Rosslyn Brewery Distribution Optimization

by

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Executive Summary

SABMiller's Rosslyn brewery is used for distribution of beverages to various depots as well as direct deliveries to customers. Thus the time spent at the brewery loading and unloading the trucks for distribution need to be as short as possible, as stationary time is wasted time for which cost is incurred. The performance of the distribution process is measured by the TAT (Turn Around Time) of a truck, the TAT is the time taken by the truck from the moment it enters the brewery's gate until it leaves the exit gate.

To identify the bottlenecks in the process and get a clear understanding of the system a time study was performed. Results obtained from this time study are used to identify the bottlenecks causing the high TAT’s and to develop a simulation model using Arena 13 software. This allowed the effects of proposed changes to the distribution process to be tested before implementation.

The results gathered by executing the simulation models shows opportunity for improvement by implementing a alternative strategy for both main and Line 5 warehouse activities.

Some operational opportunities are also identified for quick-win situations where no costs are incurred to optimize the distribution process. By acting on these operational opportunities an estimated reduction of between 24 to 34 minutes of TAT can be realised.
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Introduction and Background

SABMiller is a South African beverage company that produces 15 different beers and fruit flavoured alcoholic ciders for the local and export market through seven breweries and 42 depots nationwide. Primary distribution (inter-brewery and to depots) is done through the use of contracted road carriers (PD trucks), while secondary distribution (inter-depot and direct deliveries to customers) are made using branded SAB trucks (S&D trucks).

The Rosslyn brewery is used for both primary and secondary distribution. The facility has two warehouses, the main warehouse and the line 5 warehouse. The main warehouse is used for storage and distribution of all products produced at the brewery. The line 5 warehouse is only used for products in 750 ml amber bottles for which the off feed of the production line is in the warehouse.

The performance of the distribution system is measured by the TAT (Turn Around Time) of the trucks in the facility. This is the time taken by the truck from the moment it enters the brewery's gate until it leaves the exit gate. The standard target TAT's are 60 minutes for PD's and 45 minutes for S&D's.

At the entrance gate of the brewery the truck is checked at security to ensure that all the correct products and quantities are delivered. Returnable empty bottles or products from other breweries then need to be offloaded. The next step is for the truck to move to the correct warehouse, which is determined by the specific products that needs to be loaded.

In the warehouses the load orders are printed and loaded by the forklifts. The rate at which the truck is serviced depends on a number of factors. This includes truck capacity. The capacity of a PD truck is 30 pallets while S&D trucks have capacities of 8, 16, 20 and 26 pallets depending on the specific truck. Trucks are loaded using a double-fork forklift, thus having capacity for two pallets simultaneously. Other factors include the number of PD trucks in the warehouse, the number of SD trucks in the warehouse, offloading of empties and full pallets and forklift activity. These are factors that all need to be taken into consideration when the process is analyzed to ensure the problems are addressed. Finally the truck leaves the warehouse and is checked by security, closed up, sealed and leaves the premises. The gate configuration is such that there are three gates adjacent to each other. One gate is strictly for arriving and one for exiting distribution trucks, the third is operated as a swing gate being available for either arriving or exiting trucks as it is needed.

It has been found that the TAT’s of the trucks are excessively high during periods of high demand as this cause a rise in the number of trucks to be serviced. This problem can be
attributed to various operational and planning factors which need to be analysed and addressed.

**Project Aim**

The aim is to develop a simulation model depicting the distribution process of the Rosslyn brewery using Arena 13. In order to address the problem of high TATs, the operations as well as the resource utilization needs to be assessed. This model will then be used to:

1) Measure the effect of changes made to the process, e.g. number of forklifts used etc.
2) Select and specify a strategy for bay allocation in the Main warehouse.

The information obtained from running the simulation model will then be used for cost-benefit analysis that will provide support for any recommendations made to management.

**Project Scope**

The focus of the project will be on reducing the TAT's of the various distribution trucks at Rosslyn brewery. Data regarding the current process will be gathered by means of a focused time and motion study. The time study will allow us to analyse each step in the process in order to identify the bottlenecks and critical resources in the system.

The time study data will present accurate traceable data to be used in developing an "As-is" model of the current process for the simulation model. This model will show the accuracy to which it will be able to re-produce current operational results. Using the simulation model, the effects of the improvement opportunities identified in the time study can be analysed and used in a cost-benefit analysis. The results of the cost-benefit analysis will then be used to support recommendations made to the brewery's management regarding the Rosslyn brewery distribution strategy.

The following aspects will be studied in the project:

- Conducting a Time and Motion study
- Analysis of operational activities affecting TAT’s.
- Developing a simulation model for both As-is and To-be states
- Effect of truck arrival patterns
- Cost-benefit analysis of proposed solutions

The following is not part of the study:

- Detailed truck scheduling
- Load allocation process by site control
Literature Review

Trucks that spend idle time waiting in facilities because of congestion impose additional costs on the company, carriers and the whole supply chain (Kiani, M. et al., 2010).

To reduce truck turn-around times in a queuing system; the bottlenecks needs to be identified in three main patterns, these are 1) the arrival patterns of trucks in entrance, 2) departure patterns of trucks in exit and 3) service patterns. After analysis of these patterns three different solutions were proposed and modelled (Kiani, M. et al., 2010).

Time and motion studies were performed in order to study the performance of inbound activity assessing each intermediate activity associated with the task. The logic for the simulation model was then drawn from the process map, using the simulation model as a tool to analyse the existing inbound operations (Gopakumar, B. et al., 2008).

When Anheuser-Bush (world’s largest brewer) wanted to improve its customer response and reduce warehouse operating cost, they focused on reducing truck turnaround time and at the same time minimizing the number of trucks which would be in the facility at any one time. A key element in their success was the implementation of AGV’s. Using an automated system for transportation from line off-feeds for storage and later to shipping bays for pre-loading provided them with the ability to turn the entire warehouse in less than two days among various other benefits which included reduced loading time on trucks.

The following graph as taken from research by Zhao and Goodchild, (2009) shows the effect of the various truck arrival rates on the truck TAT (Figure 1).

Figure 1: Impact of Truck Arrival Rate
In a recent study by (Gun 2010) Arena software was used for his simulation for maximising throughput using dynamic resource allocation while in event simulation. Arena was used to determine policies for the allocation of resources bases on station workloads in order to maximize the throughput of finished goods. The effect caused by buffer allocation and size is also studied, he shows that the allocation of such buffers are not greatly sensitive to the buffer ratio on the condition that buffer space is available.

While developing a simulation framework for the optimization of truck congestion in marine terminals Kiani et al. (2010) noted that there are three groups of parameters that are essential to create a proper simulation. The elements are:

- Parameters describing the behaviour of each element, these elements includes the capacity and behaviour of the element.
- The job parameters applicable to each of the functions of the servers.
- Stage parameters, these includes supplementary information on elements.

The importance of making correct and informed assumptions when and where needed is also brought to attention. These include for example that figures published by manufacturers of facilities etc. will not change during the simulation.

By considering some of the literature available on simulation models it is clear that it can be used as a very effective tool to reduce turnaround times and increase throughput rates. The importance of using the correct methods of gathering information e.g. time and motion studies is clearly a critical factor in determining the success of the simulation model.

According to Reh (2011) a cost-benefit analysis is used to determine how well or poorly a planned action will turn out. Basically it can be seen as adding the positive factors and subtracting the negative factors. When conducting a cost-benefit analysis it is absolutely critical that all factors be taken into account. These include:

- Floor space occupied
- Installation
- Machine operator
- Maintenance
- Running costs
- Increased revenue
- Quality increase

After conclusion of the simulation a cost-benefit analysis will be an extremely useful tool to determine the feasibility of the selected solution.
Methodology

Process Mapping
In order to gather the data needed to analyse each activity of the distribution process of the Rosslyn brewery, a time and motion study was needed. In order to design the data capture forms to be used in the time study the current process needed to be mapped. The current process is depicted in the following process map:

Figure 2: Process Map

Time and Motion Study
By using the process map it is possible to identify the activities in the process to be observed and to develop a suitable data capture form to be used in the time and motion study.

The objectives of the time study are to:

- Capture the time spent on various activities by the trucks and warehouse staff as they service the vehicles travelling through the warehouse
- Understand and analyse the data captured, identifying the constraints and reasons for inefficiencies
• Generate recommendations for the overall improvement of the Warehouse TAT operation

Time Study Approach
The time study was done by the observation of vehicles according activity and by making notes (regarding flow and facility layout) in order to better the overall process. Three time study operators worked together per shift to collect the data. After each shift, data recorded manually was consolidated electronically onto the master sheet.

Operating hours were aligned to the depot which are shift based i.e. Morning shift (6am to 2pm), Afternoon shift (2pm to 10pm) and Night shift (10pm to 6am).

The observers were placed as follows:

Observer 1 – At the gate
Observer 2 – In main warehouse
Observer 3 – In line 5 warehouse

Capture Points
1. Site arrival – as soon as the truck stops at the site i.e. in the street (note if truck does not stop outside the site but stops in front of the gate, then the site arrival and gate arrival times will be the same): observer 1

   The following was also recorded:
   a. whether truck has empties
   b. truck number
   c. if it is a PD/S&D truck (S&D has SAB branding; PD does not)
   d. where the truck is coming from

2. Gate arrival – as soon as truck parked outside gate: observer 1

3. Security check - as soon as security starts check: observer 1

4. Gate leave - as soon as truck leaves gate area: observer 1

5. Arrival at bay - as soon as truck parked in a bay: observer 2/3

   a. Record whether truck has empties or raw material on arrival
   b. How many PD bays available
   c. How many FML trucks in the warehouse

6. Forklift Begins - as soon as forklifts begin operating on the truck: observer 2/3
a. Record whether mixed, strait or split load (mixed load have multiple different brand pack combinations on one load; split load contain different brands on a pallet)

7. Forklift ends - as soon as forklifts finish operating on the truck: *observer 2/3*

8. Leaves bay - Truck departs bay: *observer 2/3*

9. Gate arrival - as soon truck is parked in front of gate: *observer 1*

10. Security check – when security guard starts with physical security check: *observer 1*

11. Gate leave - as soon as truck leaves site: *observer 1*

Map of Rosslyn Brewery indicating the observation points:

**Figure 3: Rosslyn Brewery Map**
Data Analysis

The sample size of observations during the time and motion study is adequate for the purpose of the project. It gives a clear indication of the operations during each shift as well as the level of activity per shift. The number of observations also provided ample opportunity for the analysis of each activity of the distribution process for possible improvements. The magnitude of the sample size allows for the recording of more accurate activity times as the skewing effect of variances is not as severe as on smaller samples.

Time study Detail

- 4 Morning Shifts – Average of 14 PDs & 11 S&Ds per shift
- 4 Afternoon Shifts – Average of 29 PDs & 11 S&Ds per shift
- 4 Night Shifts – Average of 11 PDs & 5 S&Ds per shift
- Total 202 PD trucks and 142 S&D trucks
- 60% of trucks serviced by Main warehouse
- 40% of trucks serviced by Line 5 warehouse

During the time study a considerable amount of time was spent to get to know and understand the distribution system. Understanding the system also allowed for the observers to be able to identify inefficiencies where present.

Before the data could be used a conservable amount of data cleaning needed to be done. The data cleaning was done by means of filtering through the master data sheet and correcting typing errors and capturing mistakes to ensure the data represents the system accurately. By using the cleaned data it was possible to analyze each activity in depth. This is done by means of analyzing the times recorded for each truck serviced for that activity and also taking into account special and common causes of variance.
The above graph (Figure 4) displays the average time for each individual process, it also compares these process times for PD and S&D trucks. From this comparison clearly indicates the areas that have a negative impact on TAT’s. These areas of concern in order of importance are: 1) travel time to the warehouses (Gate leave to main, Line 5 to main, Gate leave to Line 5 and Main to Line 5), 2) Time at gate 1 (Trucks arriving) and 3) Time at gate 2 (Trucks leaving).

The differences observed between the PD and S&D trucks in the Main warehouse time to gate 2 is due to the S&D parking in the staging area after loading. The reason for the S&D trucks waiting before leaving is that doing direct deliveries to customers they only operate in business hours and the trucks will be loaded early morning for the first deliveries of the day.

**Travel Time**

When considering the travel time from the gate to the main warehouse it is seen that most trucks enter the warehouse in ten minutes or less from gate departure which is deemed as acceptable. The longer travel times is a result of batching (queues) taking place at the entrance to the warehouse. This batching is partly caused by inefficient warehouse operations and partly by inconsistent arrivals of trucks.
At present there is no clear method of bay usage in the main warehouse. The two most common practices are:

1) The usage of only two of the four loading bays available for the loading and unloading of trucks is used effectively. Pallets containing empties from arriving truck is offloaded at the first bay due the bay's proximity to the on-feed of the production line where the empties are needed, only after offloading is done the truck is moved forward to another bay for loading. This creates the batching at the entrance as the truck being offloaded blocks the warehouse entrance for other arriving trucks to enter the warehouse creating a bottleneck, leading to the under utilization of bays.

2) Using of all four loading bays with the forklifts spread across the occupied bays.

Figure 5: Gate to Main Warehouse Distribution

![Travel Time: Gate to Main Warehouse](image)

Travel Time: Gate to Main Warehouse
(avg 0:31:25)

Inefficiencies in main warehouse include:

- Offload of empties in first bay
- Forklift drivers takes breaks at busy times
- Authority of controller
- Trucks don't park in demarcated spaces – wastes bays

Further investigation into travel time to the Line 5 warehouse reveals as with the main warehouse that the major cause is also batching. Space constraints in the Line 5 warehouse means that it only has one bay for loading and offloading, this coupled with inconsistent truck arrival patterns serves as the main reason for the batching.
Inefficiencies in Line 5 warehouse include:
- Too small (only one bay)
- Trucks park too close to front of warehouse, forcing them to reverse to exit

**Time at gate 1**
Time at gate 1 is defined as the time spent by a truck at the gate when arriving at Rosslyn brewery. This includes the opening of tarps (sails covering the side of the truck's loading area), security check on incoming loads and load allocation by the site controller. It is also the point from which the TAT is measured (Figure 7).

**Figure 7: Time at Gate 1 Distribution**
Causes for the high activity times at the entrance gate include:

- Limited security check on incoming trucks
- Long time to process the load sheets for load allocation
- Trucks entering through exit bays constrain exiting trucks
- Batching of arriving trucks due to scheduling

**Time at gate 2**

Time at gate 2 is defined as the time spent by a truck when exiting the Rosslyn brewery. Here the truck is checked by security for correctness of the load and the tarps are closed and sealed. The site controller also verifies the correctness of the load and prepares the dispatch form while the truck is sealed. When the vehicle leaves the gate the TAT ends.

**Figure 8: Time at Gate Out Distribution**

![Time at Gate Out Distribution](image)

Reasons for the high activity times at the exit gate include:

- Gate capacity
- Truck sent back due to incorrect loading (minimal occurrence)
Arrival Rates

Figure 9: Average TAT’s per Arrival Rate

The above chart (Figure 9) shows the effect of arrival rates on the TAT. As a result of the uneven arrival patterns of the trucks batching occurs. The warehouses and the gate is designed with staggered arrival patterns in mind so the sudden rise in activity places strain on the resources and results in high TAT’s.

The use of maximum, minimum and mean times set in a triangular distribution is which used for the construction of the simulation model. Forklift loading times for the main warehouse are measured per trip to load or unload pallets. The following table lists the activities as well as their times:

Table 1: Current Process Times

<table>
<thead>
<tr>
<th>Process</th>
<th>Min Time</th>
<th>Most Likely</th>
<th>Max Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time To Gate 1</td>
<td>0:00:00</td>
<td>0:05:12</td>
<td>0:10:00</td>
</tr>
<tr>
<td>Time At Gate 1</td>
<td>0:06:36</td>
<td>0:12:12</td>
<td>0:27:23</td>
</tr>
<tr>
<td>Travel Time: Gate to Main Warehouse</td>
<td>0:01:30</td>
<td>0:02:00</td>
<td>0:05:16</td>
</tr>
<tr>
<td>Time Before Forklift Start: Main</td>
<td>0:01:04</td>
<td>0:04:48</td>
<td>0:07:50</td>
</tr>
<tr>
<td>Main Forklift Loading Time</td>
<td>0:08:00</td>
<td>0:12:11</td>
<td>0:19:00</td>
</tr>
<tr>
<td>Time Before Bay Leave: Main</td>
<td>0:00:45</td>
<td>0:01:47</td>
<td>0:10:31</td>
</tr>
<tr>
<td>Time Before Forklift Start: Line 5</td>
<td>0:01:00</td>
<td>0:02:27</td>
<td>0:05:15</td>
</tr>
<tr>
<td>Forklift Loading Time: Line 5</td>
<td>0:04:21</td>
<td>0:09:49</td>
<td>0:36:03</td>
</tr>
<tr>
<td>Time Before Bay Leave: Line 5</td>
<td>0:00:20</td>
<td>0:01:36</td>
<td>0:04:12</td>
</tr>
<tr>
<td>Time To Gate from Line 5 Warehouse</td>
<td>0:05:15</td>
<td>0:07:30</td>
<td>0:10:20</td>
</tr>
<tr>
<td>Time at Exit Gate Security Check</td>
<td>0:01:00</td>
<td>0:01:12</td>
<td>0:12:15</td>
</tr>
<tr>
<td>Time at Site Control</td>
<td>0:06:03</td>
<td>0:09:49</td>
<td>0:24:06</td>
</tr>
</tbody>
</table>
Simulation Model

Conceptual Design
When considering the distribution system at the Rosslyn brewery, it is evident that there is room for improvements to be made regarding the TAT's of trucks. To address the batching of trucks at the warehouses, the operations inside the warehouses needs optimization. Using Arena to construct a simulation of these processes will provide an excellent base from which to measure the effects of changes.

At the Main warehouse the issues of bay and forklift utilization is of concern. In order to resolve these issues the effectiveness of the current in-warehouse process of using the first bay for offloading must be compared to using all bays for offloading and loading. It is important to compare all possible combinations to find the optimal ratio of bays and forklifts for cost effective TAT reductions.

To address the constraints of the Line 5 warehouse of space, the effect of expanding the warehouse to add an additional loading bay. The various possible changes must also be examined in the simulation model.

The basic elements of a simulation model are the inputs, the model itself and the outputs. In figure 9 the details of the inputs and outputs are listed and discussed thereafter.

Figure 10: Basic Flow of Simulation Model
Inputs

- **Load Requirements**
  Requirements of load vary mainly between the trucks arriving with returnable empties and those without them. This is a very important aspect to be considered as it affects the bay availability in the warehouses. As this also affects the activity times of the forklifts as this requires extra activity. Data gathered during the time study is used to accurately simulate the frequency of these occurrences.

- **Resource availability**
  The availability of resources for the loading of the trucks includes the forklifts and the operators as well as the loading bays. The forklifts have to be simulated on a schedule basis, taking into account the breaks taken by the operators and forklift breakdowns. It is also important to simulate the forklift allocation to the occupied loading bay in such a way that the forklifts can be spread between the occupied bays as bay occupancy changes.

To model the loading bays as a resource it is important to take into account the purpose for which the bay is used. It can be only for loading or both offloading and loading of the trucks. At the main warehouse the throughput of trucks must be compared for the various bay usage strategies considered by the brewery (Figure 11).

**Figure 11: As-is Bay usage**

- **Arrival patterns**
  The effect on the overall TAT of the trucks caused by the different arrival patterns must also be examined. From the breweries staff’s view this is one of the major reasons of the fluctuating TAT as it causes periods of low activity where resources is idle as well as periods of very high activity which places immense strain on the resources. This theory is also confirmed if the data from the time study is analysed (figure 9).
**Outputs**

- **Resource utilization**
  After the simulation has been run it is possible to view the utilization of each forklift and loading bay. This allows the utilization of each resource to be measured for each of the different strategies proposed for the application of the resources. The data obtained from these outputs of the simulation model gives an indication on whether the current resources are sufficient and also serves as a basis from which the cost-benefit analysis will be done.

- **Turn Around Time**
  The effects of the various proposed strategies on the TAT’s can be seen from the outputs generated by the simulation model. These strategies are those of resource applications as well as the arrival patterns of trucks.

**AS-is Model**

The correct design and construction of the as-is model for the simulation is fundamental to the overall success of the project. It is important to have an understanding of all the functions that takes place in the distribution process. As each function has specific variables that effects it and thus the whole system. When completed, the as-is model is used to verify the accuracy of the simulation model compared to the actual data gathered from the time study. Once the accuracy of the model has been confirmed it can be used to test and analyse the proposed strategies.

A detail description of the logic of each part of the model follows

**Gate-in Process**

This process starts with a “create” module (Site Arrival) to introduce entities(trucks) into the system. For the as-is model the entities are introduced based on an arrival schedule similar to the arrivals observed in the time study. A “record” module (Record Trucks in) is used to count the number of entities that is introduced into the system for report generation purposes. As an entity enters the gate a “Seize” module is used to seize a resource, either the entrance gate or the swing gate if idle (preference is given to the entrance gate), if the gate’s capacity is reached any other arriving entities will be queued. Once an entity seizes the gate an “assign” module (Start Time) is used to assign a start time to that entity for the purpose of recording the entity’s TAT. A basic process module (Time at Gate) set to the action “Delay Release” delays the entity and resource for a period of time as suggested from the time study data to simulate the security check and load allocation functions. After which both is released, the resources are now available to be seized by a new entity and entity continues into the system. Lastly a “decision” module (Warehouse Allocation) allocates the entity to either the main-or line 5 warehouse. This is done on a 60% to 40% ratio (Figure 12).
Main Warehouse Process

For the simulation of the Main warehouse process, the process is considered from the moment the truck leaves the entrance gate starting with the travel time. To simulate the travel time a delay module (Time to Main Warehouse Queue) is used. This delays the entity to simulate the travel time to the warehouse. When the truck enters the warehouse a decision module (MTs_M?) is used to determine whether the truck has empty pallets to offload. This decision is made on a 95% true basis. From here the truck is sent either to the off-load bay or the loading bay.

When arriving at the off-load bay in the warehouse a basic process module (Wait for FKL Start_M_offload) is used, the module is set to “Seize Delay”. This seizes the offloading bay and delays the entity for the time taken while waiting for forklifts to start offloading. To simulate the offloading process a basic process module (Offload MTs_M) is used set to “seize delay” to which the entity moves next. This simulates the offloading process by allocating two forklifts and delaying them as well as the offload bay and entity for the required time. After the offloading process is completed a release module (Release Offload Bay_M) is used to release the off-load bay as the entity now moves to the loading area, the forklifts still allocated to the entity.

Entities not moving through the offload process (no empties to offload) has to first wait for a forklift to be allocated by use of a delay module (Wait for FKL start_M_onload) this delays the entity for the time to insert safety stops under the truck wheels and handing over of the load sheet before the forklifts start. Next a seize module (Seize FKL_M) allocates two forklifts to the truck.

In the loading area a basic process module (Load Truck_Main) set to “seize delay” allocates one of the two available loading bays to the entity and delays the entity, the allocated forklifts and loading bay for the time required to complete loading. After the loading process has been completed a release module (Release FKL_M) is used to release the forklifts allocated to the now loaded truck making them available for allocation to an arriving truck. The final module, a basic process module (Wait to Leave Line Main) set to “Delay Release” which delays the entity and the loading bay for the time required to remove the safety stops from the truck and then leave the loading bay making it available.

For the purpose of the simulation three bays are used, namely the off-load bay and the two loading bays when in reality the process uses only two. By not releasing either of the forklifts allocated to a truck in the off-load area when moving to the loading area prohibits an arriving entity from entering the off-load bay if two entities are currently in the warehouse as the required resources (2 forklifts) are not available. As the forklifts are released after loading is
completed the off-load bay becomes available even though in reality a bay has not yet become available. This allows for the present method of operation in the warehouse where forklifts begins with the off-load process of an arriving truck while another truck is preparing to leave a bay to be simulated. The forklift schedule is set up in such a way that four of the five available forklifts are available at any given time (Figure 13).

Figure 13: As-is Main Warehouse Process

**Line 5 warehouse Process**

As with the simulation model of the Main warehouse, the model for Line 5 warehouse process is considered from when the truck leaves the entrance gate, thus starting with the travel time. To simulate the travel time a “delay” module is used, this delays the entity to simulate the travel time to the warehouse. For the truck arriving at the loading bay in the warehouse a basic process module (Wait for FKL Start_L5) is used, the module is set to “Seize Delay”. This seizes the loading bay and delays the entity for the time to insert safety stops under the truck wheels and handing over of the load sheet before the forklifts start. As the only loading bay is now seized any other arriving entities will be queued. To determine whether the truck has empties to offload a decision module (MT’s_L5?) is inserted, the decision is made on a 95% true basis (trucks containing empties).

After the decision has been made the entity moves to either one of the basic process modules “Offload MT’s_L5” or “Load Truck_L5”. These modules seize and delay the two forklifts needed for the process (Forklift line 5) and also delay the loading bay seized earlier. The resources are delayed for the giving process time depending on the task. When loading is completed the entity moves to a release module (Release FKL_L5) which releases the forklifts seized for loading. The last module is a basic process module (Wait to Leave Line 5) set to “Delay Release” which delays the entity and the loading bay for the time required to remove the safety stops from the truck and then leave the loading bay. The module releases the loading bay to allow for the next entity (Figure 14).
Figure 14: As-is Line 5 warehouse Process

Gate-out process
Travel time from the warehouses is considered as part of the gate-out process. The travel time is simulated similarly to the travel time to the warehouses by using delay modules to delay the entities, “Time to Exit Gate_M” and “Time to Exit Gate_L5” for the main and line 5 warehouses respectively.

When a truck arrives at the exit-gate a basic process module “Physical Security Check” set to the action “Seize Delay” is used. This process seizes either the exit gate or the swing gate depending on availability (preference given to the exit gate) as well as a security guard. The process also delays the entity, exit gate and security guard for the period. A release module “Release Security” releases the security guard after he performs the security check. Upon receiving the security note from the security guard the site controller is seized by using a seize module “Seize Site Control” for the preparation of the delivery note. The basic process block “Ready for leave” set to action of “Delay Release” delays the site controller and the exit gate for the duration of the time needed to prepare the delivery note. After the note is completed the process releases the site controller and the exit gate as the truck leaves.

A record module “Record Trucks Out” is used to count the number of trucks leaving the brewery. The record module “Record cycle time” records the TAT of each entity as it exits the brewery. Lastly the dispose module “Site Leave” removes the entity from the simulation after it has cycled through the process(Figure 15).

Figure 15: As-is Gate-out Process

To-be Model
To construct the To-Be model the As-Is model is used as a basis from which changes are made in order to be able to simulate the proposed changes. In the To-Be model changes are made in the areas of the main warehouse and the line 5 warehouse. The main changes made
to the main warehouse is to test the theory of using all available bays for loading and unloading purposes versus the current practice as well as to find the optimal bay to forklift ratio. Changes made to the Line 5 warehouse is done in order to simulate the effect on the TAT of adding an additional loading bay.

In addition to the changes made to the various warehouse setups, the effect of changing the arrival schedules is also simulated. The rest of the process (Gate-in and Gate-out) remains exactly the same as in the As-Is model.

**Main Warehouse**

Similarly to the As-Is model two “delay” modules are used to simulate the travel time to the main warehouse from the entrance gate and the time spent waiting for a forklift. Upon arrival the entity (truck) is allocated to a bay using a “decision” module (Main Bay_All). This allocation is performed by using a variable (Bays Used). As the four available bays are depicted separately, each with an “assign” module (0 bay occupied, 1 bay occupied etc.) before the bay to indicate the bay usage. These “assign” modules updates the variable “Bays Used”, when all bays are available the variable is set to the value 0, this allows the entity to be allocated to the first bay. When allocated the entity moves through the “Bays Used” assign module which then updates the variable to 1 (Bays Used + 1). This process is continued as more entities arrive, allocating entities to empty bays as shown in the table below:

**Table 2: To-Be Bay Allocation**

<table>
<thead>
<tr>
<th>Variable Value (Bays Used)</th>
<th>Bay Allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

After the truck has completed its time in its allocated bay, it passes through another assign module (Bay_1 Avail, Bay_2 Avail, etc.) which reduces the variable “Bays Used” (Bays Used - 1) this indicates that a bay has become available for allocation. To prevent the possible occurrence of a fifth entity being allocated when all bays are occupied a “hold” module (Queue_Main) is placed before the assign module, this will hold any arriving entities in the case that all bays are occupied (Bays Used >= 3). The “signal” block (Queue_Signal) sends a signal to the hold (Queue_Main) block allowing the release of an entity when a bay becomes available (Bays Used < 4).

When the entity has been allocated to a bay a “decide” module (MT_bay1, MT_bay2, etc.) makes the decision on whether a truck contains empties or not, the decision is made on a 95% true basis. The entity then moves to the appropriate process block, either “Bay1_off_on” or “Bay1_on” depending on the allocated bay (Bay 1, Bay 2 etc.). The process block delays the entity and seize the allocated set of forklifts and loading bay for a given time by making use of an expression that selects which set of loading times to use depending on the amount of
bays in use (Figure 16). The table below displays the loading times for the main warehouse To-Be model:

Table 3: Main Warehouse Loading Times Based on Load and Bay Occupation

<table>
<thead>
<tr>
<th>Bays occupied</th>
<th>Containing Empties</th>
<th>No Empties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
<td>Average</td>
</tr>
<tr>
<td>1</td>
<td>0:11:00</td>
<td>0:17:48</td>
</tr>
<tr>
<td>2</td>
<td>0:16:00</td>
<td>0:19:17</td>
</tr>
<tr>
<td>3</td>
<td>0:17:00</td>
<td>0:22:56</td>
</tr>
<tr>
<td>4</td>
<td>0:23:00</td>
<td>0:28:37</td>
</tr>
</tbody>
</table>

Figure 16: To-Be Main Warehouse Process

Line 5 Warehouse
For the construction of the To-Be Line 5 warehouse an extra forklift is added to service an additional bay reserved for offloading the first truck in the queue if the loading bay is occupied. Similarly to the As-Is process a delay module (Time To Line 5 Warehouse) is used to simulate travel time from the entrance gate to the warehouse as well as the decision module (MTs_L5) to determine whether a truck has empties to offload bases on a 95% true basis. For trucks containing empties another decision module (Offload_bay) is used to determine whether to move to the off-load bay or directly to the main bay. This determined by means of the variable “Line 5 Load” which communicates the status of the main bay (Line 5 Load = 0 when available & =1 when occupied ) to the decision module. The variable “Line 5 Load” is controlled by means of the assign modules “Bay Enter” (Line 5 Load + 1) and “Bay Exit” (Line 5 Load - 1).
In the case that the main bay is occupied the truck moves to the off-load bay, first through a delay module (Wait for FKL Start_L5_off) to simulate waiting time for the off-load forklift to start. A basic process module (Offload MTs_L5_1) set to “Seize Delay Release” seizes and the off-load bay and forklift for the duration of the process after which both are released.

Otherwise, in the case when no empties needs offloading or the main bay is available the truck moves directly to the to the main bay. The assign module (Bay Enter) indicates that the bay is now occupied. A basic process module (Wait for FKL Start_L5_on) set to “Seize Delay” seizes the main bay and delays the truck and bay for the given time. The process module (Load Truck_L5_1) set to “Seize Delay” seizes the two main bay forklifts, delays them for the loading time after which they are released.

A process module (Wait To Leave Line 5) set to “Delay Release” delays the truck to allow for waiting time after loading has been completed and the releases both the truck as well as the main loading bay. Finally the assign module (Bay Exit) indicates that the main bay is now available(Figure 17).

**Figure 17: To-Be Line 5 Warehouse Process**

**Optimization Methodology**

After the completion of the To-Be model, it was repeatedly executed in order to determine the optimal forklift to bay ratio for the main warehouse. The simulation was run over the period of 24 hours per execution as this representative of a round the clock full working day at Rosslyn brewery. Different arrival patterns were also tested with the purpose to emphasise the importance of staggered arrivals pertaining to scheduling.

The inputs that were changed in the various executions were the following:

- Arrival patterns
- Allocation of bays in the main warehouse
- Number of forklifts in the main warehouse
- Amount of bays in the Line 5 warehouse

The simulation was executed using a number of different values for each of the above mentioned inputs. Using these inputs it was possible to determine exactly how the system reacts to the proposed changes.

Arena compiles a report after each execution of the simulation. This report contains data for each specific execution. These reports include user specified data such as average cycle time, minimum cycle time, maximum cycle time, number of trucks entering and exiting the system etc. The data from each simulation run is recorded and then used in for comparisons between
the various simulations runs. By using the comparisons between the different models a conclusion can be made in order to select an optimization strategy to be used for a cost-benefit analysis.

The cost-benefit analysis is done using the optimization models selected by executing the simulations. In this analysis the time saved (benefit) is converted into monetary value using the calculated cost of each minute for a truck in the facility. The benefit is compared to the costs that needs to be incurred to acquiring the given benefit e.g. cost of acquiring a forklift, running cost of a forklift, forklift operator costs etc.

**Results and Recommendations**

From the results obtained from the initial time study various opportunities for improvement were identified. The following recommendations were made for further investigation:

**Gate:**

- Improved scheduling of arriving trucks*
- Controller for the swing-gate
- Implementation of a light control system
- Closing of exit gates when not in use
- Expanding the gate – extra entrance*
- Load send to warehouse on truck arrival for pre-loading
- Standardise Site Controller duties (Work breakdown and process mapping)
- Upgrading of Site Control equipment (High speed printers and computers)

**Main Warehouse:**

- Empties offloading point at the end of the warehouse (Figure 18)
- Utilize all bays (better control)*
- Load communication from gate before truck arrival
- Move paperwork to warehouse (unload simultaneously)
- Dedicated bay for S&D’s
- Raw material deliveries during warehouse dead time
Figure 18: Suggested Bay Operations

Main warehouse

- Unloading station outside
- Add additional bay (might require civils)*
- Combine with Main warehouse (capital intensive)

* Recommendations for further analyses by means of the Arena simulation model.

Simulation Results
The results obtained by execution of the simulation model using various inputs and models was tabulated for analysis. The analysis is done using the average times.

Table 4: Simulation Results

<table>
<thead>
<tr>
<th>Model</th>
<th>Turn Around Time</th>
<th>Single Entrance</th>
<th>Two Entrances</th>
</tr>
</thead>
<tbody>
<tr>
<td>As-Is</td>
<td>Avg. 78.02 (current)</td>
<td>75.62</td>
<td>83.5</td>
</tr>
<tr>
<td></td>
<td>Min. 55.78</td>
<td>44.41</td>
<td>48.46</td>
</tr>
<tr>
<td></td>
<td>Max. 118.90</td>
<td>108.62</td>
<td>134.25</td>
</tr>
<tr>
<td>To-Be (Main Warehouse)</td>
<td>Avg. 68.41</td>
<td>72.27</td>
<td>215.20</td>
</tr>
<tr>
<td></td>
<td>Min. 46.42</td>
<td>48.13</td>
<td>64.57</td>
</tr>
<tr>
<td></td>
<td>Max. 109.89</td>
<td>110.52</td>
<td>434.53</td>
</tr>
<tr>
<td>To-Be (Main and Line 5 Warehouses)</td>
<td>Avg. 67.51</td>
<td>63.69</td>
<td>135.65</td>
</tr>
<tr>
<td></td>
<td>Min. 41.07</td>
<td>47.49</td>
<td>54.54</td>
</tr>
<tr>
<td></td>
<td>Max. 97.22</td>
<td>94.50</td>
<td>233.48</td>
</tr>
</tbody>
</table>
After the results was analysed, the following recommendations was made:

- The introduction of an additional entrance gate allows trucks to enter the facility to quickly causing bottlenecks at the warehouse entrances inside the brewery causing a significant rise in TAT.
- Arrival schedules is of extreme importance, having staggered arrivals eases the pressure on the various resources allowing better flow through the facility.
- Staggered arrivals makes for a more uniform spread of idle time meaning better resource utilisation.
- By utilizing all available bays in the main warehouse a considerable reduction in TAT is seen (Irregular arrivals - 9.61 reduction).
- The introduction of an additional bay and at the Line 5 warehouse for offloading purposes can be highly effective, especially when combined with a staggered arrival schedule. This strategy shows a 14.33 minute reduction in TAT.

**Cost-Benefit**

Market related prices are used to conduct the cost -benefit analysis. The analysis is done for the period of one year.

Prices are as follows (Personal contact) :

- New Twin-fork propane forklift - R 130 000
- Forklift operator salary - R 7 000 per month
- Operating and maintenance cost - R 5 500 per month
- Cost incurred by SAB for TAT - R 2.97 per minute per truck

The only cost incurred by SAD Rosslyn brewery will be that of an extra forklift for use at the off-load by at the Line 5 warehouse.

The cost will be as follows:

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Forklift</strong></td>
<td>130 000</td>
<td>x 1</td>
<td>130 000</td>
</tr>
<tr>
<td><strong>Operator</strong></td>
<td>7 000</td>
<td>x 12</td>
<td>84 000</td>
</tr>
<tr>
<td><strong>Running and Maintenance</strong></td>
<td>5 500</td>
<td>x 12</td>
<td>66 000</td>
</tr>
<tr>
<td><strong>Total Cost</strong></td>
<td></td>
<td></td>
<td>280 000</td>
</tr>
</tbody>
</table>

The brewery services 120 trucks per 24 hour period on a six working day per week basis.

The Benefit will be:

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>per day</strong></td>
<td>120</td>
<td>x 6</td>
<td>720</td>
</tr>
<tr>
<td><strong>per year</strong></td>
<td>x 52</td>
<td></td>
<td>37 440</td>
</tr>
<tr>
<td><strong>Time saving</strong></td>
<td>x 14.33</td>
<td></td>
<td>536 515.20</td>
</tr>
<tr>
<td><strong>at R 2.97</strong></td>
<td></td>
<td></td>
<td>1 593 450.14</td>
</tr>
</tbody>
</table>

Thus the implementation of the proposed distribution strategy will result in an annual saving of R 1 313 450.14 (1 593 450.14 - 280 000).
High Impact Changes

Following a discussion with Rosslyn brewery management the following high impact action plan was developed showing estimated TAT reductions. These estimates are based on operational changes as mentioned on pages 29 - 30, at minimal cost to company. The ideal times for each activity shown in the table below (Table 5) is the par-times as determined from the results of the time study in conjunction with experienced employees at the Rosslyn brewery. This is achieved by focusing on each separate activity and determining the probable reduction in activity time as an effect of the implementation of the proposed recommendations.

Table 5: High Impact TAT analysis (Time in Minutes)

<table>
<thead>
<tr>
<th>Location</th>
<th>Activity</th>
<th>Current Time</th>
<th>% of TAT</th>
<th>Ideal Time</th>
<th>Waste</th>
<th>Priority</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main</td>
<td>Site Control</td>
<td>Time to Gate</td>
<td>5</td>
<td>6%</td>
<td>2</td>
<td>3</td>
<td>Scheduling of arriving trucks</td>
</tr>
<tr>
<td>Warehouse</td>
<td>Time at Gate</td>
<td>12</td>
<td>15%</td>
<td>7</td>
<td>5</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Driving</td>
<td>Gate leave to Main</td>
<td>31</td>
<td>38%</td>
<td>10</td>
<td>21</td>
<td>1</td>
<td>Reduce DS time at staging area</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Warehouse operations</td>
</tr>
<tr>
<td>Main</td>
<td>Warehouse</td>
<td>Waiting at Bay</td>
<td>4</td>
<td>5%</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Loading Time</td>
<td>16</td>
<td>20%</td>
<td>16</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Waiting time</td>
<td>2</td>
<td>2%</td>
<td>2</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Driving</td>
<td>Main w/h time to Gate out</td>
<td>1</td>
<td>1%</td>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site Control</td>
<td>Time at Gate</td>
<td>11</td>
<td>13%</td>
<td>7</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>* Estimated TAT reduction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>82</td>
<td></td>
<td>48</td>
<td>34</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Activity</th>
<th>Current Time</th>
<th>% of TAT</th>
<th>Ideal Time</th>
<th>Waste</th>
<th>Priority</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Control</td>
<td>Time to Gate</td>
<td>5</td>
<td>7%</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>Scheduling of arriving trucks</td>
</tr>
<tr>
<td></td>
<td>Time at Gate</td>
<td>12</td>
<td>17%</td>
<td>7</td>
<td>5</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Driving</td>
<td>Gate leave to line 5</td>
<td>22</td>
<td>30%</td>
<td>10</td>
<td>12</td>
<td>2</td>
<td>Warehouse operations</td>
</tr>
<tr>
<td>Line 5</td>
<td>Warehouse</td>
<td>Waiting at Bay</td>
<td>2</td>
<td>3%</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Loading Time</td>
<td>10</td>
<td>14%</td>
<td>10</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Waiting time</td>
<td>1.5</td>
<td>2%</td>
<td>1.5</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Driving</td>
<td>Line 5 time to gate out</td>
<td>9</td>
<td>12%</td>
<td>9</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site Control</td>
<td>Time at Gate</td>
<td>11</td>
<td>15%</td>
<td>7</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>72.5</td>
<td></td>
<td>48.5</td>
<td>24</td>
<td></td>
<td>* Estimated TAT reduction</td>
</tr>
</tbody>
</table>
Conclusion

After a time study was held to analyse and collect data each process of the Rosslyn brewery distribution system. Three different simulation models was built, first an As-Is model which was used to test the accuracy of the simulation as well as the data used. Two To-Be models were also built, the first to simulate the effect of different theories of operations for loading bays and forklift usage in the main warehouse. The second to be model took this a step further in also adding an additional bay in the Line 5 warehouse for the offloading of queuing trucks. The three models were continually executed while the inputs were changed to find the most suited model for TAT reduction.

The model that produced the best results was chosen as the new To-Be model to be used for the cost-benefit analysis to be presented to management. The selected model (Main and Line 5) suggests that all available loading bays in the main warehouse should be used as required, this will greatly reduce the amount of queuing at the warehouse entrance. Further this model suggests the addition of an extra bay and forklift at the Line 5 Warehouse to be used for offloading, this will allow for increased flow through the warehouse and better TATs resulting in an estimated annual saving of R 1 313 450.14.

In conjunction to the implementation of the new distribution strategy as seen in the To-Be model a more accurate arrival schedule must be created. The effect of staggered arrivals of trucks at the brewery is that even flow is created through the facility, eliminating batching and reducing TAT.

It is of great importance that the operational issues as discussed in the recommendations be given the right attention. These issues has been brought to the attention of Rosslyn brewery's General Manager and was met with great enthusiasm. By addressing the operational issues an opportunity is created to further reduce TATs at minimal cost to the company.
References


Appendix A

Figure 19: Warehouse Capture Sheet

<table>
<thead>
<tr>
<th>WAREHOUSE</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Observer Name</td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td></td>
</tr>
<tr>
<td>Shift</td>
<td></td>
</tr>
<tr>
<td>Truck No (Reg. &amp; ID number)</td>
<td>MT's on arrival</td>
</tr>
<tr>
<td>e.g., RP116</td>
<td>Y/N</td>
</tr>
</tbody>
</table>

Figure 20: Gate Capture Sheet

<table>
<thead>
<tr>
<th>GATE</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Observer Name</td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td></td>
</tr>
<tr>
<td>Shift</td>
<td></td>
</tr>
<tr>
<td>Truck No</td>
<td>PO/FMI</td>
</tr>
<tr>
<td>e.g., RP116</td>
<td>Y/N</td>
</tr>
</tbody>
</table>
Appendix B
Figure 21: As-Is Arena Simulation Model
Figure 22: To-Be Main and Line 5 Warehouse Optimization Arena Simulation Model
Appendix C

As-Is Irregular Arrivals Arena Report

<table>
<thead>
<tr>
<th>Time</th>
<th>Average</th>
<th>Half Width</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry</td>
<td>5.57</td>
<td>0.45</td>
<td>4.30</td>
<td>7.50</td>
</tr>
<tr>
<td>Exit</td>
<td>5.57</td>
<td>0.45</td>
<td>4.30</td>
<td>7.50</td>
</tr>
</tbody>
</table>

**Other**

<table>
<thead>
<tr>
<th>Time</th>
<th>Average</th>
<th>Half Width</th>
<th>Minimum</th>
<th>Maximum</th>
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</tr>
<tr>
<td>Exit</td>
<td>5.57</td>
<td>0.45</td>
<td>4.30</td>
<td>7.50</td>
</tr>
</tbody>
</table>

**Usage**

| Day Line 1 | 0.50 | 0.00 | 0.50 | 0.50 |
| Day Line 2 | 0.50 | 0.00 | 0.50 | 0.50 |

**Number Busy**

| Day Line 1 | 0.50 | 0.00 | 0.50 | 0.50 |
| Day Line 2 | 0.50 | 0.00 | 0.50 | 0.50 |
To-Be Main and Line 5 Optimization Staggered Arrivals Arena Report

### Category Overview

**Rosslyn Brewery Main**

- **Repetitions:** 1
- **Time Units:** Minutes

### Resource

**Usage**

- **Entrance Gate:** 0.5642
- **Exit Gate:** 0.5472
- **Pallet:** 0.5315
- **Load Key Man:** 0.5171
- **Office/Bay:** 0.5058

**Total Resource Totals**

- **Entrance Gate:** 37.0000
- **Exit Gate:** 31.0000
- **Pallet:** 22.0000
- **Load Key Man:** 18.0000
- **Office/Bay:** 15.0000

### Tally

**Cycle Time**

- Average: 15.7155
- Shortest: 13.7990
- Longest: 17.9000

**Counter**

- **Count:**

**Record Trucks In**

- **Count:** 100.0000

**Record Trucks Out**

- **Count:** 80.0000

### Key Performance Indicators

**System**

- **Number Out:** 67

**To-Be Main and Line 5 Optimization Staggered Arrivals Arena Report**