)	0.00	15.3790
Weld at Station 7.Queue	4.5181	(Insufficient)	0.00	14.2555

Other

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 27 of 38

APPENDIX 5D – TOC MODEL 1 SIMULATION



02:57:37PM **Category Overview** October 12, 2012

COSIRA Model V3_1

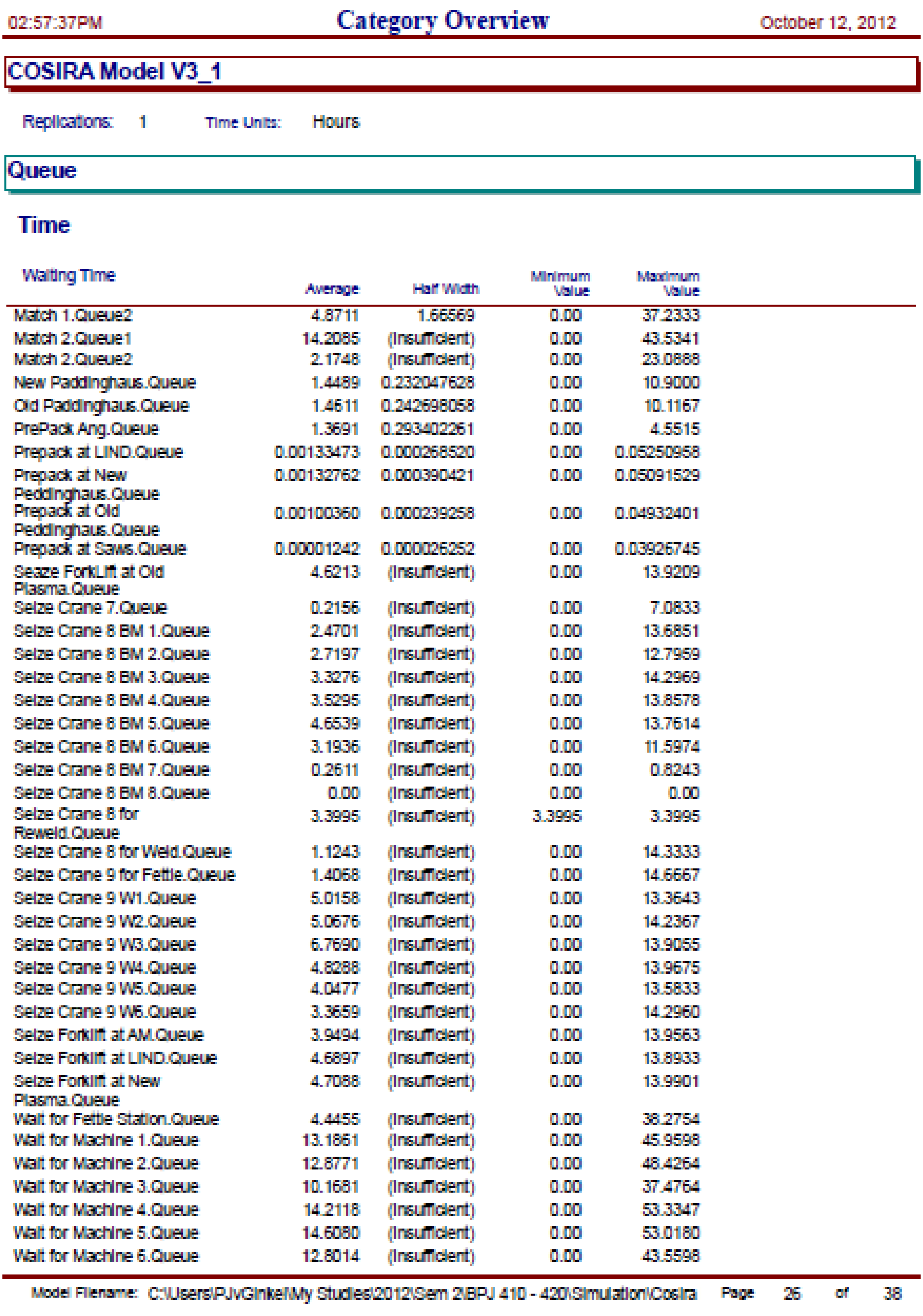
Replications: 1 Time Units: Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Batch Ang Assy.Queue	0.7067	0.156670353	0.00	17.8968
Batch Ang Pack List.Queue	0.3035	(Insufficient)	0.00	15.7130
Batch Assemblies 5.Queue	0.2415	(Correlated)	0.00	8.1822
Batch Pack List 4.Queue	0.9301	0.163028497	0.00	12.1182
Batch Plt Assemblies 1.Queue	0.8299	0.143822866	0.00	16.5944
Batch Plt Assemblies 2.Queue	0.8154	0.156154619	0.00	15.7111
Batch Plt Assemblies 3.Queue	0.6427	0.132988339	0.00	20.4089
Batch Plt Pack List 1.Queue	1.2293	0.162227007	0.00	10.1559
Batch Plt Pack List 2.Queue	1.4640	0.242698925	0.00	15.1947
Batch Plt Pack List 3.Queue	1.1612	0.196285616	0.00	17.3440
BM at Station 1.Queue	10.2098	(Insufficient)	0.00	25.1042
BM at Station 2.Queue	10.2749	(Insufficient)	0.00	31.1088
BM at Station 3.Queue	10.9209	(Insufficient)	0.00	28.1928
BM at Station 4.Queue	9.1714	(Insufficient)	0.00	21.6699
BM at Station 5.Queue	10.9210	(Insufficient)	0.00	27.4965
BM at Station 6.Queue	5.4587	(Insufficient)	0.00	23.7725
BM at Station 7.Queue	9.4812	(Insufficient)	0.00	19.8009
BM at Station 8.Queue	0.08402937	(Insufficient)	0.08402937	0.08402937
CNC Old BDL.Queue	0.7677	0.106561028	0.00	8.9167
CNC Saw 21.Queue	0.8676	0.125162585	0.00	8.5000
CNC Saw 6.Queue	0.8062	0.091273841	0.00	9.1667
Fettle at St1.Queue	8.9838	(Insufficient)	0.00	52.4287
Fettle at St2.Queue	5.6298	(Insufficient)	0.00	41.2532
Fettle at St3.Queue	8.0739	(Insufficient)	0.00	45.9663
Fettle at St4.Queue	6.6367	(Insufficient)	0.00	35.1203
Ficep A166 Angle.Queue	0.4332	0.074901486	0.00	7.1333
Ficep A206 Angle.Queue	0.5264	0.084058156	0.00	8.0667
Hold for Bay 2.Queue	58.1145	(Insufficient)	0.00	132.78
Inspect at F1.Queue	4.8133	(Insufficient)	0.00	28.5428
Inspect at F2.Queue	8.3301	(Insufficient)	0.00	32.5507
Inspect at F3.Queue	8.5705	(Insufficient)	0.00	32.8323
Inspect at F4.Queue	8.6512	(Insufficient)	0.00	25.9088
Inspect BM ST 1.Queue	6.5579	(Insufficient)	0.00	27.2567
Inspect BM ST 2.Queue	8.3800	(Insufficient)	0.00	28.4878
Inspect BM ST 3.Queue	7.2434	(Insufficient)	0.00	27.0606
Inspect BM ST 4.Queue	10.1955	(Insufficient)	0.00	30.8250
Inspect BM ST 5.Queue	8.5333	(Insufficient)	0.00	28.6089
Inspect BM ST 6.Queue	9.9738	(Insufficient)	0.00	26.9891
Inspect BM ST 7.Queue	5.8278	(Insufficient)	0.00	11.3721
Inspect BM ST 8.Queue	8.0825	(Insufficient)	8.0825	8.0825
LIND.Queue	1.3585	0.259371911	0.00	9.8667
Match 1.Queue1	1.3183	0.544616240	0.00	18.4975

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 25 of 38



02:57:37PM **Category Overview** October 12, 2012

COSIRA Model V3_1

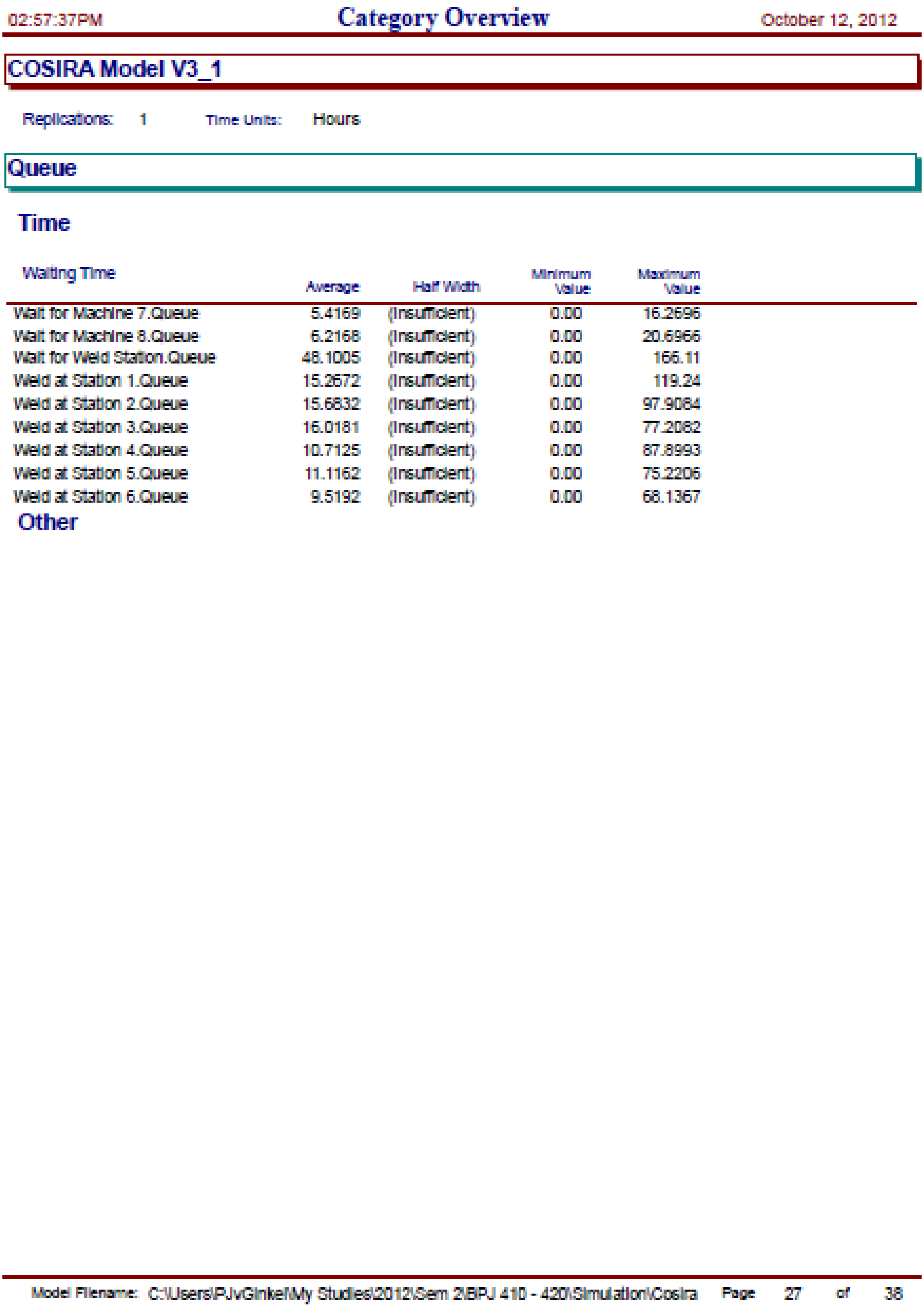
Replications: 1 Time Units: Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Match 1.Queue2	4.8711	1.66569	0.00	37.2333
Match 2.Queue1	14.2085	(Insufficient)	0.00	43.5341
Match 2.Queue2	2.1748	(Insufficient)	0.00	23.0888
New Paddinghaus.Queue	1.4489	0.232047628	0.00	10.9000
Old Paddinghaus.Queue	1.4611	0.242698058	0.00	10.1167
PrePack Ang.Queue	1.3691	0.293402261	0.00	4.5515
Prepack at LIND.Queue	0.00133473	0.000268520	0.00	0.05250958
Prepack at New Peddinghaus.Queue	0.00132762	0.000390421	0.00	0.05091529
Prepack at Old Peddinghaus.Queue	0.00100360	0.000239258	0.00	0.04932401
Prepack at Saws.Queue	0.00001242	0.000026252	0.00	0.03926745
Seaze ForkLift at Old Plasma.Queue	4.6213	(Insufficient)	0.00	13.9209
Seize Crane 7.Queue	0.2156	(Insufficient)	0.00	7.0833
Seize Crane 8 BM 1.Queue	2.4701	(Insufficient)	0.00	13.6851
Seize Crane 8 BM 2.Queue	2.7197	(Insufficient)	0.00	12.7959
Seize Crane 8 BM 3.Queue	3.3276	(Insufficient)	0.00	14.2969
Seize Crane 8 BM 4.Queue	3.5295	(Insufficient)	0.00	13.8578
Seize Crane 8 BM 5.Queue	4.6539	(Insufficient)	0.00	13.7614
Seize Crane 8 BM 6.Queue	3.1936	(Insufficient)	0.00	11.5974
Seize Crane 8 BM 7.Queue	0.2611	(Insufficient)	0.00	0.8243
Seize Crane 8 BM 8.Queue	0.00	(Insufficient)	0.00	0.00
Seize Crane 8 for Reweld.Queue	3.3995	(Insufficient)	3.3995	3.3995
Seize Crane 8 for Weld.Queue	1.1243	(Insufficient)	0.00	14.3333
Seize Crane 9 for Fettle.Queue	1.4068	(Insufficient)	0.00	14.6667
Seize Crane 9 W1.Queue	5.0158	(Insufficient)	0.00	13.3643
Seize Crane 9 W2.Queue	5.0676	(Insufficient)	0.00	14.2367
Seize Crane 9 W3.Queue	6.7690	(Insufficient)	0.00	13.9055
Seize Crane 9 W4.Queue	4.8288	(Insufficient)	0.00	13.9675
Seize Crane 9 W5.Queue	4.0477	(Insufficient)	0.00	13.5833
Seize Crane 9 W6.Queue	3.3659	(Insufficient)	0.00	14.2960
Seize Forklift at AM.Queue	3.9494	(Insufficient)	0.00	13.9563
Seize Forklift at LIND.Queue	4.6897	(Insufficient)	0.00	13.8933
Seize Forklift at New Plasma.Queue	4.7088	(Insufficient)	0.00	13.9901
Wait for Fettle Station.Queue	4.4455	(Insufficient)	0.00	38.2754
Wait for Machine 1.Queue	13.1861	(Insufficient)	0.00	45.9598
Wait for Machine 2.Queue	12.8771	(Insufficient)	0.00	48.4264
Wait for Machine 3.Queue	10.1681	(Insufficient)	0.00	37.4764
Wait for Machine 4.Queue	14.2118	(Insufficient)	0.00	53.3347
Wait for Machine 5.Queue	14.6080	(Insufficient)	0.00	53.0180
Wait for Machine 6.Queue	12.8014	(Insufficient)	0.00	43.5598

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 26 of 38



02:57:37PM **Category Overview** October 12, 2012

COSIRA Model V3_1

Replications: 1 Time Units: Hours

Queue

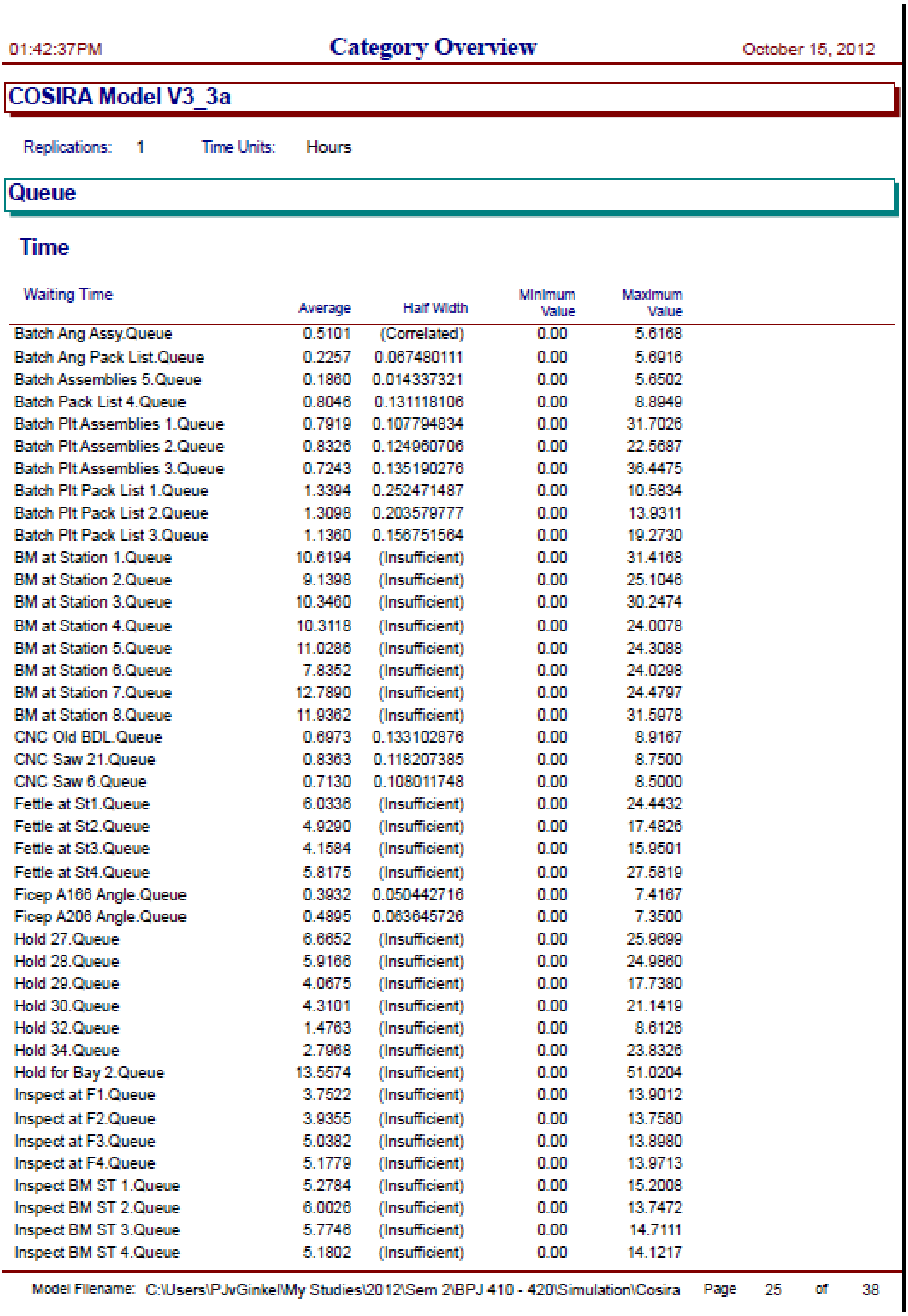
Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Wait for Machine 7.Queue	5.4169	(Insufficient)	0.00	16.2696
Wait for Machine 8.Queue	6.2168	(Insufficient)	0.00	20.6966
Wait for Weld Station.Queue	48.1005	(Insufficient)	0.00	166.11
Weld at Station 1.Queue	15.2672	(Insufficient)	0.00	119.24
Weld at Station 2.Queue	15.6832	(Insufficient)	0.00	97.9084
Weld at Station 3.Queue	16.0181	(Insufficient)	0.00	77.2082
Weld at Station 4.Queue	10.7125	(Insufficient)	0.00	87.8993
Weld at Station 5.Queue	11.1162	(Insufficient)	0.00	75.2206
Weld at Station 6.Queue	9.5192	(Insufficient)	0.00	68.1367

Other

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 27 of 38

APPENDIX 5E – TOC MODEL 2 SIMULATION



01:42:37PM **Category Overview** October 15, 2012

COSIRA Model V3_3a

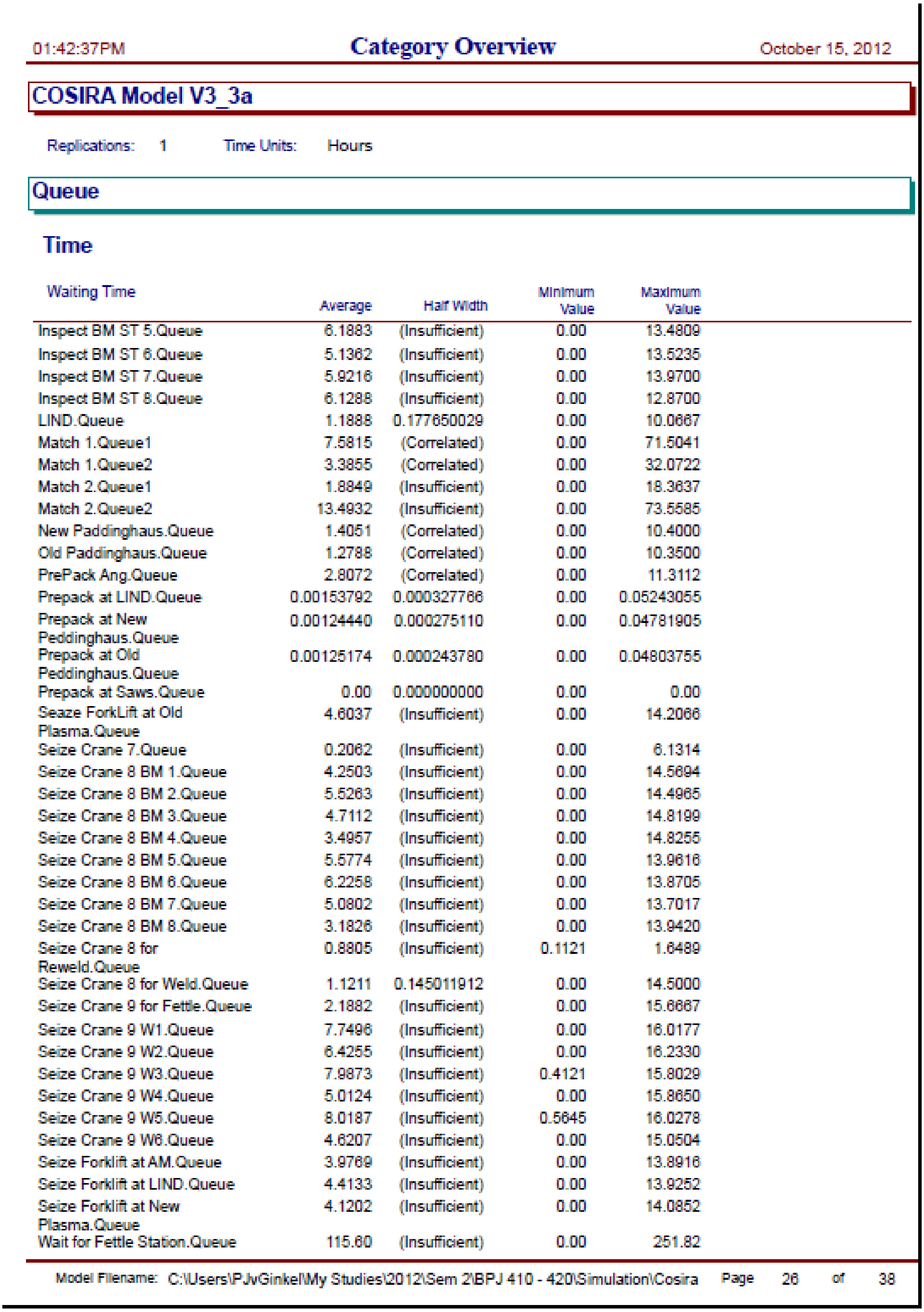
Replications: 1 Time Units: Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Batch Ang Assy.Queue	0.5101	(Correlated)	0.00	5.6168
Batch Ang Pack List.Queue	0.2257	0.067480111	0.00	5.6916
Batch Assemblies 5.Queue	0.1860	0.014337321	0.00	5.6502
Batch Pack List 4.Queue	0.8046	0.131118106	0.00	8.8949
Batch Plt Assemblies 1.Queue	0.7919	0.107794834	0.00	31.7026
Batch Plt Assemblies 2.Queue	0.8326	0.124960706	0.00	22.5687
Batch Plt Assemblies 3.Queue	0.7243	0.135190276	0.00	36.4475
Batch Plt Pack List 1.Queue	1.3394	0.252471487	0.00	10.5834
Batch Plt Pack List 2.Queue	1.3098	0.203579777	0.00	13.9311
Batch Plt Pack List 3.Queue	1.1360	0.156751564	0.00	19.2730
BM at Station 1.Queue	10.6194	(Insufficient)	0.00	31.4168
BM at Station 2.Queue	9.1398	(Insufficient)	0.00	25.1046
BM at Station 3.Queue	10.3460	(Insufficient)	0.00	30.2474
BM at Station 4.Queue	10.3118	(Insufficient)	0.00	24.0078
BM at Station 5.Queue	11.0286	(Insufficient)	0.00	24.3088
BM at Station 6.Queue	7.8352	(Insufficient)	0.00	24.0298
BM at Station 7.Queue	12.7890	(Insufficient)	0.00	24.4797
BM at Station 8.Queue	11.9362	(Insufficient)	0.00	31.5978
CNC Old BDL.Queue	0.6973	0.133102876	0.00	8.9167
CNC Saw 21.Queue	0.8363	0.118207385	0.00	8.7500
CNC Saw 6.Queue	0.7130	0.108011748	0.00	8.5000
Fettle at St1.Queue	6.0336	(Insufficient)	0.00	24.4432
Fettle at St2.Queue	4.9290	(Insufficient)	0.00	17.4826
Fettle at St3.Queue	4.1584	(Insufficient)	0.00	15.9501
Fettle at St4.Queue	5.8175	(Insufficient)	0.00	27.5819
Ficep A166 Angle.Queue	0.3932	0.050442716	0.00	7.4167
Ficep A206 Angle.Queue	0.4895	0.063645726	0.00	7.3500
Hold 27.Queue	6.6652	(Insufficient)	0.00	25.9699
Hold 28.Queue	5.9166	(Insufficient)	0.00	24.9860
Hold 29.Queue	4.0675	(Insufficient)	0.00	17.7380
Hold 30.Queue	4.3101	(Insufficient)	0.00	21.1419
Hold 32.Queue	1.4763	(Insufficient)	0.00	8.6126
Hold 34.Queue	2.7968	(Insufficient)	0.00	23.8326
Hold for Bay 2.Queue	13.5574	(Insufficient)	0.00	51.0204
Inspect at F1.Queue	3.7522	(Insufficient)	0.00	13.9012
Inspect at F2.Queue	3.9355	(Insufficient)	0.00	13.7580
Inspect at F3.Queue	5.0382	(Insufficient)	0.00	13.8980
Inspect at F4.Queue	5.1779	(Insufficient)	0.00	13.9713
Inspect BM ST 1.Queue	5.2784	(Insufficient)	0.00	15.2008
Inspect BM ST 2.Queue	6.0026	(Insufficient)	0.00	13.7472
Inspect BM ST 3.Queue	5.7746	(Insufficient)	0.00	14.7111
Inspect BM ST 4.Queue	5.1802	(Insufficient)	0.00	14.1217

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 25 of 38



01:42:37PM **Category Overview** October 15, 2012

COSIRA Model V3_3a

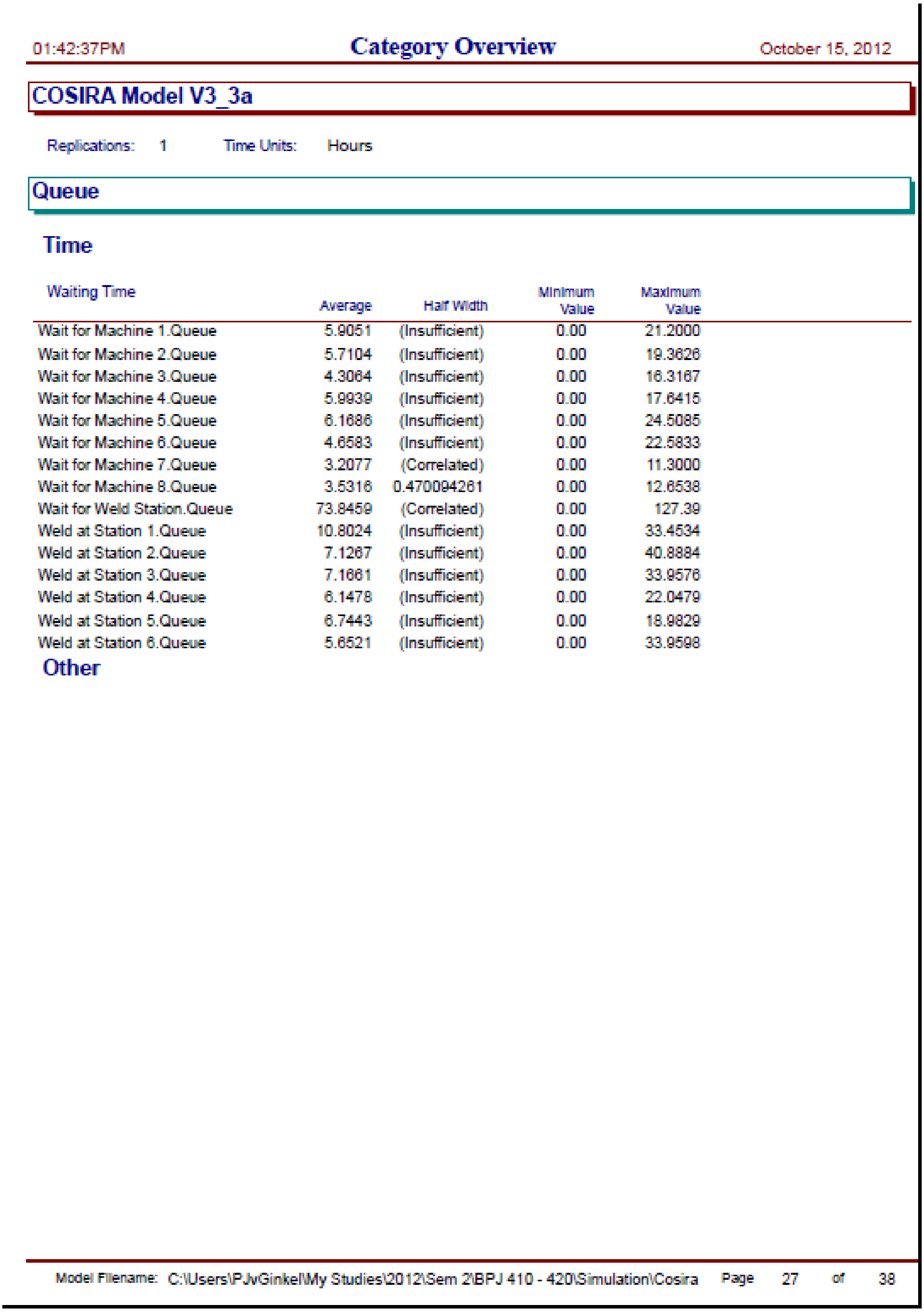
Replications: 1 Time Units: Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Inspect BM ST 5.Queue	6.1883	(Insufficient)	0.00	13.4809
Inspect BM ST 6.Queue	5.1362	(Insufficient)	0.00	13.5235
Inspect BM ST 7.Queue	5.9216	(Insufficient)	0.00	13.9700
Inspect BM ST 8.Queue	6.1288	(Insufficient)	0.00	12.8700
LIND.Queue	1.1888	0.177650029	0.00	10.0667
Match 1.Queue1	7.5815	(Correlated)	0.00	71.5041
Match 1.Queue2	3.3855	(Correlated)	0.00	32.0722
Match 2.Queue1	1.8849	(Insufficient)	0.00	18.3637
Match 2.Queue2	13.4932	(Insufficient)	0.00	73.5585
New Paddinghaus.Queue	1.4051	(Correlated)	0.00	10.4000
Old Paddinghaus.Queue	1.2788	(Correlated)	0.00	10.3500
PrePack Ang.Queue	2.8072	(Correlated)	0.00	11.3112
Prepack at LIND.Queue	0.00153792	0.000327766	0.00	0.05243055
Prepack at New Peddinghaus.Queue	0.00124440	0.000275110	0.00	0.04781905
Prepack at Old Peddinghaus.Queue	0.00125174	0.000243780	0.00	0.04803755
Prepack at Saws.Queue	0.00	0.000000000	0.00	0.00
Seaze ForkLift at Old Plasma.Queue	4.6037	(Insufficient)	0.00	14.2066
Seize Crane 7.Queue	0.2062	(Insufficient)	0.00	6.1314
Seize Crane 8 BM 1.Queue	4.2503	(Insufficient)	0.00	14.5694
Seize Crane 8 BM 2.Queue	5.5263	(Insufficient)	0.00	14.4965
Seize Crane 8 BM 3.Queue	4.7112	(Insufficient)	0.00	14.8199
Seize Crane 8 BM 4.Queue	3.4957	(Insufficient)	0.00	14.8255
Seize Crane 8 BM 5.Queue	5.5774	(Insufficient)	0.00	13.9616
Seize Crane 8 BM 6.Queue	6.2258	(Insufficient)	0.00	13.8705
Seize Crane 8 BM 7.Queue	5.0802	(Insufficient)	0.00	13.7017
Seize Crane 8 BM 8.Queue	3.1826	(Insufficient)	0.00	13.9420
Seize Crane 8 for Reweld.Queue	0.8805	(Insufficient)	0.1121	1.6489
Seize Crane 8 for Weld.Queue	1.1211	0.145011912	0.00	14.5000
Seize Crane 9 for Fettle.Queue	2.1882	(Insufficient)	0.00	15.6667
Seize Crane 9 W1.Queue	7.7496	(Insufficient)	0.00	16.0177
Seize Crane 9 W2.Queue	6.4255	(Insufficient)	0.00	16.2330
Seize Crane 9 W3.Queue	7.9873	(Insufficient)	0.4121	15.8029
Seize Crane 9 W4.Queue	5.0124	(Insufficient)	0.00	15.8650
Seize Crane 9 W5.Queue	8.0187	(Insufficient)	0.5645	16.0278
Seize Crane 9 W6.Queue	4.6207	(Insufficient)	0.00	15.0504
Seize Forklift at AM.Queue	3.9769	(Insufficient)	0.00	13.8916
Seize Forklift at LIND.Queue	4.4133	(Insufficient)	0.00	13.9252
Seize Forklift at New Plasma.Queue	4.1202	(Insufficient)	0.00	14.0852
Wait for Fettle Station.Queue	115.60	(Insufficient)	0.00	251.82

Model Filename: C:\Users\PJvGinkel\My Studies\2012\Sem 2\BPJ 410 - 420\Simulation\Cosira Page 26 of 38



01:42:37PM

Category Overview

October 15, 2012

COSIRA Model V3_3a

Replications: 1 Time Units: Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Wait for Machine 1.Queue	5.9051	(Insufficient)	0.00	21.2000
Wait for Machine 2.Queue	5.7104	(Insufficient)	0.00	19.3626
Wait for Machine 3.Queue	4.3064	(Insufficient)	0.00	16.3167
Wait for Machine 4.Queue	5.9939	(Insufficient)	0.00	17.6415
Wait for Machine 5.Queue	6.1686	(Insufficient)	0.00	24.5085
Wait for Machine 6.Queue	4.6583	(Insufficient)	0.00	22.5833
Wait for Machine 7.Queue	3.2077	(Correlated)	0.00	11.3000
Wait for Machine 8.Queue	3.5316	0.470094261	0.00	12.6538
Wait for Weld Station.Queue	73.8459	(Correlated)	0.00	127.39
Weld at Station 1.Queue	10.8024	(Insufficient)	0.00	33.4534
Weld at Station 2.Queue	7.1267	(Insufficient)	0.00	40.8884
Weld at Station 3.Queue	7.1661	(Insufficient)	0.00	33.9576
Weld at Station 4.Queue	6.1478	(Insufficient)	0.00	22.0479
Weld at Station 5.Queue	6.7443	(Insufficient)	0.00	18.9829
Weld at Station 6.Queue	5.6521	(Insufficient)	0.00	33.9598

Other

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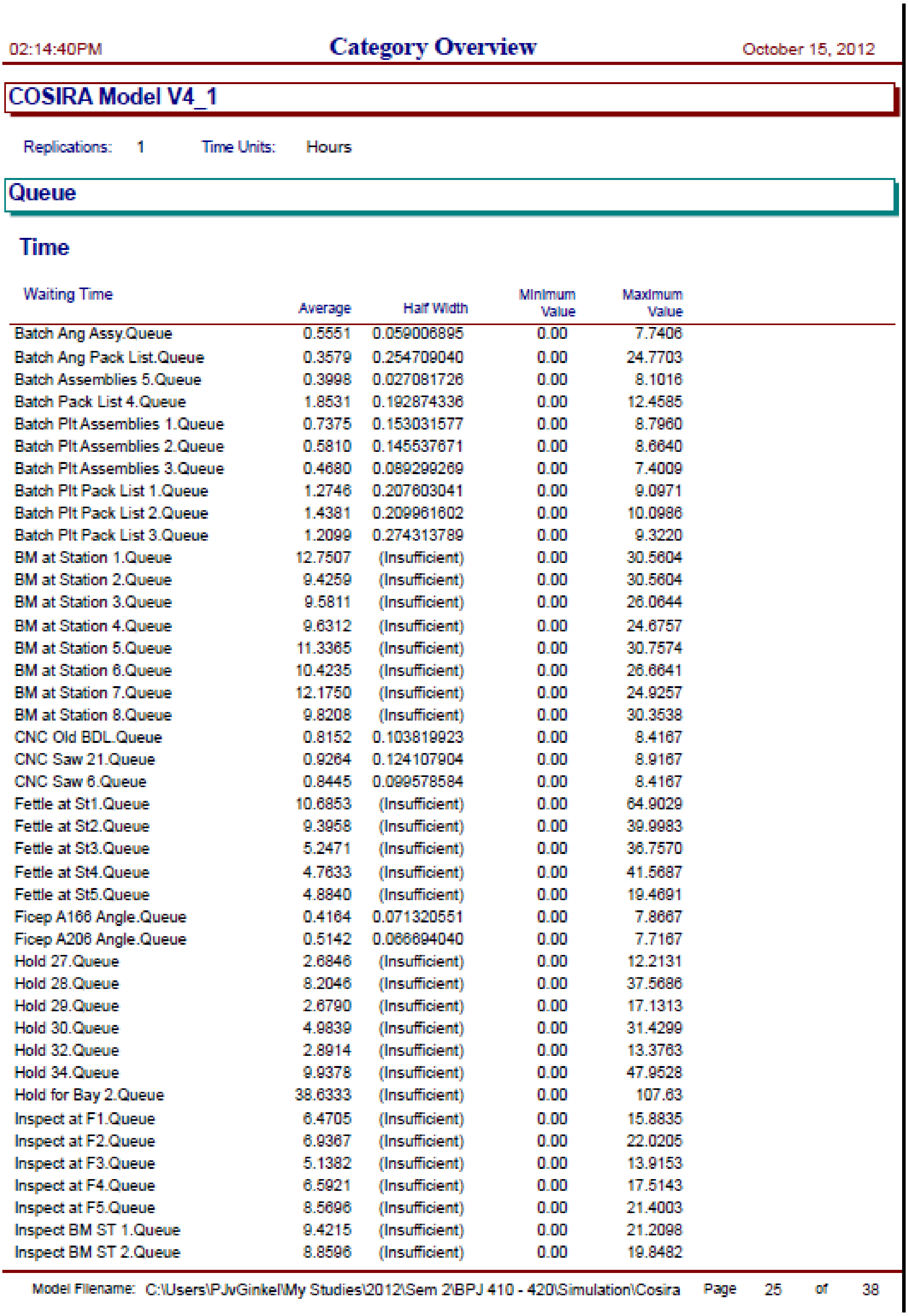
APPENDIX 5F – FINAL MODEL SIMULATION



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Category Overview

October 15, 2012

COSIRA Model V4_1

Replications: 1 Time Units: Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Batch Ang Assy.Queue	0.5551	0.059006895	0.00	7.7406
Batch Ang Pack List.Queue	0.3579	0.254709040	0.00	24.7703
Batch Assemblies 5.Queue	0.3998	0.027081726	0.00	8.1016
Batch Pack List 4.Queue	1.8531	0.192874336	0.00	12.4585
Batch Plt Assemblies 1.Queue	0.7375	0.153031577	0.00	8.7960
Batch Plt Assemblies 2.Queue	0.5810	0.145537671	0.00	8.6640
Batch Plt Assemblies 3.Queue	0.4680	0.089299269	0.00	7.4009
Batch Plt Pack List 1.Queue	1.2746	0.207603041	0.00	9.0971
Batch Plt Pack List 2.Queue	1.4381	0.209961602	0.00	10.0986
Batch Plt Pack List 3.Queue	1.2099	0.274313789	0.00	9.3220
BM at Station 1.Queue	12.7507	(Insufficient)	0.00	30.5604
BM at Station 2.Queue	9.4259	(Insufficient)	0.00	30.5604
BM at Station 3.Queue	9.5811	(Insufficient)	0.00	26.0644
BM at Station 4.Queue	9.6312	(Insufficient)	0.00	24.6757
BM at Station 5.Queue	11.3365	(Insufficient)	0.00	30.7574
BM at Station 6.Queue	10.4235	(Insufficient)	0.00	26.6641
BM at Station 7.Queue	12.1750	(Insufficient)	0.00	24.9257
BM at Station 8.Queue	9.8208	(Insufficient)	0.00	30.3538
CNC Old BDL.Queue	0.8152	0.103819923	0.00	8.4167
CNC Saw 21.Queue	0.9264	0.124107904	0.00	8.9167
CNC Saw 6.Queue	0.8445	0.099578584	0.00	8.4167
Fettle at St1.Queue	10.6853	(Insufficient)	0.00	64.9029
Fettle at St2.Queue	9.3958	(Insufficient)	0.00	39.9983
Fettle at St3.Queue	5.2471	(Insufficient)	0.00	36.7570
Fettle at St4.Queue	4.7633	(Insufficient)	0.00	41.5687
Fettle at St5.Queue	4.8840	(Insufficient)	0.00	19.4691
Ficep A166 Angle.Queue	0.4164	0.071320551	0.00	7.8667
Ficep A206 Angle.Queue	0.5142	0.066694040	0.00	7.7167
Hold 27.Queue	2.6846	(Insufficient)	0.00	12.2131
Hold 28.Queue	8.2046	(Insufficient)	0.00	37.5686
Hold 29.Queue	2.6790	(Insufficient)	0.00	17.1313
Hold 30.Queue	4.9839	(Insufficient)	0.00	31.4299
Hold 32.Queue	2.8914	(Insufficient)	0.00	13.3763
Hold 34.Queue	9.9378	(Insufficient)	0.00	47.9528
Hold for Bay 2.Queue	38.6333	(Insufficient)	0.00	107.63
Inspect at F1.Queue	6.4705	(Insufficient)	0.00	15.8835
Inspect at F2.Queue	6.9367	(Insufficient)	0.00	22.0205
Inspect at F3.Queue	5.1382	(Insufficient)	0.00	13.9153
Inspect at F4.Queue	6.5921	(Insufficient)	0.00	17.5143
Inspect at F5.Queue	8.5696	(Insufficient)	0.00	21.4003
Inspect BM ST 1.Queue	9.4215	(Insufficient)	0.00	21.2098
Inspect BM ST 2.Queue	8.8596	(Insufficient)	0.00	19.8482

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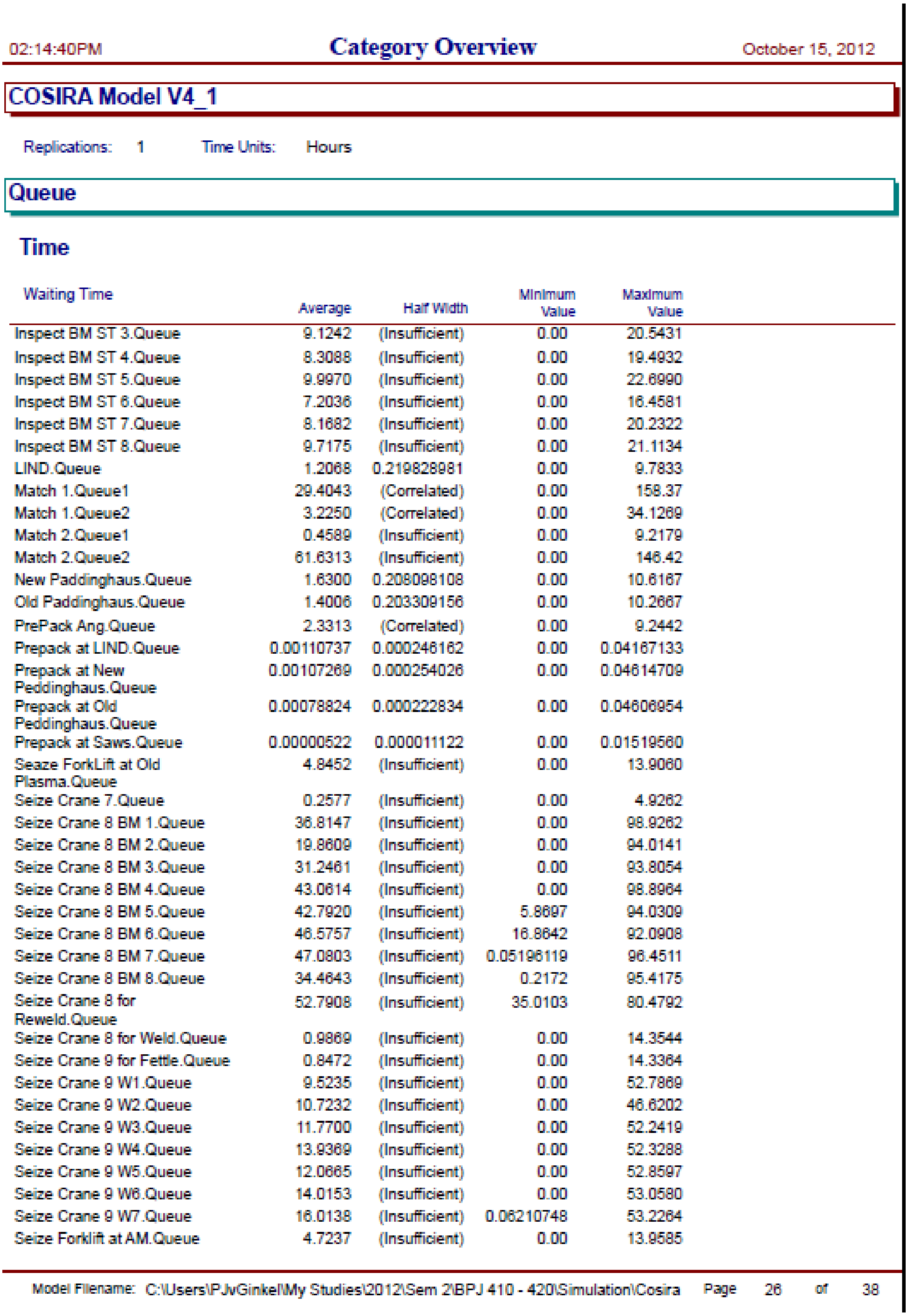

02:14:40PM **Category Overview** October 15, 2012

COSIRA Model V4_1

Replications: 1 Time Units: Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Inspect BM ST 3.Queue	9.1242	(Insufficient)	0.00	20.5431
Inspect BM ST 4.Queue	8.3088	(Insufficient)	0.00	19.4932
Inspect BM ST 5.Queue	9.9970	(Insufficient)	0.00	22.6990
Inspect BM ST 6.Queue	7.2036	(Insufficient)	0.00	16.4581
Inspect BM ST 7.Queue	8.1682	(Insufficient)	0.00	20.2322
Inspect BM ST 8.Queue	9.7175	(Insufficient)	0.00	21.1134
LIND.Queue	1.2068	0.219828981	0.00	9.7833
Match 1.Queue1	29.4043	(Correlated)	0.00	158.37
Match 1.Queue2	3.2250	(Correlated)	0.00	34.1269
Match 2.Queue1	0.4589	(Insufficient)	0.00	9.2179
Match 2.Queue2	61.6313	(Insufficient)	0.00	146.42
New Paddinghaus.Queue	1.6300	0.208098108	0.00	10.6167
Old Paddinghaus.Queue	1.4006	0.203309156	0.00	10.2667
PrePack Ang.Queue	2.3313	(Correlated)	0.00	9.2442
Prepack at LIND.Queue	0.00110737	0.000246162	0.00	0.04167133
Prepack at New Peddinghaus.Queue	0.00107269	0.000254026	0.00	0.04614709
Prepack at Old Peddinghaus.Queue	0.00078824	0.000222834	0.00	0.04606954
Prepack at Saws.Queue	0.00000522	0.000011122	0.00	0.01519560
Seaze ForkLift at Old Plasma.Queue	4.8452	(Insufficient)	0.00	13.9060
Seize Crane 7.Queue	0.2577	(Insufficient)	0.00	4.9262
Seize Crane 8 BM 1.Queue	36.8147	(Insufficient)	0.00	98.9262
Seize Crane 8 BM 2.Queue	19.8609	(Insufficient)	0.00	94.0141
Seize Crane 8 BM 3.Queue	31.2461	(Insufficient)	0.00	93.8054
Seize Crane 8 BM 4.Queue	43.0614	(Insufficient)	0.00	98.8964
Seize Crane 8 BM 5.Queue	42.7920	(Insufficient)	5.8697	94.0309
Seize Crane 8 BM 6.Queue	46.5757	(Insufficient)	16.8642	92.0908
Seize Crane 8 BM 7.Queue	47.0803	(Insufficient)	0.05196119	96.4511
Seize Crane 8 BM 8.Queue	34.4643	(Insufficient)	0.2172	95.4175
Seize Crane 8 for Reweld.Queue	52.7908	(Insufficient)	35.0103	80.4792
Seize Crane 8 for Weld.Queue	0.9869	(Insufficient)	0.00	14.3544
Seize Crane 9 for Fettle.Queue	0.8472	(Insufficient)	0.00	14.3364
Seize Crane 9 W1.Queue	9.5235	(Insufficient)	0.00	52.7869
Seize Crane 9 W2.Queue	10.7232	(Insufficient)	0.00	46.6202
Seize Crane 9 W3.Queue	11.7700	(Insufficient)	0.00	52.2419
Seize Crane 9 W4.Queue	13.9369	(Insufficient)	0.00	52.3288
Seize Crane 9 W5.Queue	12.0665	(Insufficient)	0.00	52.8597
Seize Crane 9 W6.Queue	14.0153	(Insufficient)	0.00	53.0580
Seize Crane 9 W7.Queue	16.0138	(Insufficient)	0.06210748	53.2264
Seize Forklift at AM.Queue	4.7237	(Insufficient)	0.00	13.9585

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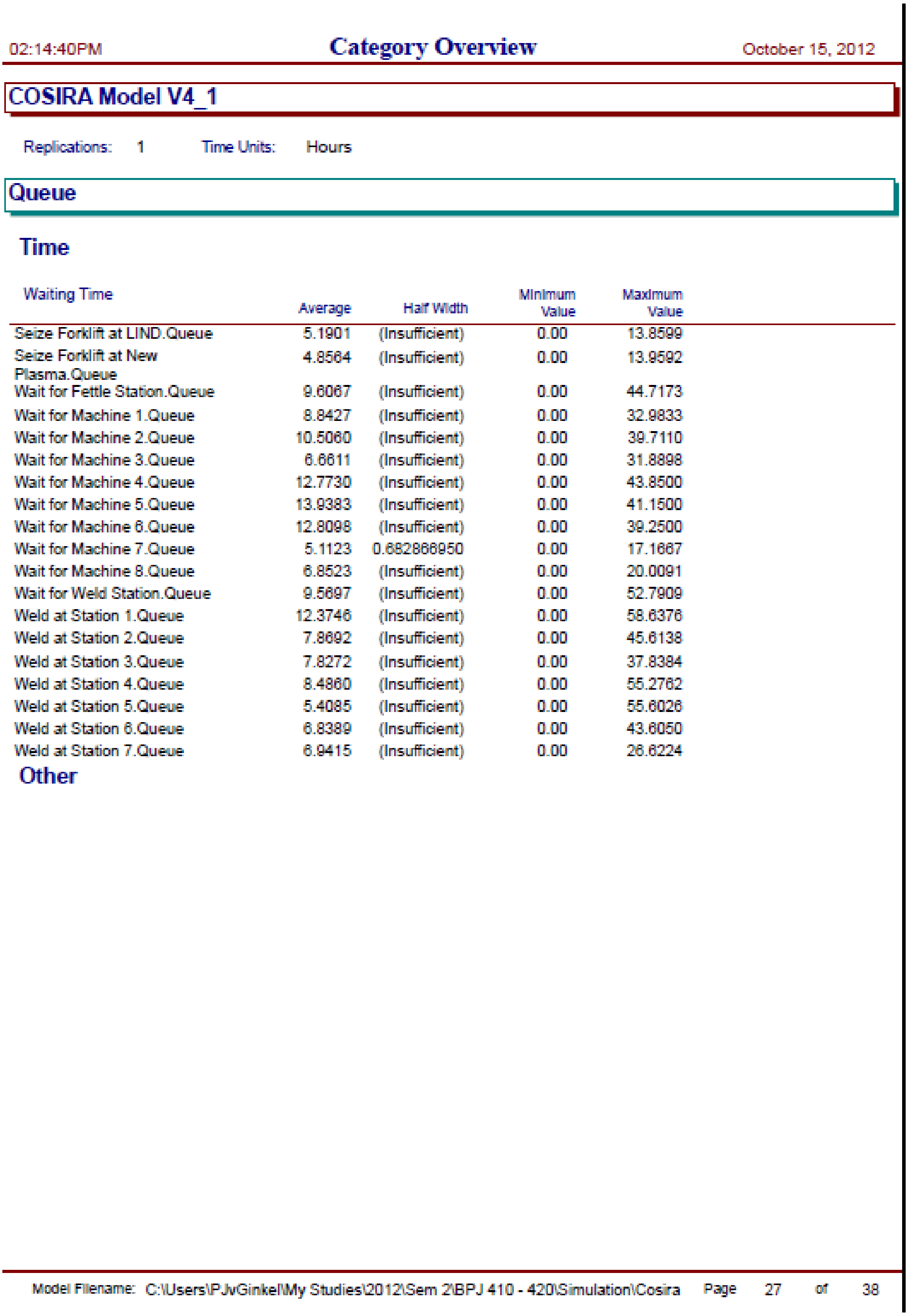

02:14:40PM **Category Overview** October 15, 2012

COSIRA Model V4_1

Replications: 1 Time Units: Hours

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Seize Forklift at LIND.Queue	5.1901	(Insufficient)	0.00	13.8599
Seize Forklift at New Plasma.Queue	4.8564	(Insufficient)	0.00	13.9592
Wait for Fettle Station.Queue	9.6067	(Insufficient)	0.00	44.7173
Wait for Machine 1.Queue	8.8427	(Insufficient)	0.00	32.9833
Wait for Machine 2.Queue	10.5060	(Insufficient)	0.00	39.7110
Wait for Machine 3.Queue	6.6611	(Insufficient)	0.00	31.8898
Wait for Machine 4.Queue	12.7730	(Insufficient)	0.00	43.8500
Wait for Machine 5.Queue	13.9383	(Insufficient)	0.00	41.1500
Wait for Machine 6.Queue	12.8098	(Insufficient)	0.00	39.2500
Wait for Machine 7.Queue	5.1123	0.682866950	0.00	17.1667
Wait for Machine 8.Queue	6.8523	(Insufficient)	0.00	20.0091
Wait for Weld Station.Queue	9.5697	(Insufficient)	0.00	52.7909
Weld at Station 1.Queue	12.3746	(Insufficient)	0.00	58.6376
Weld at Station 2.Queue	7.8692	(Insufficient)	0.00	45.6138
Weld at Station 3.Queue	7.8272	(Insufficient)	0.00	37.8384
Weld at Station 4.Queue	8.4860	(Insufficient)	0.00	55.2762
Weld at Station 5.Queue	5.4085	(Insufficient)	0.00	55.6026
Weld at Station 6.Queue	6.8389	(Insufficient)	0.00	43.6050
Weld at Station 7.Queue	6.9415	(Insufficient)	0.00	26.6224

Other

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