The simulation of a Manganese Railway Siding Facility

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Submitted in partial fulfillment of the requirements for
the degree of
BACHELORS OF INDUSTRIAL ENGINEERING
at the
FACULTY OF ENGINEERING, BUILT ENVIRONMENT AND INFORMATION TECHNOLOGY
UNIVERSITY OFPRETORIA

October 2010

UNIVERSITY OF PRETORIA

DEPARTMENT: INDUSTRIAL AND SYSTEMS ENGINEERING

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Executive Summary

ITE consulting takes pride in providing a proposal to evaluate and confirm the design parameters and operational philosophy of the rail siding operations near the manganese mines at Lohatla.

The client, a logistics company, has been contracted by a mining company to assist with the export of Manganese ore from various mines in the Lohatla region.

The client will be provided with one train from Transnet Freight Rail daily and their contractual arrangement is to have a turnaround time of not more than 12 hours. They need confirmation that their proposed layout will achieve this objective.

Because the data supplied by the customer didn't include any variation, different sets of data were used in the simulation. The first set excluded any variation, whilst the second set of inputs included added randomness. This ensures that the simulation is a better representation of the real world where variation is common. Outputs from both sets of inputs were analysed and compared before recommendations were made.

Whilst simulating the Manganese Railway Siding Facility, a bottle neck was identified at the weighbridge. This bottleneck made it impossible to achieve a train turnaround time of less than 12 hours.

After analysing all results obtained from the simulation done in Arena, it is recommended that the weigh time at the weighbridge be decreased to 5 minutes or less, or a second weighbridge be installed. Either of the proposed solutions would enable the system to produce a train turnaround time of less than 12 hours.

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Chapter 1

Introduction and Background on the Company

ITE Consulting

ITE Consulting specialises in modeling and analysing operational environments, locating problem areas and evaluating future opportunities to help a client make the right decisions.

In September 2008 ITE Consulting combined its interests with ConsultLink, a Gauteng -based consultancy for operations, analysis and systems development.

ITE Consulting (ITE-C) is a consulting engineering company with branches in Durban and Pretoria. The company specialises in developing and implementing Intelligent Technologies to locate problem areas and evaluate future opportunities.

ITE-Consulting service is to assist decision-makers and stakeholders to better understand the implications of decisions before they are made. With the use of advanced technologies such as Gensym's G2 Expert System, together with conventional tools such as spreadsheets, database and programming applications, the company is able to both speed up the process of evaluating numerous options and provide a more rigorous analysis of the outcomes.

ITE-Consulting's approach has benefited companies by avoiding costly mistakes such as plant upgrades that wouldn't have worked and deferring capital expenditure by increasing efficiencies of existing operations. The intelligent tools developed to aid longer-term decision-making can also be integrated with existing Information Systems to support the daily decision-making in planning and managing operations.

ITE-Consulting's approach also includes a tactical understanding of the client's operational and management processes, together with the roles and responsibilities and the organisational structures necessary to support these processes. Through interviews with key personnel, observations and time studies of work being performed, analysis of past performance, and then use Intelligent Technology to help find ways to improve, measure the potential benefit, determine the best option, and develop the business case for change.

Most logistical environments such as supply chains, materials handling facilities, transport systems and production lines are steeped in complex inter-dynamics that make decision-making a difficult task. ITE-Consulting's expertise helps to make understanding these environments simpler - especially when considering future plans such as plant expansions and production increases, where decision-makers have to rely on rules-of-thumb or "gut-feel" to make their choices.

Past Clients include Companies like BHP Billiton, Murray & Roberts, De Beers, Kumba, CSIR and Toyota.

*Information taken directly from ITE Consulting's Website (www.ite.co.za)

The Customer

Some background info on the Operations in Lohatla:
The Company involved is a Logistics company, and has been contracted to export Manganese Ore from various mines in the Lohatla region.
They will be provided with 1 train from Spoornet daily and their contractual arrangement is to have a turnaround time for the train of less than 12 hours.
They need to determine the feasibility of their manganese railway siding design.

Introduction and Problem Background

ITE consulting was approached by the customer to evaluate and confirm the intended design of a planned railway siding located near the manganese mines in the Lohatla area.

In the event that the turnaround time is more than 12 hours, a problem area or bottle neck must be identified and the effects of a proposed solution must be analysed.

This project's main goal is to confirm the customer's proposed Manganese Railway siding facility, and like in the case reported by D.W Starks, R.S Schwieters and D Craces (2006) the results obtained from the simulation would enable ITE Consulting to confirm or make recommendations to the customer, which in turn will be able to make an informed decision concerning the intended layout and process of the planned facility prior to committing capital required for the project.

Proposed Layout

As can be seen in figure 2 Appendix A p30, the incoming trucks enter the system at point A. At point A, a security check is preformed and the truck is weighed. From point A on the map the truck moves to point B where it is kept on hold if necessary, otherwise it moves on to point C where it dumps the manganese ore on one of seven piles depending on the grade. From here the truck returns to point A, where the truck is weighed and checked again by security. From the stockpiles at C a truck gathers the ore and moves it to a conveyer that feeds it into a hopper at D, the hopper loads the ore onto the train positioned below on the railway siding. The reason why the trucks first unload onto the piles, is that a particular grade is loaded onto the train, whilst various grades are being delivered by the trucks.

The above explains the layout as planned by the customer which has been simulated in this project.

Project Aim

The main objective of the project is to confirm the design parameters and operation philosophy of the rail siding operations near the manganese mines at Lohatla, which is to achieve a turnaround time of less than 12 hours per train.

Chapter 2

Literature Study

Simulation Modeling

What is Simulation

According to Kelton, Sadowski and Sturrock (2007) simulation refers to a wide collection of applications and methods to mimic the expected behavior of a real system, usually on a computer making use of appropriate software. Because there is no dealing with an actual system, but rather a mere computer programme, it is fast, inexpensive and not to difficult to get useful feedback and interpret the effect of proposed changes to a system simply by manipulating the programme's inputs.

Kelton, Sadowski and Sturrock (2007) also mentioned that from a more practical point of view, simulation should be a process of designing and creating a computerised model or representation of a proposed or real live system for the purpose of conducting numerical experiments to provide a clearer understanding of the system's behavior for a given set of conditions.

Another definition given by Winston W.L (2004) is that simulation is a technique that imitates the operation of a real world system as it evolves and changes over time. This is usually done by creating a simulation model. Usually a simulation model takes the form of a set of assumptions about the operation of the system, expressed as logical or mathematical relations between objects of interest in the system. In contrast to the exact mathematical solutions available with most analytical models, the process of simulation involves the process of running or executing the model through time, mostly on a computer, to generate representative samples of the measures of performance.

In a paper presented by U Chinbat and S Takakuwa at the 2009 Winter Simulation Conference held in Austin Texas they quoted R.E Shannon's definition of a simulation; it stated that a simulation is a process of designing a model of a real system or process and conducting experiments with this model for the main purpose of understanding the behavior of the system, and evaluating various strategies for the operation of the system. U Chinbat and S Takakuwa (2009) also went on to say that simulation can help mining project managers to comprehend the behavior of the system and help optimise the system through various strategies in a virtual reality.

To conclude, for this project a simulation model should be a realistic computerised representation of the manganese railway siding facility at Lohatla, with assumptions and input data that is a realistic representation of the system, but still be practical and possible to model in Rockwell Software's Arena.

Why Simulate

According to S Hartmann (1996) the main reasons to run a simulation is firstly to investigate the detailed dynamics of a system, secondly to develop hypotheses, models and theories, thirdly to perform numerical experiments, fourthly to support experiments, and lastly to gain understanding of a process.

G. Confessore, G Liotta P. Cicini, F. Rondinone and P. De Luce presented a paper at the 2009 Winter Simulation Conference held in Austin Texas titled, a Simulation-based Approach for Estimating the Commercial Capacity of Railways. In this paper they stated that the simulation model was exploited for verification and validation purposes.

In a paper presented D.W Starks, R.S Schwieters and D Creces at the 2006 Winter Simulation Conference held in the city of Monterey, California USA; D.W Starks, R.S Schwieters and D Creces reported that Dafasco Steel was able to identify bottlenecks in their system, improve their throughput by making better use of available system resources, and help Dafasco Steel to better understand the possible impact of proposed system changes or upgrades, before they are required to invest additional capital.

Advantages and Disadvantages of Simulation

According to S Hartmann (1996), a major advantage of a simulation is that simulation allows the users to explore detailed dynamic properties of a real world process. In many cases it is not only impractical, but impossible for practical reason to extract this information experimentally; the applicable time scale turns out to be either too large (e.g. for the evolution of galaxies) or too small (e.g. for nuclear reactions). For these purposes, simulation modeling is often the only appropriate tool to learn something new about a system or process.

Kelton, Sadowski and Sturrock (2007) stated, that because some real life systems and processes are affected by random and uncontrollable inputs, many simulation models involve stochastic or random input components; this causes the output to be random too. So running a simulation model once is like performing a random physical experiment once. In many simulations, as the runtime of the model is enlarged, most outputs will tend to settle down and become less variable, but it can be very hard to determine how long is a long enough time to run the model. In the design and analyzing of simulation experiments, it is important to take into account the uncertainty and randomness in the results. They further state that uncertainty can completely be removed from the system by making a lot of over-simplified assumptions about the system; this would provide an uncomplicated model with nice, non-random results. Unfortunately, such an over-simplified model will probably not be a valid representation of the system. An approximated answer to the right problem is preferred to an exact answer to the wrong problem.

In a paper presented by N.P. Anderson and G.W. Evans at the 2008 Winter Simulation Conference held in Miami USA, they stated that some of the disadvantages of a simulation model are that the development of a simulation model is often expensive and time consuming, and that evaluation of policies must often be based on multiple, conflicting performance measures. Mostly, estimates of performance measures can be attained, and the number of practicable policies for evaluation is often too many for complete enumeration.

Software

Rockwell Automation – Arena

According to the Arena Simulations website, Arena simulation software helps predict, demonstrate and measure system strategies for efficient, effective and optimised performance. Arena simulation software also helps to protect businesses by analysing the potential impact of new business ideas, strategies and rules before implementation.

Top universities around the world choose Arena simulation as the basis of their simulation courses; this includes international universities to the likes of Harvard, Massachusetts Institute of Technology, Cambridge University, and most local universities, including the University of Cape Town, Kwazulu Natal, Witwatersrand and the University of Pretoria.

Arena offers a family of products that are the perfect tools to solve most business problems. Ease of use is insured by flowchart methodology, avoiding the complex environment of classic coding. Each Arena package provides unlimited model size and corporate wide runtime privileges. www.arenasimulation.com

Furthermore, Arena Simulation offers a free Student version with full functionality, the only limitation on the student package is the size of the model that can be simulated; this is done by limiting the number of entities allowed in the system. Because Arena is the software used as the platform for the simulation module presented at the University of Pretoria and is therefore freely available, and because of the functionality it offers, simulation of the Railway siding facility was done in Rockwell Software's Arena version 12.

The table below shows the different products provided by Rockwell Automation:

Product Name	Product Type	Application Domain
Basic	Introductory	Customer service, internal business processes such order fulfillment, service, or simple manufacturing flows.
Basic Plus	Enhanced Introductory	More detailed business processes including advanced animation and material handling. Ability to attach other Arena templates.
Standard	Robust Mid-line	All the features of Basic Plus with addition of advanced logic for modeling pull, Kanban and other advanced systems. Connectivity to external data sources and creation of user-specified statistics.
Professional	Flagship - Development Platform	Complex, large-scale projects involving highly sensitive changes related to supply chain, manufacturing, processes, logistics, distribution, warehousing, and service systems. Ability to create custom templates for complex, repetitive logic, to simplify model development and reduce model development time.
Enterprise	Comprehensive Product Bundle	Comprehensive offering of products for the organization facing a wide range of modeling problems.

Figure 1Arena Software

*Table 1 is copied directly from Arena Simulation's website; www.arenasimulation.com

Simul8

According toSimul8's website their simulation software will take the risk out of decision making; this is due to their product's ability to simulate business processes across the industry. Simul8 also offers tailored products which are customised to meet the customer's exact demand. Simul8 2010 also includes a Carbon Footprint calculator to monitor the expected carbon output of a planned process and Simul8's report function has also been upgraded.

Extendsim

According to Extendsim's website they offer a leading edge and powerful simulation tool. By using Extendsim a wide variety of dynamic models of real life processes can be modelled. Extendsim make uses of "building blocks" to create models in a visual way.

Extendsim have the capacity to do the following:

- Predict results and course of actions
- Stimulate creative thinking and help workers gain insight
- Visualize your project in a virtual word or logically
- Identify problem areas in a system before implementation
- The potential effects of modifications can be explored
- Optimise operations
- Inefficiencies can be identified and new ideas tested
- Explanation of observed events
- Communicate the feasibility of plans

Extendsim allows the user to model and simulate any process or system by creating a logical representation in an easy to use visual format. www.extendsim.com

One of the more attractive features of Extendsim is the software's ability to dynamically adjust setting while the simulation is running. Another attractive feature is the software's ability to render a 2D or 3D representation of the system or process that is being modelled; this can be used in presentation and can contribute in explaining complex systems visually.

Data

Importance of data

According to Kelton, Sadowski and Sturrock (2007) the recommendations made from a simulation model's results are no better than the data used and the model itself. If the data used is not accurate and representable of the system or process modeled, no confidence can be placed on the accuracy of the results or the conclusions made from the interpretation thereof.

Skoogh S and Johansson B (2008) stated that one of the more crucial parts of a simulation project is the management of input data. They also stated that previous studies have shown that the input data phase of a project consumes on average 31% of time spent on a project. Skoogh and Johansson (2007). Similar reports were also made by Trybula (1994), stating that between 10 and 40% of project time is consumed by the input data phase of a simulation.

This indicates just how important the data of a project is, and that time should be spent to ensure that the inputs of the system are not just convenient, but a realistic representation of the system that is being modeled.

Chapter 3

Input Data and distributions

Background

Because the data supplied by the customer didn't include any variation, the values supplied were used as the mean value in statistical distributions such as normal, exponential and Poisson distributions, where applicable. This ensures that the simulation is a better representation of the real world where variation is common.

According to Gitlow H.S and AJ Oppenheim A.J (2005), common causes of variation are due to the process itself and that process capability is determined by common causes of variation. This includes things such as poor hiring, inadequate training and poor management, and could also be caused by the design of the service or product itself. Therefore, employees cannot control and should not be held responsible for common variation in a system.

In the simulation values have been changed to add some variance and randomness to the system. This was done by using values supplied by the customer as mean values of distributions and the standard deviations where applicable were created by using a value of ten percent of the value supplied.

Input data

For the simulation two sets of data were used to simulate the Manganese Siding Facility. The first set of data is a fixed set as supplied by the customer, with almost no variation. The second set of data used was a set of inputs containing more randomness and variation. During the simulation, small alterations were made in some of the input values to evaluate the importance and effect of the specific input.

Arrival of External Trucks

External trucks or Pay loaders deliver seven grades of ore from various mines to the siding facility. It is given that trucks arrive at equal hourly intervals daily, but at any random second within the hour. A fixed amount of 3276 tonnes of manganese ore will arrive weekly for each of the 7 grades of ore. That amounts to 3276 tonnes and 105.6 trucks daily.

The arrival times will be generated using a Random Exponential distribution with a inter arrival time of 1.59 hours. This value is used for both sets of input data.

Security

A Security check is preformed at the main gate, this include a quick search of the arriving truck as well as the confirmation of the required paper work. The time includes the travelling time between the security check point and the weighbridge.

At the gate only one truck can be checked by security at a time.

The time used for this process will be represented by:

1. A constant value of 5 minutes.
2. A normal distribution with a mean value of 5 minutes and a standard deviation of 0.5 minutes.

Weighbridge

All trucks are weighed on their way in and out of the facility; this is done to calculate the exact weight of the ore delivered. The time includes travelling to and from the stockpiles to the weighbridge and the time to weigh the truck.

The time for this process is represented by:

1. A constant time of ten, nine, eight, seven, six and five minutes respectively.
2. A normal distribution with a mean value and standard deviation as follows:
   - Ten minutes mean, and a standard deviation of 1 minute.
   - Nine minutes mean, and a standard deviation of 0.9 of a minute.
   - Eight minutes mean, and a standard deviation of 0.8 of a minute.
   - Seven minutes mean, and a standard deviation of 0.7 of a minute.
   - Six minutes mean, and a standard deviation of 0.6 of a minute.

- Five minutes mean, and a standard deviation of 0.5 of a minute.

3. A constant time of 10 minutes, with 2 weighbridges available.
4. A normal distribution with a mean of 10 minutes and a standard deviation of 1 minute, with 2 weighbridges available.

For input sets 1 and 2, only one weighbridge is available.

Stockpiles

At the stockpiles the trucks dump the ore on the correct pile depending on the grade, the dump rate of the trucks are given as 465 tonnes per hour. After dumping the ore, the trucks return to the gate and get checked by security before leaving the system.

Internal trucks

Internal trucks move the ore from the piles to the Load-out station where the ore are loaded onto the trains.

The number of internal trucks is given as 5, each with a capacity of 31 tonnes, and which are loaded at a rate of 465 tonnes per hour.

The dump rate and load rate of all trucks within the system will be represented as a normal distribution with a mean value of 465 and a standard deviation of 23.25 tonnes.

The trucks are given to be 98% reliable. (Percentage of calendar time)

Travelling times for the internal trucks between the respective stockpiles and the load-out station are:

Stockpile 1	4 minutes
Stockpile 2	4.333minutes
Stockpile 3	4.667 minutes
Stockpile 4	5 minutes
Stockpile 5	5.333 minutes

Stockpile 6	5.667 minutes
Stockpile 7	6 minutes

Travelling time from the load-out station back to the piles are 5 minutes.

Travelling times above are represented as constant values because the travelling time is small in comparison with other operations and no queues can form in this area of the simulation.

Trains

Each day a train arrives at 6h00 and consists of 4 rakes, three rakes of 15 wagons, and one of 7 wagons giving a total of 52 wagons. Prior to loading a rake, there is a preparation time of 60 minutes. Each wagon has a capacity of 63 tonnes.

The arrival time of the train is generated on a fixed schedule, each day at 06h00.

The capacity of the wagons is represented firstly a constant value, rake 1 to 3 which consist of 15 wagons each with a constant capacity of 945 tonnes for each rake, and rake 4 which consist of 7 wagons with a constant capacity of 441 tones. For the second set of data rake 1 to 3's capacity is represented by a normal distribution with a mean value of 945 tonnes and a standard deviation of 94.5 tonnes, and rake 4's capacity by a normal distribution with a mean value of 441 tonnes and a standard deviation of 44.1 tonnes.

Load-out Station

This is where the internal trucks dump the ore and where after the ore gets loaded onto the wagons.

Firstly the loading load rate is represented as a constant rate of 625 tonnes per hour, with the second set of inputs represented as a normal distribution with a mean of 625 tonnes per hour, and a standard deviation of 62.5 tonnes.

The load-out station has a storage facility with a capacity of 320 tonnes.

The facility is 95% reliable (percentage of calendar time).

Operational Stoppages

Shift Changes happen daily at 06h00 and again at 18h00, the duration of a shift change is one hour.

Each shift includes one lunch break and two tea breaks. The lunch break has duration of 30 minutes and the combined duration of the two tea times is also 30 minutes. A schedule was used to represent the lunch breaks, tea breaks and shift changes.

This concludes the input data for the railway siding facility. The results obtained from the simulation is presented and discussed in chapter 5.

Chapter 4

The Arena Model

Documentation

The following part of the report focuses on how the actual model of the railway siding was build in Arena. Each segment of the model is be explained in a short paragraph and reference is made to the applicable Table or Figure where the model flow is illustrated.

Also in Appendix B is a table that explains all the modules that was used in the Arena model.

The Model

Train Logic

The daily train was modelled as follows:

Each train consists of 4 Rakes, and preparation time before each rake can be loaded is 60 minutes.

Rake 1	15 Wagons
Rake 2	15 Wagons
Rake 3	15 Wagons
Rake 4	7 Wagons

Wagon Capacity is 63 tonnes each.

A Create Module was used to create an entity called “Train”. This entity is created at 06h00 each day, after which this entity moves to the module called “Train Arrives At Station”. This is a Seize Module which would then seize the resource called "Train Station". When this resource is seized, it won't allow another train into the station. The next module is a Delay Module named "Prepare Rake", followed by a Flow Module named "Load Rake". Combined, these two modules delay the train for the preparation needed, and thereafter loads the rake with ore. This is repeated for each rake. After the train is fully loaded it moves to the next module called "Train Leaves Station". This module releases the resource called "Train Station" and enables the next train to move into the loading area. Lastly, the train moves to the final module called "Train Leaves System". This is a Dispose Module which disposes the train.

The train Logic can be seen in Figure 3, Appendix A p 31.

External Trucks

Creation of External Trucks

For each of the seven grades of ore there is a Create Module called "Create Truck Grade()". This enables the system to move the truck to the correct stockpile later on in the model. From the create module the truck moves to the "Security Check" module. This is a Process Module which seizes, delay and release the resource named "Security". By doing this, the process of the security check is simulated and ensures that no more than one truck enters the security or gate area at any given time. From the security checkpoint, the truck moves to the weighbridge. This is a Process Module which seizes, delays and then releases the resource named "Bridge". This simulates the weighing process of the trucks and ensures that no more than the correct amount of trucks enters the weighbridge(s) at a time. From the weighbridge, trucks move into a Decide Module that route each truck to the stockpile with the corresponding grade of ore.

Stockpile - External Trucks

From the Decide Module mentioned above, the truck moves into a Seize Module called" Seize Pile()". Here two resources are seized, firstly a resource called "Pile()"which ensures that only one truck access that specific pile at a given time. The second resource seized is called “Pile()U” and is used for the purpose of simulating failures. Next, the truck moves into a Flow Module called “Unload Truck At Pile()” where the truck deposits its ore and then moves on. Resources are then released, where after the truck is directed back to the gate where it is weighed and checked again by security where after it leaves the system.

The External Truck Logic can be seen in Figure 7, Appendix A p33.

Internal Trucks

Creation of Internal Trucks

Five Internal Trucks are created at the start of the simulation. This is to represent the five permanent internal trucks owned by the facility that never leaves the work area, except to be serviced.

Stockpiles – Internal Trucks

From the Creation Module called “Creation of Internal Trucks”, the trucks move directly to a Decide Module at stockpile 1. The Decide Module determines whether there is enough ore at Pile 1, which on first creation is not a constraint since all stockpiles have a starting stock level of 2500 tonnes. Thereafter the trucks move to an Assign Module called “From pile()’. Here the value of a variable called “Variable 1” is changed to match the number of the stockpile the truck is about to enter. This variable is used to return the truck to the same stockpile later on. From there the truck moves into a Hold Module. Here the truck can wait if necessary until the stockpile becomes available. From the Hold Module the truck moves on to a Seize Module. Here two resources are seized, firstly a resource called “Pile()”(The same resource as with external trucks). This resource ensures that only one truck access that specific pile at a given time. The second resource seized is called “Pile()L”. This resource is used for the purpose of simulating failures. Next the truck move into a Flow Module called “Load Truck At Pile()” where ore is deposited onto the truck. The next module releases all resources that were seized and lastly the truck is delayed, this represents travel time to the Load-out station.

The Stockpile Logic can be seen in Figure 5, Appendix A p32.

Load-out Station

From the Delay Module mentioned above the truck moves onto a Seize Module called "Seize Load Station". Here the resource called "Load Station" is seized which ensures that only one truck can dump ore at the Load-out station at any given time. Next the truck moves into a Flow Module called "Load Out Station". Here the truck dumps its ore. Thereafter all resources involved are released, and the truck is delayed to simulate travel time back to the piles.

The Load-out Station Logic can be seen in Figure 6, Appendix A p32.

Decide

When a truck returns from the Load-out Station there are a few decisions that must be made. Firstly, the ore should be taken from the same pile until depleted before ore from the next pile may be used. Secondly, the next pile from which ore must be taken must be the largest at that point in time. Lastly, a truck may only return to a pile from which it just came if there is enough ore to fill the truck. For these, trucks in line as well as the truck being loaded should be considered.

When a truck returns from the stockpile it moves into a Decide Module called "From Which Pile". Here the truck is returned to the pile from which it took ore the previous time. From there it move onto the next decide module that determines whether there is enough ore on the pile, if so the truck moves into the loading process again which was explained earlier. Otherwise the truck moves on into a Hold Module. Here the truck can wait if necessary until one of the stockpiles has sufficient ore. Next, the truck moves to another Decide Module. Here the truck is routed to the Decide Module in front of the stockpile with the most ore (this is the same Decide Module mentioned earlier). Here it is confirmed that there is enough ore, if so the truck moves through to the stock pile, if not the process described above will repeat.

The Decide Logic can be seen in Figure 4, Appendix A p31.

Chapter 5

Overview

In this chapter the results obtained from the simulation is discussed and recommendations are made. The data and other inputs from chapter 3 is combined with the method discussed in chapter 4.

After the simulation was ran with the first set of inputs, it was clear that a bottleneck exists in the system. Thereafter this problem area was the main area of focus.

This chapter also discusses the effect of different inputs on this particular simulation. Mainly variations of two sets of inputs was used; one without variation and randomness, and another with more randomness and variation.

Effect of Inputs

The following tables display some of the results obtained from the simulation. Table 1 and Table 2 displays the following information; the average number of trucks in the queue at the weigh in station, the average time in hours a train waits at the station before loading can start and the average total time a train spends in the system from arriving at the station until it leaves the system. The time a truck takes to be weighed is the variable that was changed in each instance. For Table 1 a constant value was used for the weigh time. For Table 2 a normal distribution was used, the standard deviation is also displayed in the table.

Results From Data with Minimum Variations			
Weigh time	**Total Train Time**	**Queue Length**	**Train Wait time**
5	11.3858	2.3083	0.05224661
6	67.949	717.43	24.3555
7	273.12	1694.43	124.15
8	446.24	2492.47	209.13
9	591.55	3130.62	280.42
10	702.39	3658.65	334.57

Table 1 Results - Fixed Data

Results From Data with Added Variations				
Standard Deviation	Weigh time	Total Train Time	Queue Length	Train Wait Time
0.5	5	11.4107	2.1484	0.03221259
0.6	6	86.3151	592.19	32.9294
0.7	7	276.01	1726.82	125.62
0.8	8	444.43	2430.24	208.27
0.9	9	598.19	3065.65	283.65
1	10	715.74	3571.59	341.19

Table 2 Results - Random Data

From Table 1 and Table 2 as well as from Figure 8, Appendix A p34, it can be seen that the difference in results of the data without, and the data with added variation is so small in relation to the values that for this simulation it would not have made a significant impact on any decisions or recommendations.

Results

The main objective of the Manganese Railway Siding Facility is to achieve a train turnaround time of 12 hours or less. From Table 1 and Table 2 as well Figure 8, Appendix A p34, it can clearly be seen that for the original specified time of ten minutes for weighing in and again for weighing out it is impossible to achieve a train turnaround time of 12 hours. In Table 1 and Table 2 as well as in Figure 9 and Figure10, Appendix A p335, it is also visible that for a weighing time of any value more than 5 minutes, a queue of unrealistic lengths and waiting times will form in front of the weighbridge.

Other input data was also used. The number of weighbridges was increased from the original one, to two. This allowed two trucks to be weighed simultaneously. The simulations with the added weighbridge were run with both the random and constant inputs. As can be seen in Table 3 and Table 4 on page 28, when the weighbridges increased from one to two, the train turnaround time decreased dramatically and is again within the required limit. The average waiting time of a train at the station is also within an acceptable range and the average time a truck is expected to wait at the weighbridge on its way in is also acceptable.

Weigh Time	Total Train Time	Queue Length	Train Wait time
10	11.3259	2.9297	0.04598596

Table 3 Results - Two Weighbridges Fixed Data

Standard Deviation	Weigh Time	Total Train Time	Queue Length	Train Wait time
1	10	11.4094	3.2333	0.03503948

Table 4 Results - Two Weighbridges Random Data

Recommendation and conclusion

To conclude, the proposed layout and working of the Manganese Railway Siding Facility was simulated using different sets of data; data without variation and with variations. From the results obtained it was clear that both sets of inputs delivered almost identical outputs.

A bottleneck was identified at the weighbridge where trucks are weighed in and out. The purposed weigh time for a truck was 10 minutes. But to achieve the main objective of a train turnaround time of less than 12 hours, either the weighing time needs to be reduced to 5 minutes or less, or another weighbridge must be added. By doing this a train turnaround time of less than 12 hours can be expected.

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Rockwell Software Arena's Help Files.

ITE Consulting   www.ite.co.za

Arena Simulation www.arenasimulation.com

Extendsim www.extendsim.com

Simul8.com www.simul8.com

Appendix A

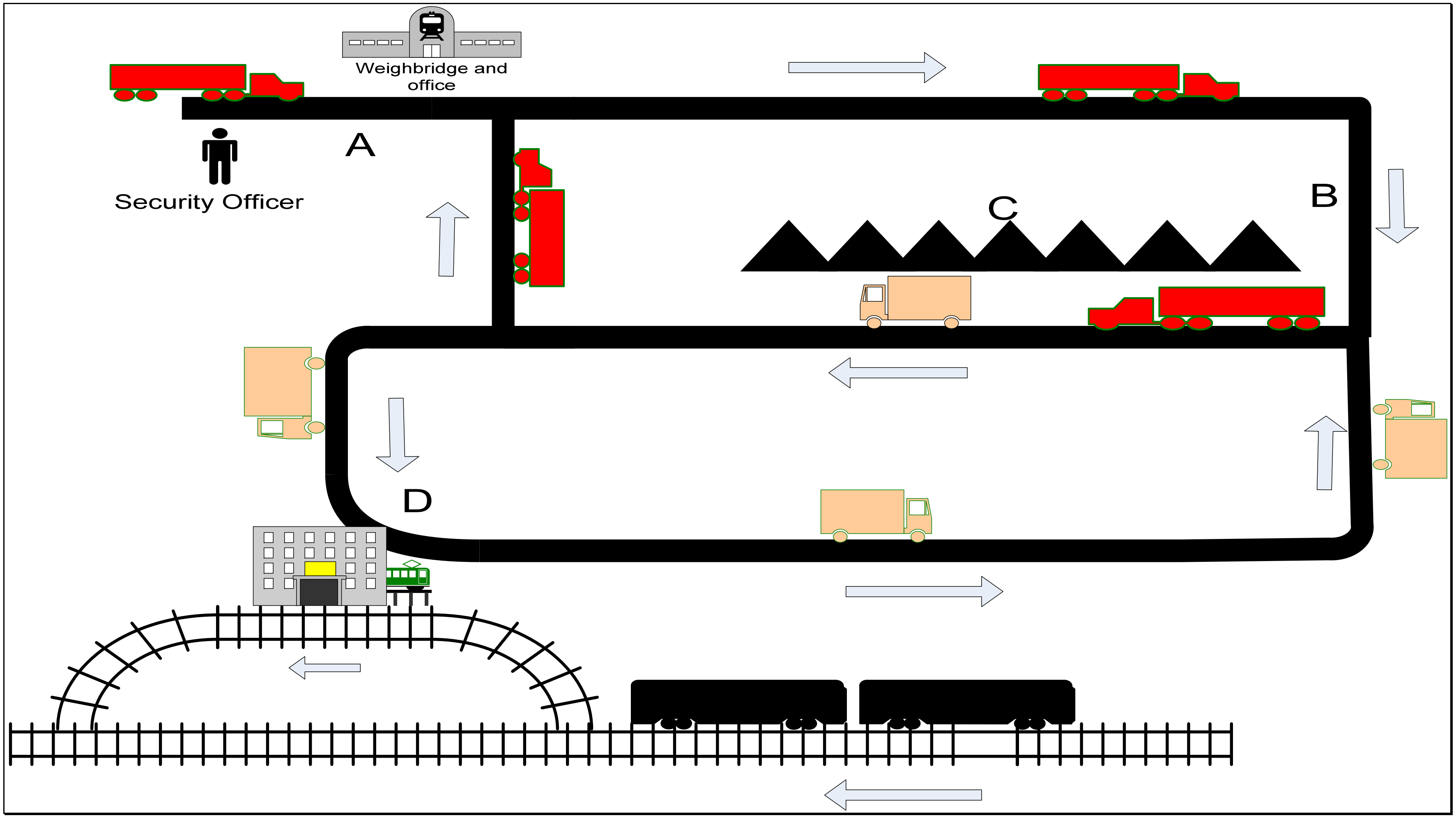


Figure 2 Proposed Layout

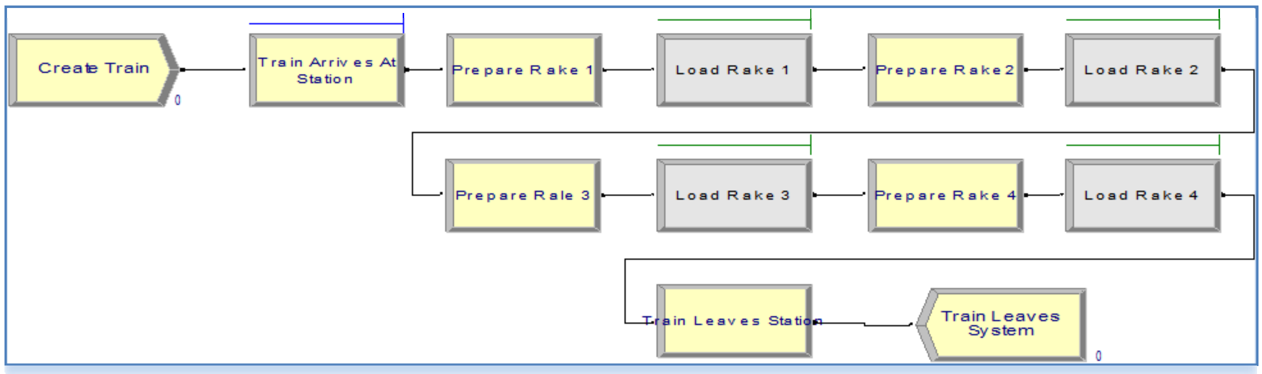


Figure 3 Train Logic

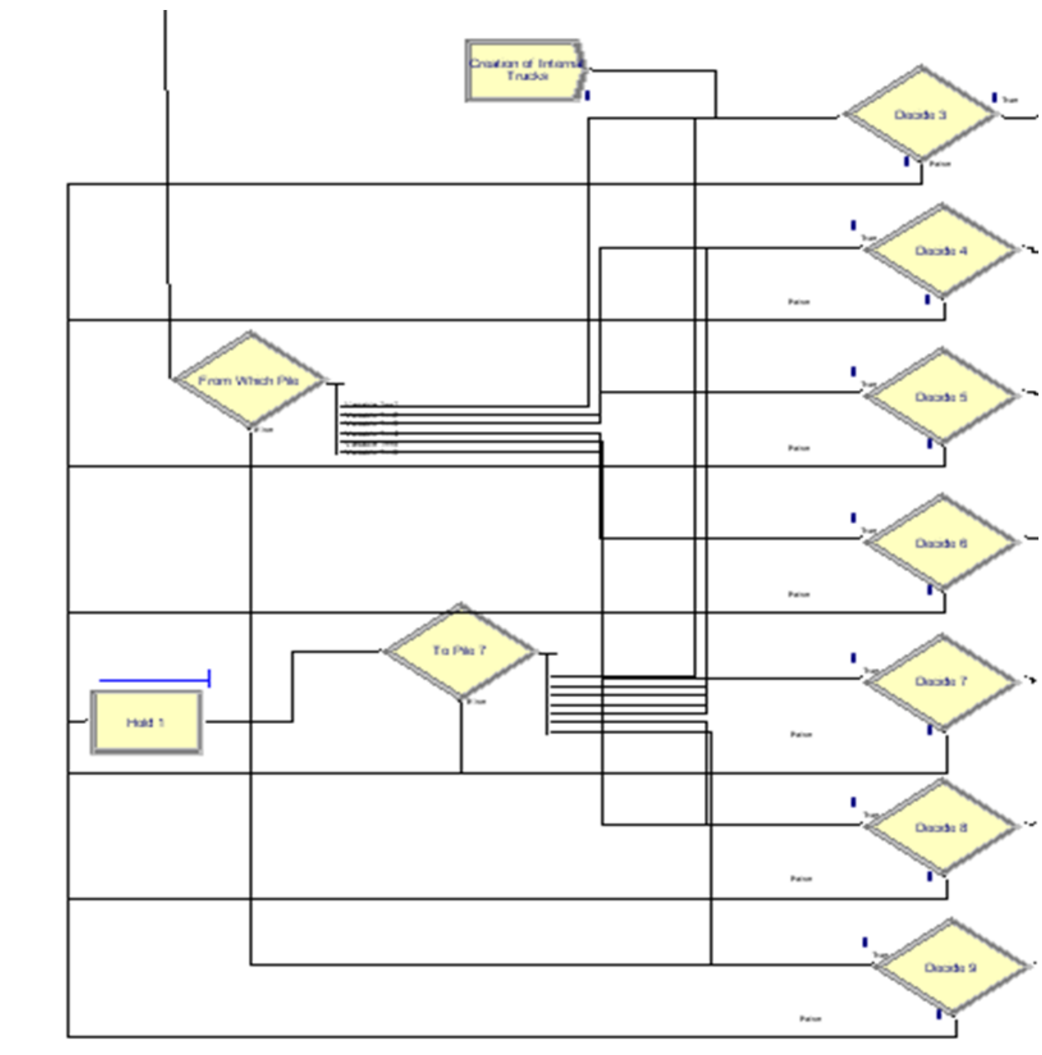


Figure 4 Decide Logic

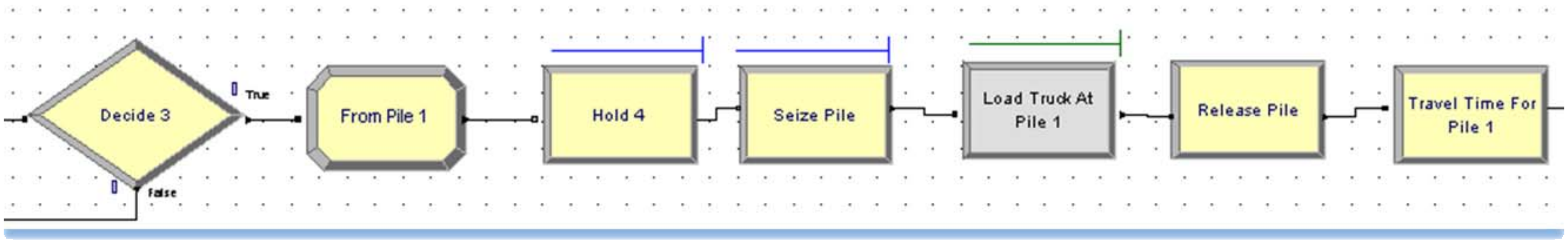


Figure 5 Stockpile - Internal Trucks

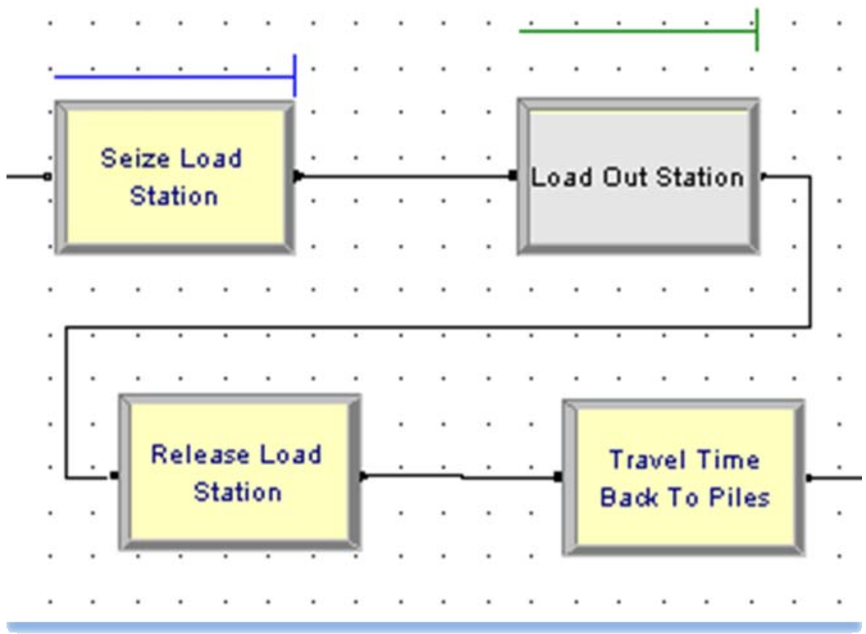


Figure 6 Load-out Station

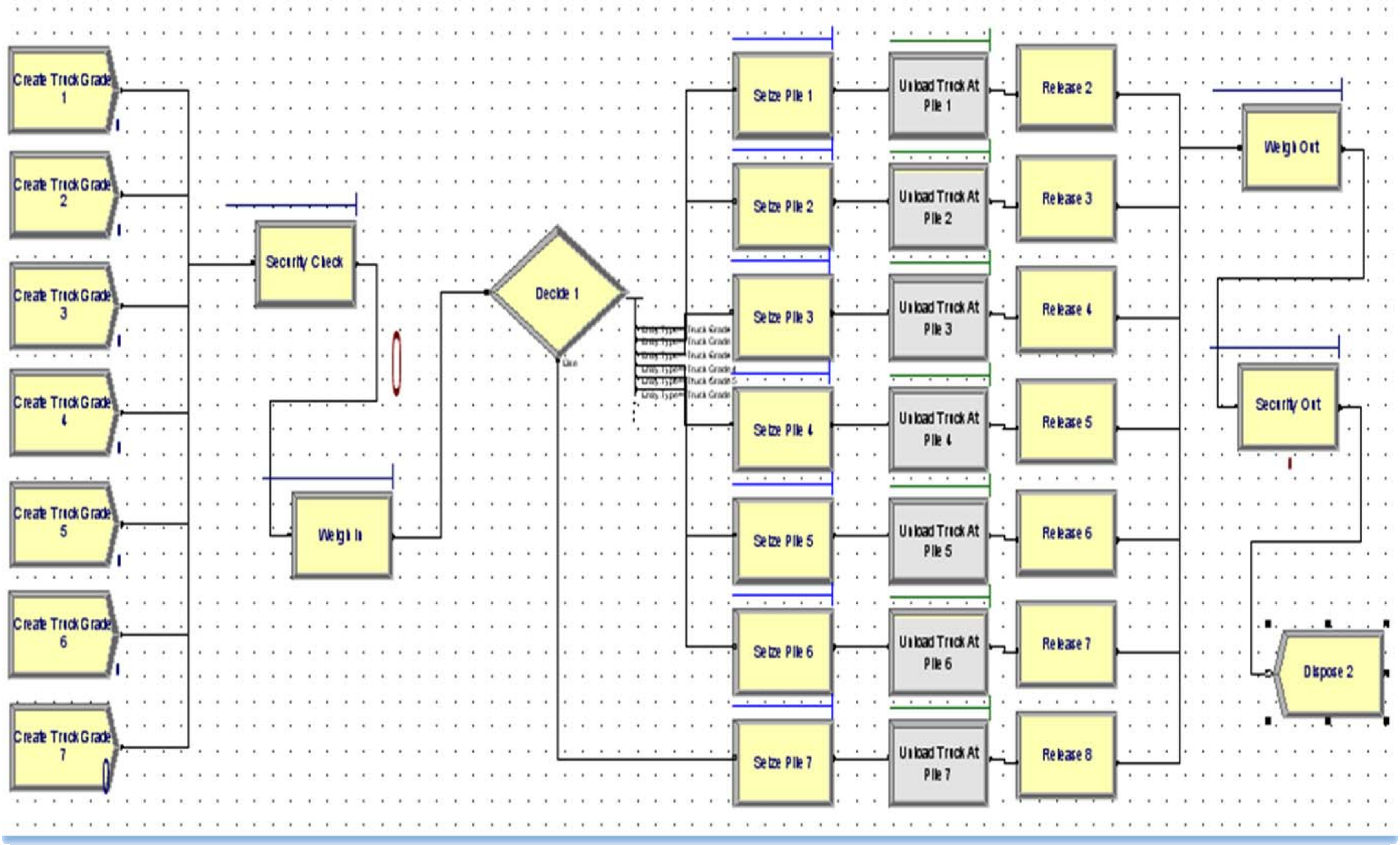


Figure 7 External Truck Logic

Random VS Fixed Data
800
700
600
500
400
300
200
100
0
Total Train Time
5
6
7
8
9
10
Time Needed to Weigh Truck
Fixed Data
Random Data

Figure 8 Random vs. Fixed Data

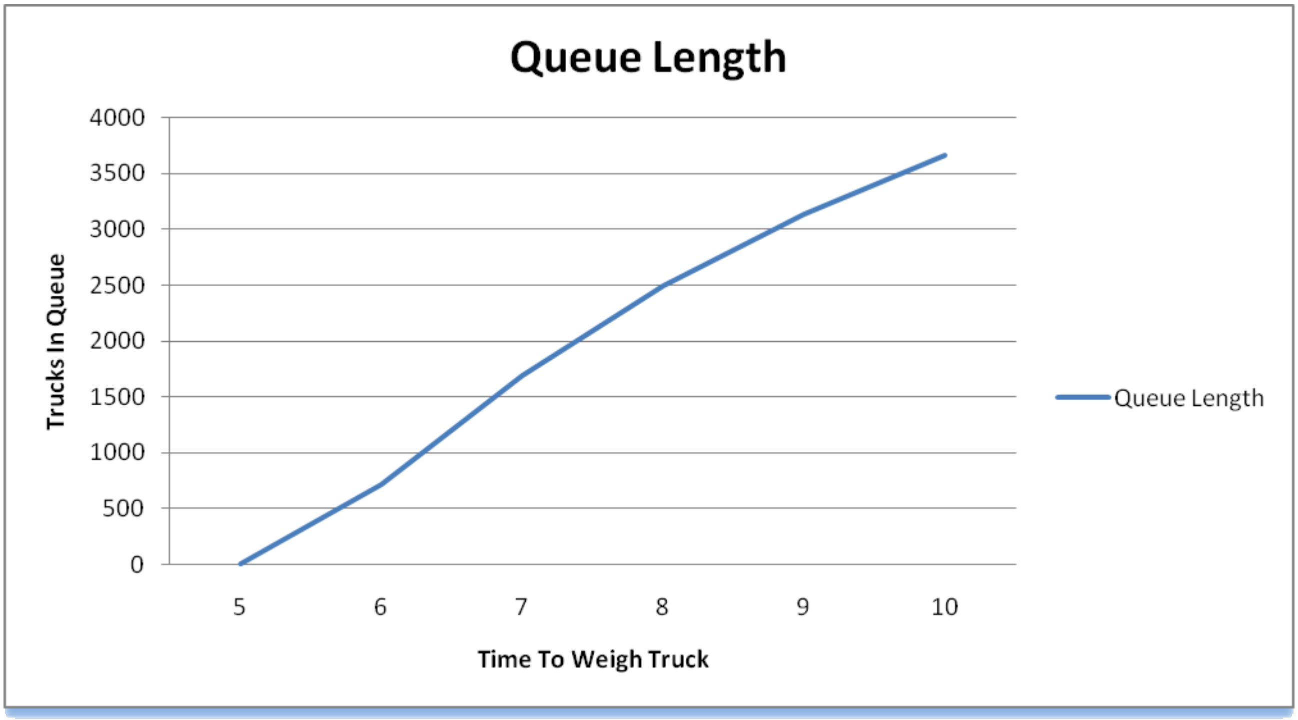


Figure 9 Effects on Queue Length

Figure 10 Effects on Wait Time

Appendix B

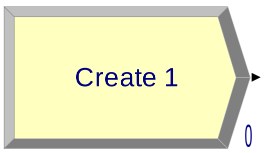
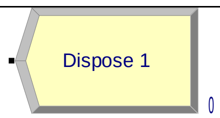
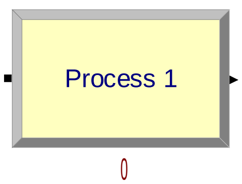
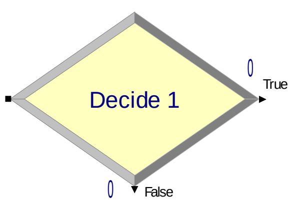
Module	Description
	This module is intended as the starting point for entities in a simulation model. Entities are created using a schedule or based on a time between arrivals. Entities then leave the module to begin processing through the system. The entity type is specified in this module.
	This module is intended as the ending point for entities in a simulation model. Entity statistics may be recorded before the entity is disposed.
	This module is intended as the main processing method in the simulation. Options for seizing and releasing resource constraints are available. Additionally, there is the option to use a "sub model" and specify hierarchical user-defined logic. The process time is allocated to the entity and may be considered to be value added, non-value added, transfer, wait or other. The associated cost will be added to the appropriate category.
	This module allows for decision-making processes in the system. It includes options to make decisions based on one or more conditions (e.g., if entity type is Gold Card) or based on one or more probabilities (e.g., 75% true; 25% false). Conditions can be based on attribute values (e.g., Priority), variable values (e.g., Number Denied), the entity type, or an expression (e.g., NQ (ProcessA.Queue)).

Table 5 Arena Modules

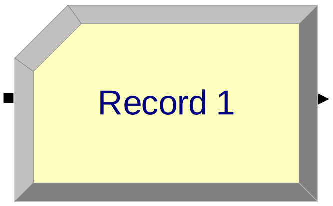
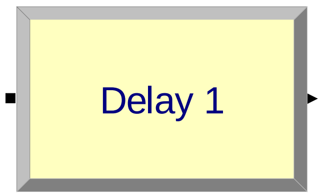
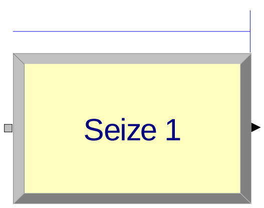
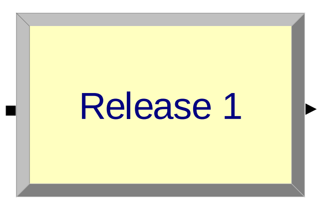
	This module is used to collect statistics in the simulation model. Various types of observational statistics are available, including time between exits through the module, entity statistics (time, costing, etc.), general observations, and interval statistics (from some time stamp to the current simulation time). A count type of statistic is available as well. Tally and Counter sets can also be specified.
	The Delay module delays an entity by a specified amount of time. When an entity arrives at a Delay module, the time delay expression is evaluated and the entity remains in the module for the resulting time period. The time is then allocated to the entity's value added, non-value added, transfer, wait or other time. Associated costs are calculated and allocated as well.
	The Seize module allocates units of one or more resources to an entity. The Seize module may be used to seize units of a particular resource, a member of a resource set, or a resource as defined by an alternative method, such as an attribute or expression. When an entity enters this module, it waits in a queue (if specified) until all specified resources are available simultaneously. Allocation type for resource usage is also specified.
	The Release module is used to release units of a resource that an entity previously has seized. This module may be used to release individual resources or may be used to release resources within a set. For each resource to be released, the name and quantity to release are specified. When the entity enters the Release module, it gives up control of the specified resource(s). Any entities waiting in queues for those resources will gain control of the resources immediately.

Table 6 Arena Modules

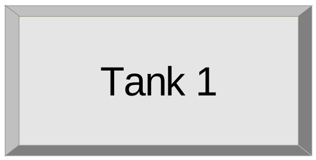
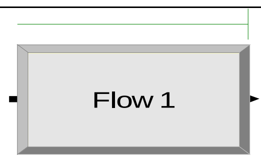
	The Tank module defines a location where material is held or stored. The *Capacity* is the maximum quantity that may be stored in the tank. The *Initial Level* is the quantity in the tank at the beginning of the simulation or when the system is cleared. The *Regulators* repeat group specifies a list of devices that may be used to add or remove material from the tank (e.g., valves or pumps) at a specified rate. Semi-continuous flow operations may then be executed by discrete entities using the regulators via the Flow module.
	The Flow module is used in conjunction with the Tank module to model semi-continuous flow operations such as adding material to a tank, removing material from a tank, or transferring material between two tanks. When an entity enters the Flow module, a flow operation of the specified *Type* is initiated (i.e., Add, Transfer, or Remove). The tanks affected by the flow are determined by the regulators specified as the source and/or destination. A regulator is a device (e.g., a valve) that is used to add or remove material from a tank. A tank's regulators are defined in the Tank module.

Table 7 Arena Modules

*The explanation of each module was obtained directly out of the Rockwell Software's Arena's help files.