Spar Bakery-Bread Production Section

Equipment Replacement and Simulation Modeling

by

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Executive Summary

Renbro Spar requires information that a simulation model will provide regarding the process to determine where the problem areas and bottlenecks are situated and why the bread department currently has problems in reaching the optimal production levels. The Simulation of the process will highlight the areas where improvement is required and also eliminate the unnecessary use of resources and determine the maximum production level of breads per day that the current system can deliver. It will also help to see what effects the replacement of the equipment will have on the overall flow of the system and to address the problems that may occur. Currently the Renbro Spar is considering the replacement of the mixer equipment with a new mixer unit or a baking plant accordingly to the results of the simulation modeling and physically requires the operation research equipment replacement calculations as this will have a large impact on the costs, the equipment’s prices are very high. Thus concluding the best option regarding the equipment replacement model which will affect the costs and eliminate some of the other processes in the flow and have effects on a lot of other aspects such as:

- The layout of the bakery, considering factors like space, electricity and water points.
- Employees and labor involving the process
- Management involvement
- Training involved in replacing equipment etc.
- Capital and depreciation factors
- Return on Investment
- Payback Time of implementation of the project
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1) **Introduction and Background**

Operations Research can be seen as a tool used by many to solve problems that were seen as unsolvable many years ago. The field provides an evidence base for policy and procedures; it can also be addressed as the in-depth exploration and research that are driven by real problems and real reasons for problems that are set in actual context which therefore provides direct answers to problems. Operational Research findings are seen to provide opportunities to improve services and are more likely to affect the attitudes about the importance to alter control measures in a positive way, rather than just knowledge. It provides many benefits. Economic benefits include cost-effectiveness because Operational Research uses existing resources and will attract additional external resources for a high quality research.

*History of the Company by Lawrence Hunt:*

The Renbro Spar was a family owned business started in 1946 that started in a small shop in Walmer Bridge. Within the following 20 years the family added 2 more shops. In 1969 James Halls invited the Hunt’s to be involved in Euxton Cholrley. By 1980 the Limited Company had expanded to 6 stores and from there the company grew into a franchise-store and became more popular each decade. The Renbro Spar won several awarding prizes over the past years. However, they found that they are struggling to meet the demand of bread in the bakery department during peak times and need a solution for the problem. A mathematical linear method is used to evaluate the costs involved in replacing of current equipment. Evaluation of all aspects will be done, before making any drastic decisions in solving the issue. Exact calculations are needed and a linear programming model should be built and examined carefully for the most accurate results.

2) **Problem Statement**

The Renbro Spar situated just outside of Pretoria is currently producing 4200 breads per day but, according to the manager, the bakery has enough resources to produce up to 7000 breads per day. This leads to the assumption that there are unnecessary delays and bottlenecks in the current production process that results in lower production levels which disables the system to meet the constant demand of the customers. The customer service is influenced and all of this will eventually decrease the profits of the bakery. An in-depth study will be applied to determine whether the bakery should replace the current equipment or solve the problem relating to the production level with other methods. Simulation modeling will be used to identify all problem areas in the flow of the production.
3) **Project Aim**

The main aim of this project is to establish whether it is better to replace the current mixer with a new improved mixer to solve the lack in production levels.

Objectives acting as a basis for the aim:

- Attempt to apply linear programming as a sub-division of operational research in such a way that all the aspects influencing the results will be clearly outlined and addressed to get a clear solution on the problem.
- A proposed Cost analysis will be addressed. Calculation of the Return on Investment
- Create the simulation model in such a fashion that all the glitches in the flow of the production will be identified

4) **Project Scope**

The project will start off with an in-depth literature review on operational research to get a clearly outlined and defined scope. The project will further include the Simulation Modeling of the Bread-Department processes in the Renbro Spar Bakery. Issues that can influence the production rates and the service provided to the customers in relation with this process will be addressed. A mathematical analysis in equipment replacement will be modeled to determine which option will have the highest costs involving the replacement of the equipment.

External factors that do not take place on a frequent basis will be included by determining the probabilities of the basis it will occur on ex. Breakage, downtimes and maintenance of the machines. The goal of this project is to determine where the problems in the RUNNING system occur and the maximum production level that the working system can achieve per day. Conclusions that arise by evaluating the simulation models and the equipment replacement model will assist in planning future changes in the process and the implementation of different methods and equipment regarding the Bread Production department to achieve optimality in the problem areas addressed.
5) **Deliverables & Main Objectives**

- Accurate time studies of the production flow during peak times and non-peak times
- Identification of the current constraints in the flow
- Applying operations research to decide how frequently the equipment should be replaced and the effects it will have on the costs.
- A proposed cost-analysis in determining the Return on investment and the estimated payback time
- Building of Arena simulation Model
- Evaluation of the model to determine the problem areas and bottlenecks
- Increasing the total productivity of the bread department at the Spar Bakery
- The increase in productivity will ensure that the demand will be met at all times
- Customer service will improve
- All the above stated will eventually increase the profit made from the bread-sales per day!
- Concluding of all the results
- Presenting the results
- Approving of all the results by Spar

![Figure 1 – Photo of the bakery](image-url)
6) **Project Plan**

The Project plan will be divided into 3 Main subgroups and will be executed according to the Gantt Chart

- **Activities and Tasks**
  - Perform and in-depth study of the industry
  - Time studies of the different workers and their schedules
  - Collecting all data relating the electricity and water points
  - Determining the estimated payback time and the Return on investment
  - Precise studying of the flow of the system during peak and non-peak times
  - Identifying all bottlenecks and constraints in the system
  - Building of the simulation model
  - Gather all data relating the current and new considered equipment
  - Building of a mathematical linear program to determine the best solution regarding the equipment replacement
  - Examination of the results and conclusion
  - Presentation of the Project
  - Implementing the Plan if approved by management

- **Resources**
  - Transportation
  - Stationary
  - Mr. Brett (Project Leader)
  - Management of the Renbro Spar
  - Employees – Time studies and direct information and problems that they are confronted with
  - Internet regarding the background and literature reviews
  - Company where the new equipment will be bought
7) **Literature Review**

7.1) **Introduction**

The gathering of data before performing and working on a project is extremely important in the industry. It will give a good indication of the market competitiveness and what is dealt with regarding the specific project and set a clear scope in which to work and start from. Important tools will come to light, they can then be compared and the best alternatives can eventually be applied.

The following literature review was made to acquire all relevant information regarding the project. The main reason for this project, as stated in the project scope and aim is to increase the production and profit by evaluating the current system, gathering data and analyzing the data. There are many different methods to achieve this and these methods will be discussed in the following study. The information was gathered through three methods:

1. **Actual observations by the use of the following tools:**
   1. Possible methods to identify the problems in the production line and the possible bottlenecks:
      - Time studies
      - Flow process chart
      - Two handed process chart
      - Line balancing analysis
      - Simulation Modeling
      - Layout planning
ii. Methods regarding the actual mathematical solution of the problems identified by the above mentioned methods:

- Operations research equipment replacement linear programming
- Break Even Point method

2. Literature studies regarding the above mentioned.

3. Interviews and verbal communication

Managers
- Information on all the costs involved in the project.
- The specs of the machines
- The information regarding the shifts of the workers
- Problems that they have recognized
- Recommended solutions and improvements

Employees
- Lunch times
- Problems occurring during production and recommendations
7.2) Actual observation Tools:

- Time Studies
- Fish Diagram (Cause and Effect Diagram)

These diagrams show the causes of a certain event. These categories typically include:
- People
- Methods
- Machines
- Materials
- Measurements
- Environment

Figure 2 – Example of the fish-diagram
• **Flow Process Chart**

Is the analyzing process, certain actions along the way are often important, especially when looking for sources to eliminate waste. The flow process chart is a method of showing the steps in a process with simple half-text, half-pictures, using symbols to indicate the actions being taken and text to give details of the action. The purpose of this chart is to selectively show what happens to selected people, materials or equipment. When to use the flow diagram:

- When observing a physical process to record actions as they physically happen, thus getting an accurate description of the process
- When analyzing the steps in a process, to help identify and eliminate waste.
- When the process is mostly sequential, containing few decisions, then use it rather than a flow diagram.

**Symbols used in the flow process chart:**

- Operation
- Transportation
- Storage
- Delay
- Inspection

![Flow Process Chart](image)

*Figure 3 – Steps followed when solving a problem*
• Two-Handed motion charts

This chart shows the motions and delays made by the hands of the operators, also the relationship between the divisions of accomplishment executed by the hands. It can help to eliminate delays, because the restriction of movement is identified. An example of a cause of restriction can be the operator position, space and the arrangement of equipment.

• Line Balancing

To achieve high productivity one should start with good planning to use in the production line balancing method. By understanding the dynamic nature of this method there will be an increase in the responsiveness to interruptions that occurs daily. Thus, it is important to rebalance in the minimum time to ensure that productivity will not be sacrificed. Line balancing is an alternative method other than using a simulation program (Arena) in the simulation process of the production lines to identify problem areas and all occurring bottle necks, as well as problems with the labor shifts. This method is often encountered and deals situations where several operators are present which work as a unit. (Benjamin Niebel and Andris Freivalds. 2004)

• Simulation modeling

Simulation modeling can be defined as the manipulation of models in a way that it operates on space as well as time to compress it. This will enable one to identify and recognize the interactions that wouldn’t be apparent otherwise because of separation in time and space present in these interactions. A system at a certain instance in time and space that intends to support the understanding regarding the real system can be said to be a model.

The simulation and modeling is a guideline for the developing of the level of understanding the interaction of parts in a system as a whole. Evaluation on whether a model is a good one or not depends on the level it promotes understanding. The level of detail included in the model always has a trade-off. Too little detail included can run the risk of missing important interactions and the model will not have good understanding. Looking at the flip side – including too much detail tend to cause a very complex and can therefore prevent the growth of understanding. Simulation modeling is a powerful problem-solving tool made by the digital computers and is used in many different disciplines. (Balci, O. and Richard, E. N. 1987.)
• **Layout Planning**

Physical arrangement of facilities and equipment in a Plant is called the Plant Layout. Productivity, quality and safety of the products can be improved by the optimization of the layout of a plant. The layout is crucial when considering the replacement of equipment and new equipment may need more space, electricity, water points etc. Decent layout planning will influence the decision on the replacement of the equipment to a large extend and can eliminate the not-obvious problems that can arise in the future. The layout planning procedure discusses significant considerations in the planning of internal layout systems. Poor planning will increase the chance of problems occurring in the system. (Bob Jefferis.1998).

7.2) **Methods regarding the actual mathematical solution of the problems identified by the above mentioned methods:**

*Operations research - equipment replacement linear programming*

Operations Research can be seen as a tool used by many to solve problems that were seen as unsolvable 5 years ago. The field provides an evidence base for policy and procedures; it can also be addressed as the in-depth exploration and research that are driven by real problems and real reasons for problems that are set in actual context which therefore provides direct answers to problems. Students across the world identified additional features which include “a focus on impact”. Operational Research findings are seen to provide opportunities to improve services and are more likely to affect the attitudes about the importance to alter control measures in a positive way, rather than just knowledge. It provides many benefits. Economic benefits include cost-effectiveness because Operational Research uses existing resources and will attract additional resources from outside for high quality research.

Analysts found that if operational research is conducted successfully, it will establish a commitment to ongoing research for evidence-based policy. By having ongoing Operational Research, the ability to address new problems and to have a quick respond to it will be easier. The
direct effect of this will be positive on a large scale, because it will ensure higher productivity and profitability and lower the costs.

In Practice, Operational research focuses on the optimizing of system and organizational performances by using advanced analytical methods to help in making better decisions on a regular, every day basis. Operations research helps to solve business drivers’ problems by identifying the best product placements in retail establishments to ensure appropriate inventory levels.

It is used in different industry segments, from health care to financial services to logistics and provides many benefits if used in practice. The most common techniques that are applied are: linear programming, simulation and various heuristics. In a cross-tabulation survey, researchers found that these 3 techniques were used in almost all application areas. Manufacturing-related problems were the most common application area.

One of the popular operations research methods are equipment replacement:

Christer and Goodbody (1980) introduced the replacement of capital models to consider the decisions-making process regarding an existing asset. Eilon et al. (1966) and Christer (1984) developed the model further by providing an alternative to the continuous improvement in technology modeling. The ideas were to model the current age of the plant’s replacement decision and considering current operate-and-replacing cycle with value K (finite time units). Then considering the following operate-replace cycle looking at the new equipment with length, L. Christer and Scarf (1994) described costs that are complex to measure. An example of these costs is failure and delay related costs that are called penalty costs.

The equipment replacement method will include all the costs involved in the decision of the new and old equipment considered in the model. Costs can include:

- Salvage cost
- Replacement cost
- Opex
- Income revenue

However, other costs can also be included if present.
The formulation of the equipment replacement model starts with the identification of the different stages and states. A graph is then constructed where the x-axis takes on the stages, thus years and the y-axis the age values of the equipment in the current year.

The desired outcome of this method is to calculate the best time to replace the old equipment with the new equipment to have the maximum net income during years i, i+1,.., n given machine t-years old at the start of year t.

7.3) **Summary on the Key elements in the decision making process:**

- Investigate the feasible asset solutions and implementation of the solution;
- Prioritizing projects by using relevant criteria which contributes to the asset replacement approval. Inclusion of all relevant costs and with the help of NPV calculations supporting the decision-making of various options and then examining sensitivities;
- Facilitating of airing the project appraisal with an open structured management.
- Resources together with data to transform the gathered data into a case for a solution to the replacement decision problem;
- Providing a process that allows easy response to changing objectives, this will ensure that advantage can more easily be taken over evolving conditions. A method allowing quick reaction to replacement needs that occur outside the normal approved cycle.
- A good relationship based on trust with the operator for the assets that comes with the maintenance provider.
- An asset replacement strategic plan with long-, medi - and short-term plans.
- Ensure that all key aspects in divisions of decisions are included.
- Value-based approach that’s using summary class
- Linear programming helps to use the best of available resources (example: time, machines, labor etc.)
- Bottle necks may occur in production processes. Linear programming has a significant advantage that is highlighted in bottle necks (Bowe and Lee. 2004).
7.4) The Relationship between cost, quality and profit

Another aspect to look at is the relationship between the quality, cost and productivity that should be in a fine balance before making drastic decisions regarding the replacement of equipment. Quality can be defined as the predictable level of consistency and dependability, at small cost and appropriate to the market. Productivity is the relationship between the amounts of input to product a given amount of output. Profitability is when money is left over from sales after costs are paid. Quality affects productivity and both affects profitability.

![Figure 4: The influence of Quality, productivity and profit on each](image)

By improving the quality, the following benefits will be gained: Promoting quality will unleash the chain reaction of quality. Rework will decrease, productivity rises and quality improves then the cost per good unit is decreased. The price can be cut and it will usually result in the increase of the moral of workers because they are not seen as the problem.
7.5) Evaluation of the Literature review

Evaluation of the information gave a clear perspective and overview of all the methods and tools that can be used in this project. It is obvious that there are many different methods to solve a problem and the method that one choose should give the best outcome and the desired format and structure of information and solutions. There are a lot of different elements to consider and the most important ones should be evaluated first, there after the other aspects can be included and looked at. The literature review highlighted the best methods to use for this project, also taking the client’s desires into account.

Firstly, the discussed tools will be used to identify the problem areas and bottlenecks in the current process as well as the new machine and its related processes at a later stage in the project. The applicable tools will be executed to gather thorough information: Time studies, Flow process chart, Simulation Modeling, Layout planning. Verbal information on all the costs involved will be collected.

Secondly, the information has to be evaluated and set into a mathematical model with the help of The Operations Research equipment modeling method to calculate the costs and profit as it is the most important factors and should be maximized by the model. After the option with the maximum profit is identified then other factors for example the layout related problems as well as equipment capacity problems will require attention. It is also concluded that all the information gathered in the literature study can be transformed in these helpful tools and methods to eventually get the optimal solution in the replacement of equipment.
8) Selection of Industrial Engineering Techniques

8.1) Time Studies
Time studies will be used to evaluate the current process flow times and cycle times.

8.2) Fish diagram
The fish diagram will help with the identification of the problem areas of the existing process which adds to the main problem; low production levels. This will then help with the improvements in the current problem areas.

8.3) Simulation modeling
Modeling the process flow on Arena will highlight the bottleneck areas regarding the data and figures gathered. This will help with method 8.4 – Equipment replacement.

8.4) Equipment replacement
Because the Renbro spar required calculations regarding the best equipment replacement option over 5 years the method will be used to evaluate the current system’s replacement costs and to compare it with the two new options’ equipment replacement costs.

8.5) Cost Analysis
In doing cost analysis, problem areas regarding the costs of the current and new methods will be identified and thus addressed during the evaluation phase.

8.6) Layout planning
Layout planning will be necessary as the above mentioned methods’ outcomes will have a huge impact on the layout changes of the bakery. To accommodate the changes regarding the layout, an in-depth layout planning study of the current layout have to be made.
9) **Data evaluation and development of the ideal methods mentioned on pg 20**

9.1) **Information gathered verbally regarding the costs of different options:**

Table I below – shows all the data gathered regarding the 3 different machines

<table>
<thead>
<tr>
<th>Bread baking plant</th>
<th>Bread baking plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can produce up to 11000 per day @ R3.80 per bread=</td>
<td>R41800 income per day.</td>
</tr>
<tr>
<td>Electricity expense=</td>
<td>2.75 kW/day*R2.28=6.27/day=R2288.55/year</td>
</tr>
<tr>
<td>3 Workers thus Labour =</td>
<td>R 1700*3 =R5100 per month</td>
</tr>
<tr>
<td>Capital New Machine=</td>
<td>R 750 000</td>
</tr>
<tr>
<td>Depreciation =</td>
<td>20% per year = R150 000</td>
</tr>
<tr>
<td>Maintenance =</td>
<td>R5000*2 per year = R10000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>New convertible mixer specs</th>
<th>New convertible mixer specs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Has 2 mixing bowl which will eliminate the delay caused by current mixer</td>
<td></td>
</tr>
<tr>
<td>Electricity expense=</td>
<td>1.4kW/day*R2.28=R3.192/day=R1165/year</td>
</tr>
<tr>
<td>4 workers thus labour=</td>
<td>R 1700*4=R6800 per month</td>
</tr>
<tr>
<td>Capital of new machine=</td>
<td>R 300 000</td>
</tr>
<tr>
<td>Depreciation</td>
<td>20% per year = R60 000</td>
</tr>
<tr>
<td>Maintenance=</td>
<td>R3500 per year</td>
</tr>
</tbody>
</table>
Current Mixer

| Can Produce a max of 5000 breads per day @ average of R3.80 per bread = | R19000 income per day. |
| 4 Workers thus Labor = | R1700*4 = R6800 |
| Electricity expense = | 0.9kW/day*R2.28=R2.05/day=R748.98/year |
| Depreciation = | 20% per year = R30 000 |
| Maintenance = | R3000 per year |

| Table 2 – Data regarding the electricity rates (calculations per year above) |
| Energy Charge [c/kWh] | Environmental levy [c/kWh] | Total |
| Block 1 [≤ 50 kWh] | 52.70 | 60.08 | 2.00 | 2.28 | 54.70 | 62.36 |
| Block 2 [51 - 350 kWh] | 56.48 | 64.39 | 2.00 | 2.28 | 58.48 | 66.67 |
| Block 3 [351 - 600 kWh] | 74.35 | 84.76 | 2.00 | 2.28 | 76.35 | 87.04 |
| Block 4 [> 600 kWh] | 81.74 | 93.18 | 2.00 | 2.28 | 83.74 | 95.46 |

9.2) Important Factors and problems identified in the process gathered verbally:

- The proven time will be decrease if the pans are kept warm. The time can be decreased from 65 min to 35 min.
- Should the bread sell slower and the space on the rack decreases to unpack the bread, the bakers should slow down the process and pick it up again if the demand picks up again.
- Time delays are caused by the trolleys due to their wheels that are not working properly. The broken wheels are also damaging the floor.
- The one proven is running 20 – 30 minutes slower than the other due to one broken element.
- Hand wash basin is leaking.
- Chiller unit is leaking.
- Display of the scale is damage.
9.3) Time Study

Fixed and Variable time factors:

<table>
<thead>
<tr>
<th>Mixing process =</th>
<th>Fixed process. The time is set on the machine for 20 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proven Time =</td>
<td>Fixed process. The time is set on the machine for 60 min</td>
</tr>
<tr>
<td>Baking =</td>
<td>Fixed process. Oven time is set for 37 min</td>
</tr>
</tbody>
</table>
| Variable Time =  | - Ingredients into mixer – Weighing  
|                  | - Cutting and Molding Time till the trolley full |

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Element Number and Description</th>
<th>Throwing the ingredients into mixer</th>
<th>Mixing process</th>
<th>Weighing process</th>
<th>Cutting Process</th>
<th>Moulding into pans</th>
<th>Pans onto trolley</th>
<th>Time till trolley full (208 Breeds)</th>
<th>Proven Time</th>
<th>Baking Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>20</td>
<td>0.92</td>
<td>0.5</td>
<td>0.73</td>
<td>0.7</td>
<td>1.4</td>
<td>60</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2.6</td>
<td>20</td>
<td>0.67</td>
<td>0.4</td>
<td>0.3</td>
<td>0.65</td>
<td>1.3</td>
<td>60</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3.2</td>
<td>20</td>
<td>0.38</td>
<td>0.3</td>
<td>0.83</td>
<td>0.72</td>
<td>1.44</td>
<td>60</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>20</td>
<td>0.43</td>
<td>0.38</td>
<td>0.4</td>
<td>0.7</td>
<td>1.4</td>
<td>60</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>3.3</td>
<td>20</td>
<td>0.5</td>
<td>0.4</td>
<td>0.6</td>
<td>0.68</td>
<td>1.36</td>
<td>60</td>
<td>37</td>
<td></td>
</tr>
</tbody>
</table>
9.4) Fish Diagram

- **Layout**
  - Not enough space
  - Takes up a lot of space

- **Methods**
  - Difficult movement
  - Hot and high temperature
  - Time consuming
  - Vary in times with cycles
  - Depends on external factors

- **Capacity Oven**
  - Limited proven capacity
  - Lunch times not fixed and checked
  - Shifts

- **Equipment**
  - Limited oven space

- **Machines**
  - Time consuming

- **Human**
  - Lunch times not fixed and checked

Figure 5: Application of the Fish diagram
### Table 3: Explanation of the arena steps followed

<table>
<thead>
<tr>
<th>Steps (Blocks in the Arena model)</th>
<th>Explanations of programming and steps</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
<td>This is the first step in the process, where the 100kg raw unprocessed ingredients enter the system. A new batch will enter the system every 20 min.</td>
</tr>
<tr>
<td></td>
<td>This Assign block assigns a variable to the number of 100kg ingredients that enters the system. This will ensure that every second 100kg batch of ingredients entering the system will go to the brown mixer.</td>
</tr>
<tr>
<td><strong>Color Variable</strong></td>
<td>The decision module is used to decide if the batch of ingredients passing through the system should be brown or white bread. The expression builder is used to send every second batch of 100kg dough to the brown bread mixer and the other 50% to the white bread mixer. We use the colour variable in step 2. <strong>Expression:</strong> MOD(colour, 2) == 0</td>
</tr>
<tr>
<td><strong>White of Brown ingredients into the Mixer?</strong></td>
<td>This process block presents the mixing of the white bread dough. The resource and mixer is seized and delayed, but can only be released once all the mixed dough went through the rest of the system steps. The mixer takes 18 min to mix the white dough.</td>
</tr>
<tr>
<td><strong>Mixing white</strong></td>
<td>This process block represents the mixing of the Brown bread dough. It also uses the resource mixer, because there is currently only one mixer in the system. It takes 20 min to mix the brown ingredients.</td>
</tr>
</tbody>
</table>
Number 6 is the assign module; it assigns a variable number to the amount of actual loaves of bread in the system. Each 100kg of mixed dough can make 280 breads.

**Variable:** Amount of breads

**New value:** Amount of breads + 1

Decision module. At stage 7 in the process, one should decide if there is enough loaves to fill a trolley. Again, the expression builder was used together with the variable created at step 6.

**Expression:** Amount of breads == 0, then it means that 280 breads are done.

Step 8: If the answer to the decision module (step 7) was NO, then we move to step 8. To weigh the mixed dough in batches of 12.5kg. Since this is the amount of dough that the cutter can handle and cut at one instance. 12.5 kg of dough creates 8 breads.

**Thus, for the expression at stage 7 to be true, the system will run 35 times through the false and step 8-14 to fill a trolley and then go to steps 15-20. Resource:** Worker 1

Step 9: The process where the 12.5 kg batches of dough is taken from the scale and put into the cutter.

**The resource here is worker B.**

Step 10: The cutting process of the 12.5 kg dough into 8 bread loaves.

**Resource:** Cutter
Step 11: Process module, the 8 bread loaves goes from the cutter to the molding machine. Resource: Worker B.

Step 12: Molding Process. Resource: Molder. Because of the time the molder takes to mould 8 bread loaves, the queue at this stage in the process tent to be longer than the rest of the queues.

Step 13: Packing the molded breads into bread pans and then onto the trolley. Resources: Worker A and C

Expression: Variable: amount of bread

Amount of breads – 8. The system will deduct 8 breads each time because of the restriction on the cutter that can only cur 8 loaves at a time (12.5 kg).

If the answer is Yes at step 7 – decision module. Then we go to step 15. Since the trolley is filled with 280 breads, it means that the mixer is now empty (100kg mixed dough went through the system.) Now we can release the mixer for the next 100kg of dough to be mixed.

We use the assign module once again to calculate the amount of trolleys that are filled with 280 loaves to enter the proven and oven. Variable = trolley

New value of variable = trolley + 1
At stage 17 the system has to decide whether there are enough trolleys to fill up the oven for the baking process. The oven requires 5 trolleys of 280 breads each to be filled up. Since the baking process has a delay of 35 min, the best would be to fill it up each time.

Stage 18: If the answer is YES, then the filled up trolleys will enter the proven stage. A delay model was used since no resources are used during this stage that has to be seized and released. If the answer at stage 17 is NO, then the system will return to step 7.

Stage 19: The baking stage has one resource, the oven.

The dispose of the bread loaves into the spar! The arena model will give a value of 4 as an output, this is 4 full baked ovens per day, which is: 5 trolleys*280 loaves each*4 ovens == 5600 breads per day

9.6) The Arena Results

The Model ran for a 9 hour day. The lunch times of the Workers A, B & C were not included in the model, because they take lunch and Toilet breaks when they wait for the mixer to finish. The cleaning also takes place during these times.

The report of the model stated that there will be 4 entities out of the system. This means that 4 full ovens came out of the system, thus 5600 breads baked per day, of which 2800 are white loaves. (Stated earlier in the explanation of the Arena Model) It also showed that accumulated wait time for
the different stages, we can see that the Mixing stage-17.164, from cutter to molder-0.148, molding-58.2567 and weighing the mixed dough-0.02, has wait times and can cause bottlenecks.

9.7) Conclusion Drawn from the Arena model

The Model report and data clearly stated where the problem areas with queues and bottlenecks occur in the process. The main problem areas: moulding and mixing. Although the system has delays and bottlenecks at these 2 points, the output (5600) is still more than the current output (4200). By evaluating the time studies it was found that the workers also lacked motivation and didn't perform with the speed and efficiency required of them.

Spar will still have difficulty in meeting the demand during the peak times of the month with the current system even performing at its best it can produce 4 ovens (5600 breads). During peak times, the demand rises up to 7000 breads per day. The system can achieve this if another mixer is added to eliminate the long waiting times. However, this can cause other problems downstream in connection with the space, electricity, increase in loan because of more workers and the queue at the molding stage. It is recommended that more intense studies and evaluations of all aspects in the system should be done. A lingo model should be constructed to weigh the costs of the different options up against each other.
9.8) Equipment Replacement calculations on the 2 different options:

9.8.1) Option I: Replacing the weighing, cutting and molding process with the Macadams Straight dough line:

**MACADAMS STRAIGHT DOUGH LINE**

**FEATURES & BENEFITS**

- **Weight Range:**
  - 70 - 1000 g (SD-180 XS)
  - 150 - 1200 g (CE-100 I)
  - 30 - 1800 g (MO-671 Midi)

- **Throughput:**
  - 750 - 1800 pcs/hr (SD-180 XS)
  - Up to 1800 pcs/hr (CE-100 I)
  - Up to 3000 pcs/hr (MO-671 Midi)
# MACADAMS
## STRAIGHT DOUGH LINE
### TECHNICAL SPECIFICATIONS

<table>
<thead>
<tr>
<th></th>
<th>SD-180 XS SUCTION DOUGH DIVIDER</th>
<th>CE-100I CUP ELEVATOR, without base</th>
<th>M0-671 MOULDER “MIDI”</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WEIGHT RANGE</strong></td>
<td>70 - 1000 g</td>
<td>150 - 1200 g</td>
<td>90 - 1800 g</td>
</tr>
<tr>
<td><strong>CAPACITY RANGE</strong></td>
<td>750 - 1200 pieces/hour</td>
<td>up to 1200 pieces/hour</td>
<td>up to 5000 pieces/hour</td>
</tr>
<tr>
<td><strong>POWER SUPPLY</strong></td>
<td>400V: 1.1kW, 2.6A/fuse 1.6A</td>
<td>400V: 0.55kW, 1.5A/fuse 10A</td>
<td>1.1kW</td>
</tr>
<tr>
<td><strong>VARIABLE SPEED</strong></td>
<td>520 - 2200 pieces/hour</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>HOPPER</strong></td>
<td>100 litre</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>WORKING WIDTH</strong></td>
<td>-</td>
<td>-</td>
<td>up to 650 mm</td>
</tr>
<tr>
<td><strong>DIMENSIONS (mm)</strong></td>
<td>670 (w) x 1510 (l) x 1846 (h)</td>
<td>1360 (l) x 2000 (h)</td>
<td>820 (w) x 2120 (l) x 1870 (h)</td>
</tr>
<tr>
<td><strong>WEIGHT</strong></td>
<td>Net: 540 kg</td>
<td>550 kg</td>
<td>610 kg</td>
</tr>
<tr>
<td></td>
<td>Gross: 900 kg</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### SD-180 XS SUCTION DOUGH DIVIDER
- CE-approved hopper guard.
- Stainless steel covers.
- Stainless steel dough knife.
- 5 m connection cable and CEE-plug.
- Frequency converter drive.

### CE-100I CUP ELEVATOR, without base
- Photocell controlled, working step by step to link up cone rounder with moulder type M0-671.
- With electric cabinet mounted on elevator.

### M0-671 MOULDER “MIDI”
- Two pair of rollers.
- Foldable pressure board with two wedges in food approved plastic.

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We reserve the right to both technical and design modifications.

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Durban Branch Telephone: (031) 599-6290 Fax: (031) 599-6290
Email: info@macadam.co.za Website: www.macadam.co.za

JANUARY 2008

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Figure 6: Specs of the Straight line dough cutter machine
Option 1
Replacing the weighing, cutting and moulding process with the bread mixing plant (macadams straight dough line)

Costs included in the model:

\[ R(t) \] Revenue from machine if \( t \) years old

\[ C(t) \] Operating cost of machine \( t \) years old
\[ C(t) = P(t) + M(t) + E(T) \]

\[ I \] Cost of new machine

\[ E(t) \] Cost of electricity use for machine year \( t \)

\[ M(t) \] Average maintenance cost during year \( t \)

\[ P(t) \] Labour costs

\[ S(t) \] Salvage value in year \( t \)

\[ F_i(t) \] Maximum net income years \( i, i+1, \ldots, n \) given machine \( t \) years old at the start of year \( i \)
\[
\text{Revenue} = (\text{Amount of breads/ year})(\text{Price per bread}) = \text{R41800/day} = \text{R15257000/year}
\]

\[
\text{Operating Cost} = E(t) + M(t) + P(t)
\]
The revenue each year was estimated by looking at the specs of the machine and the amount that was produced over 5 years in other companies, because the machine has a maintenance check twice a year, it ensures that the production levels and thus revenues will not drop in the next years as with option 2’s convertible bread mixer.

C(t) increases each year as the inflation increases the average inflation per year is +-3.34% (Taking the average of the previous 5 years)

<table>
<thead>
<tr>
<th>Salvage value calculations in Table above</th>
<th>Revenue value calculations in table above</th>
<th>Operating costs value calculations in table above</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Salvage value of current Age-1)-(20%*Salvage value of current Age-1)</td>
<td>Amount of breads that machine able to produce per day*(price of bread R3.80)*356 days in a year</td>
<td>([P(t)+E(t)]^{((year-x-1)\times inflation)})</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Current Age</th>
<th>0 years (new machine)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plan duration</td>
<td>5 years</td>
</tr>
<tr>
<td>Life of machine</td>
<td>5 years (time until salvage value=0)</td>
</tr>
</tbody>
</table>
### Table 5: Stages and calculations

#### Stage 4

<table>
<thead>
<tr>
<th></th>
<th>Keep</th>
<th>Replace</th>
<th>Optimal Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>t</td>
<td>( r(t) + s(t+1) - c(t) )</td>
<td>( r(0) + s(t) - c(t) - I )</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>13654527</td>
<td>12535789</td>
<td>F4(1)=13654527 K</td>
</tr>
<tr>
<td>2</td>
<td>13938718</td>
<td>12301242</td>
<td>F4(2)=13938718 K</td>
</tr>
<tr>
<td>3</td>
<td>14222910</td>
<td>12066696</td>
<td>F4(3)=14222910 K</td>
</tr>
<tr>
<td>4</td>
<td>14507101</td>
<td>11832149</td>
<td>F4(4)=14507101 K</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>11597602</td>
<td>F4(5)=11597602 R</td>
</tr>
</tbody>
</table>

#### Stage 3

<table>
<thead>
<tr>
<th></th>
<th>Keep</th>
<th>Replace</th>
<th>Optimal Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>t</td>
<td>( r(t) - c(t) + F4(t+1) )</td>
<td>( r(0) + s(t) - c(t) - I + F4(t) )</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>27143245</td>
<td>26190316</td>
<td>F3(1)=27143245 K</td>
</tr>
<tr>
<td>2</td>
<td>27861627</td>
<td>25945769</td>
<td>F3(2)=27861627 K</td>
</tr>
<tr>
<td>3</td>
<td>28580011</td>
<td>25721223</td>
<td>F3(3)=28580011 K</td>
</tr>
<tr>
<td>4</td>
<td>26104703</td>
<td>25486676</td>
<td>F3(4)=26104703 k</td>
</tr>
</tbody>
</table>

---

**Optimal Solution**

F3(1)=27143245 K
F3(2)=27861627 K
F3(3)=28580011 K
F3(4)=26104703 k
### Stage 2

<table>
<thead>
<tr>
<th></th>
<th>Keep</th>
<th>Replace</th>
<th>Optimal Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>t</td>
<td>r(t)-c(t)+F3(t+1)</td>
<td>r(0)+s(t)-c(t)-I+F3(t)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>41066154</td>
<td>39679034</td>
<td>F2(1)=41066154 K</td>
</tr>
<tr>
<td>2</td>
<td>42218729</td>
<td>39444487</td>
<td>F2(2)=42218729 K</td>
</tr>
<tr>
<td>3</td>
<td>40177613</td>
<td>39209941</td>
<td>F(2)=40177613 K</td>
</tr>
</tbody>
</table>

### Stage 1

<table>
<thead>
<tr>
<th></th>
<th>Keep</th>
<th>Replace</th>
<th>Optimal Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>t</td>
<td>r(t)-c(t)+F2(t+1)</td>
<td>r(0)+s(t)-c(t)-I+F2(t)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>55423256</td>
<td>12535789</td>
<td>F1(1)=55423256 K</td>
</tr>
<tr>
<td>2</td>
<td>53816331</td>
<td>53367696</td>
<td>F2(2)=53816331 K</td>
</tr>
</tbody>
</table>

The optimal solution will be K,K,K,K.
### Option 2: Replacing the current mixer with a convertible mixer

<table>
<thead>
<tr>
<th>Age</th>
<th>Salvage</th>
<th>Revenue</th>
<th>Operating costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>300000</td>
<td>8322000</td>
<td>2486665</td>
</tr>
<tr>
<td>1</td>
<td>240000</td>
<td>7628500</td>
<td>2656274.222</td>
</tr>
<tr>
<td>2</td>
<td>180000</td>
<td>7281750</td>
<td>2840400.69</td>
</tr>
<tr>
<td>3</td>
<td>120000</td>
<td>6935000</td>
<td>3037048</td>
</tr>
<tr>
<td>4</td>
<td>60000</td>
<td>6588250</td>
<td>3247067.272</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>6588250</td>
<td>3457086</td>
</tr>
</tbody>
</table>

#### Stage 4

<table>
<thead>
<tr>
<th>t</th>
<th>Keep</th>
<th>Replace</th>
<th>Optimal Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>s</td>
<td>r(t)+s(t+1)-c(t)</td>
<td>r(0)+s(t)-c(t)-1</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>5152226</td>
<td>5605726</td>
<td>F4(1)=5605726 R</td>
</tr>
<tr>
<td>2</td>
<td>4561349</td>
<td>5661600</td>
<td>F4(2)=5661600 R</td>
</tr>
<tr>
<td>3</td>
<td>3957952</td>
<td>5404952</td>
<td>F4(3)=5404952 R</td>
</tr>
<tr>
<td>4</td>
<td>3341183</td>
<td>5134933</td>
<td>F4(4)=5134933 R</td>
</tr>
<tr>
<td>5</td>
<td>(Must replace)</td>
<td>4864932</td>
<td>F4(5)=4864932 R</td>
</tr>
</tbody>
</table>

---

**Equations & calculations**
### Stage 3

<table>
<thead>
<tr>
<th>t</th>
<th>Keep</th>
<th>Replace</th>
<th>Optimal Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(r(t)-c(t)+F4(t+1))</td>
<td>(r(0)+s(t)-c(t)-F4(1))</td>
<td>(F3(1)=11211453) R</td>
</tr>
<tr>
<td>2</td>
<td>10517952</td>
<td>11211453</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>9846301.4</td>
<td>10967326</td>
<td>(F3(2)=10967326) R</td>
</tr>
<tr>
<td>4</td>
<td>9032885</td>
<td>10710678</td>
<td>(F3(3)=10710678) R</td>
</tr>
<tr>
<td>5</td>
<td>8206115</td>
<td>9729864</td>
<td>(F3(4)=9729864) R</td>
</tr>
</tbody>
</table>

### Stage 2

<table>
<thead>
<tr>
<th>t</th>
<th>Keep</th>
<th>Replace</th>
<th>Optimal Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(r(t)-c(t)+F3(t+1))</td>
<td>(r(0)+s(t)-c(t)-F3(1))</td>
<td>(F4(1)=17156396) R</td>
</tr>
<tr>
<td>2</td>
<td>16295426</td>
<td>17156396</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>15045606</td>
<td>16817179</td>
<td>(F4(2)=16817179) R</td>
</tr>
<tr>
<td>4</td>
<td>13627816</td>
<td>16411053</td>
<td>(F4(3)=16411053) R</td>
</tr>
</tbody>
</table>

### Stage 1

<table>
<thead>
<tr>
<th>t</th>
<th>Keep</th>
<th>Replace</th>
<th>Optimal Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(r(t)-c(t)+F4(t+1))</td>
<td>(r(0)+s(t)-c(t)-F4(1))</td>
<td>(F1(1)=22762122) R</td>
</tr>
<tr>
<td>2</td>
<td>21789405</td>
<td>22762122</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>20852403</td>
<td>22517996</td>
<td>(F1(2)=22517996) R</td>
</tr>
</tbody>
</table>

The Optimal solution is R,R,R,R
10) Layout planning
10.1) Current Layout

Figure 7: Current Layout
10.2) New improved layout

Figure 8: Improved layout for option 1
II) Cost Comparison over 5 years

Table 6: Income Statement

<table>
<thead>
<tr>
<th></th>
<th>Option 1</th>
<th>Option 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Income revenue</td>
<td>R 99 323 070</td>
<td>R43343750</td>
</tr>
<tr>
<td>Electricity</td>
<td>(R57213.75)</td>
<td>(R29130.50)</td>
</tr>
<tr>
<td>Labour</td>
<td>(R127500)</td>
<td>(R175000)</td>
</tr>
<tr>
<td>Operating cost</td>
<td>(R 16 188 189)</td>
<td>(R 17 724 541)</td>
</tr>
<tr>
<td>Equipment replacement costs</td>
<td>(R0)</td>
<td>(R1500000)</td>
</tr>
<tr>
<td>Maintenance costs</td>
<td>(R500000)</td>
<td>(R175000)</td>
</tr>
<tr>
<td>Expense total</td>
<td>(R16422922.75)</td>
<td>(R19281867.1)</td>
</tr>
<tr>
<td>Net Income per 5 years</td>
<td><strong>R82900167.25</strong></td>
<td><strong>BEST OPTION!</strong></td>
</tr>
<tr>
<td></td>
<td><strong>R4615711.4</strong></td>
<td></td>
</tr>
</tbody>
</table>

Figure 9: Convertible mixer-option 2
12) Conclude evaluating the simulation modeling, cost analysis and operations research

12.1) Evaluating Option 1

The simulation modeling’s outcome was that there were bottlenecks at the mixer as well as the moulding process. When implementing the straight dough line plant, the mixer’s bottleneck will be eliminated as the operator takes out the whole batch of dough that were mixed and put it into the straight dough cutter plant. By implementing this machine, the molding problem will also be eliminated as the machine replaces the moulding process done by the operator and the slower moulding machine. We can thus see that this option will eliminate the 2 major hold ups in the process. Then, by looking at the equipment replacement calculations, the outcome said that the equipment should be kept over the 5 year period examined. One of the client’s requirements was that they didn’t want to replace equipment frequently as the operators struggle to get use to the updated models of the machines. Then, the cost analysis said that option one’s net income is far higher than option 2. The difficulty with the implementation of the straight dough line cutter is that there would have to be layout changes because of it’s large dimensions.

12.2) Evaluating Option 2

The implementation of the convertible mixer will eliminate the waiting for the mixer, but now the bottleneck at the moulding process will just be longer and thus not solving the delay in the production process. The equipment replacement calculations stated that the machine will have to be replaced every year which is also a negative aspect. The main reason for the often replacing of the equipment is that it’s not the ideal way and few companies use this method. The design of the machine isn’t very well and the probability of breakage is very high. Because of the mixing bowls rotation the whole time and the strain that the operators put on the link of the bowl to the machine it will not have a long life span and production levels decrease with time because the state of the machine. This machine also requires frequent cleaning between all the links which is a time consuming and complex process. The only positive aspect about this machine is that it will not
affect the layout of the bakery and no layout changes will have to be made. The net operating income is also much lower than that of option 1.

12.3) Concluding according to the evaluation of the options

All 3 methods of evaluation stated that option 1 is by far the best and will produce very high profits and lower costs than option 2. Option 1 will be able to meet the customer requirements in every situation, looking at the highest demand and lowest demand. If the demand levels are low, the machine can be set to produce lower amounts of bread and ensuring no loss during the process.

Spar accepted the proposed project and the outcome of all the calculations and implemented the machine. Management discovered that they could help the community by lowering the price of the breads.

Figure 10: Macadams dough cutter plant – the machine considered in option 1
Community Project

Regarding the new machine and implementation of the project:

Spar decided to decrease the price per bread from R5.20 to R2.99 in order to lift the sales and ensure that 8000 breads per day will be sold as well as help the community as the Renbro Spar is situated in a rural area.

The decrease in profits are as follows:

<table>
<thead>
<tr>
<th>On implementation of option 1</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Income revenue</strong></td>
<td>Decrease from R 99 323 070 to R43 056 000</td>
</tr>
<tr>
<td><strong>Electricity</strong></td>
<td>(R57213.75)</td>
</tr>
<tr>
<td><strong>Labour</strong></td>
<td>(R27500)</td>
</tr>
<tr>
<td><strong>Operating cost</strong></td>
<td>(R 16 188 189)</td>
</tr>
<tr>
<td><strong>Equipment replacement costs</strong></td>
<td>(R0)</td>
</tr>
<tr>
<td><strong>Maintenance costs</strong></td>
<td>(R50000)</td>
</tr>
<tr>
<td><strong>Expense total</strong></td>
<td>(R 16422902.75)</td>
</tr>
<tr>
<td><strong>Net Income per 5 years</strong></td>
<td></td>
</tr>
</tbody>
</table>

The loss in Profit will be then seen as a positive distribution to the community in order to help society as well as the environment.
Appendix:

- Current Layout of the Bakery
- Gantt chart
Figure 13: The current layout of the bakery
Figure 14: Gantt chart
Bibliography:


