# Business Optimisation of the Ya Rena Precast Plant

**By**

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# BPJ 420 Project Report
## Business Optimisation of Ya Rena Precast Concrete Plant
## 20/10/2008


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# Executive Summary

This report documents the work that was conducted for the Business Optimisation of the Ya Rena Precast Plant. The project was completed as part of the course in Industrial Engineering at The University of Pretoria.

The precast plant, which is located in Polokwane, is a fairly new business and as a result there are a few minor issues which are currently hampering the organisation from performing at its full potential. The project focuses on four different areas where improvement could be made namely the storing of production information, production planning, material requirement planning & production and onsite ergonomics.

Literature studies were conducted on each section followed by a design phase. To address the issues at hand the following items were developed; a Microsoft Access Database system to aid in data capturing, a production planning algorithm which is executed using LINGO and interfaces with the Access Database, an ARENA Simulation of the block forming production line and recommendation over onsite ergonomics including relevant aids and worker moral improvement suggestions.

The project aims at empowering the onsite manager with the required tools which would enable him/her to make more informed decisions on the day to day running of the plant. A user manual has been attached to the project which clearly explains how each tool is to be used.

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# Chapter 1: Project Information and Proposal

## 1. Introduction and Background

Ya Rena Civils (Pty) Ltd are located in Polokwane and have been running for 10 years. The company employs around 70 – 100 people and deals mainly in civil construction with an emphasis on concrete related works.

About two years ago a decision was taken by the company's management to open a precast concrete plant in Polokwane as there was a large demand for these products in the area yet very little supply.

The plant, named Ya Rena Precast, deals mainly in the supply of precast lintels, road curbing, bricks and various types of hollow form blocks used in the construction of suspended floors. The business supplies these precast concrete products to building suppliers and hardware stores in Polokwane and the nearby surrounding communities. On an average day the plant produces around 1000 meters of lintel and pre-stressed beams, 500 hollow form blocks and 80 meters of curbing.

The precast plant is run by a full time onsite manager who has 30 laborers all with various levels of experience and expertise.

The business deals in high volume and low variety products. Due to the fact that the business is fairly new there are many small problems which are currently hampering the business from being able to perform at its full potential.

## 2. Project Aim

The project takes an in-depth look into the operation of the Ya Rena Precast Plant. Specific areas in the company were analysed and problems identified. Solutions to these problems have been suggested as well as ways to implement them into the company. Optimisation tools for the block forming production line, materials and product control as well as system improvement are a key point of the project. The project gives a broad overview into the improvement and streamlining of various aspects within the company's system and production strategy.

The various systems which have been developed focus on empowering the onsite manager with the ability to make use of the tools without the need of recruiting outside assistance. For this reason all of the programs come complete with a user interface and a user manual has been attached to the project to aid in the understanding of how the programs are to be used.

## 3. Project Scope

The project is restricted to Ya Rena Precast and does not involve any studies into the parent company Ya Rena Civils although there may be overlaps between the two companies in terms of the management and overheads of the companies.

The studies are based on information gathered from the various board members, directors and managers of Ya Rena Precast as well as from time studies and past records of the plant. Marketing, imaging and the securing of clients are not included in the project.

The implementation of the various ideas and solutions will be decided by the management of Ya Rena Precast yet recommendations are given in the context of the project.

# Chapter 2: Literature Study

## 4. Deliverable Reasoning and Literature Review

The deliverable reasoning and literature review has been divided up among the four deliverables with each one being discussed and reported on separately.

### 4.1. Development of Microsoft Access Database for Use by the Onsite Manager

At the present stage there is no set method for storing various pieces of data and information that are accumulated from the operations of the plant. This poses a serious problem in that the manager's decision making abilities are based on a 'gut feel' more than on statistics. It was decided that a database program needed to be developed as a middle management data capturing tool.

This interface will provided the manager with the opportunity to record various key pieces of information on a daily basis and keep records of events. The information, based on production, sales or staff performance, can be used to monitor the plants operation. The system will also be used to keep a running check on product stock levels and purchases which could be useful in detecting theft or unnecessary waste of material.

Monthly reports can be generated from the program which could then be presented to the board members. These reports give a clear insight into various aspects of the plants operation which allows for control and understanding of the month's performance results.

Research was conducted into various databases which could have been used for the development of the program yet it was found that due to the specific nature, detail and type of information which this database would be required to store and the reports which management requires from the program, it was best to begin a database from the ground up.

Building a new database allowed for more accuracy to be placed into the essential areas of the program allowing for less troubleshooting and error fixing due to the developer knowing exactly how the database was created.

To aid in the development of the database reference was be made to:

- Systems Analysis & Design for the Global Enterprise 7th Edition by Bentley and Whitten.
- The relevant work carried out in the course Information Design 320.

## 4.2. Production Planning

The plant produces many different products each with their own advantages and disadvantages. Some items make a good profit yet take a long time or are difficult to produce. Certain products i.e. curbing, are ordered in mass and there may not be enough stock on hand to supply certain customers. Research was done into the availability and production time for products to produce quantities on such a time scale that the available stocks should never be depleted.

Identification of two journals which were used to aid in giving a better understanding of which products should be produced when, were sourced. All of the journals which were studied made reference to the fact that production scheduling and forecasting are techniques which have not yet been fully explored or standardized for the precast industry and these decisions are based mainly on experience and knowledge.

In conclusion to the journal “A Survey of Current Production Planning Practices in the Precast Industry” Dawood and Neale (1990) identified that there was a need for the development of a computerized system which could assist middle management in forecasting and production planning.

The production planning was done by making reference to the planning algorithm constructed and documented in Nashwan N Dawood's journal, "Developing a Production Management Modeling Approach for Precast Concrete Building Products" (1992).

### 4.3. Material Requirements Planning (MRP) & Optimisation of Production Lines

The quantities of products produced are dependant on the efficiency and productivity of the workers. A study was done using linear programming and ARENA Simulation to depict and provide an optimisation tool for the hollow form block production line in an effort to streamline the production and increase profits.

Raw materials are stored in stock piles on the plant but due to there being limited available storage space and the cost of double handling, these raw materials are only ordered once critical levels of the materials are reached. Occasionally the raw materials are completely depleted resulting in production ceasing. The materials requirements plan seeks to develop a system whereby a minimal level of raw material and stock will be kept on hand yet it will ensure that production should never stop due to a shortage of materials.

These two topics, MRP and optimisation of the production line, have been grouped together due to the fact that they were investigated by constructing a simulation model of the plant which was analysed to determine an optimal situation.

Research was conducted and there were a vast number of journals available on this topic. The journals range in their complexities and depth to which they deal with the simulation yet most of them share insight into how the development of a simulation should be done. The analysis and evaluation of alternatives from the journal "Simulation of Large Precast Operations" by Edmundo Babontin-Bravo (1990) was used as a guideline in the collection and processing of data which was used in the simulation model. The main basis around which the simulation will be focused has been drawn from the journal "Simulation Based Planning for Precast Production with Two Critical Resources" by Tiong et al (2007). As an introduction and a general overview of this journal the author explains and states:

> "A specialized planning model based on simulation technique and genetic algorithm (GA) is presented in this paper for precast production with two critical resources. A novel priority rule, the critical precast component (CP) rule, is established for mold considerations during simulation, and a bi-directional simulation is adopted to reduce excessive overtime and precast stock. On this basis, three simulation approaches are designed using different simulation heuristics and directions. To test the validity of the proposed model with different approaches, a planning experiment is carried out. By comparison, it is clear that the Simulation-GA based model using CP rule and bi-directional simulation can generate a satisfying resource plan and production schedule".

The two journals were used in conjunction with Rockwell Simulation ARENA 10.0 as well as making reference to the syllabus given in Simulation Modeling

### 4.4. Evaluation and Recommendations over Onsite Ergonomic Features

Due to the fact that the workers are working in extreme conditions consisting of being exposed to the elements for long hours, working with heavy products and machinery and being in a dangerous environment the ergonomic elements are very harsh and this often results in minor injuries and fatigue among the workers. A study was conducted over the possible advances that could be made in the working environment that could benefit the staff and make the working environment easier.

Production follows a monotonous and mundane procedure and this leads to boredom amongst the workers. Ways to correct this were looked into which should give the workers a feeling that a good day's work was had at the end of their shift.

The journals which were located did not deal specifically to the precast concrete industry but gave more of a general overview to ergonomics in the production industry as well as in dealing with boredom and monotony in production which ultimately can lead to accidents.

To combat boredom and monotony in the workplace as well as to reduce the injuries caused, two journals were consulted.

The first journal which was consulted was by Paul Branton and is named "A Field Study of Repetitive Manual Work in Relation to Accidents at the Work Place". It will be noted from this journal that repetitive work does lead to accidents which are both costly and delay production.

The second journal, "Work satisfaction and social reward quota" by Donald F. Roy looked into ways in which the average day of the worker could be made more rewarding was by introducing a monetary incentive scheme based on production figures. Studies into alternative ways of alleviating boredom were looked into and these included rotation of work and placing more production responsibility into the job of the worker.

Due to the heavy weight of the products being produced and that these products are moved by hand, journals have been sourced which give reference to various aids and techniques whereby the stresses experienced can be reduced. The two journals which were consulted are "Hand-Intensive Jobs" by Stephen Bao and "Ergonomic Aids for Industrial Workers" by Julie Copeland. The aids which the journal by Julie Copeland has documented will serve a great purpose for the workers yet further aids were needed to be sourced as the one's mentioned are not sufficient.

## 5. Data Collection

A system was developed to calculate theoretical values for the various products that are produced. These values range from theoretical production cost to theoretical production times.

The main phases of each stage of production were noted and these were split up into activities which make up each phase. A time study was done on each activity being completed at 100% efficiency. These times were all noted and combined with hourly monetary rates for labour as well as raw material costs giving an indication of what each products activity cost per metre

is. These activities were summed for each phase and each phase summed for each product giving a theoretical total of what a metre/unit of each product should cost the company.
These values were used in various aspects of the deliverables which included:

- Production times in the development of the simulation model
- Various figures which were required in the planning algorithm
- Reference to the bulk weight which labourers have to handle on a daily basis.

The tables containing the time studies are located in the appendices section of this project.

The sales information depicted in the appendices was gathered from the on-hand records at Ya Rena Civils. As can be seen the data is very limited and no real information or conclusions can be drawn from the day to day production runs of the plant. The helps to prove that the need for a middle management computerized data capturing system is well founded.

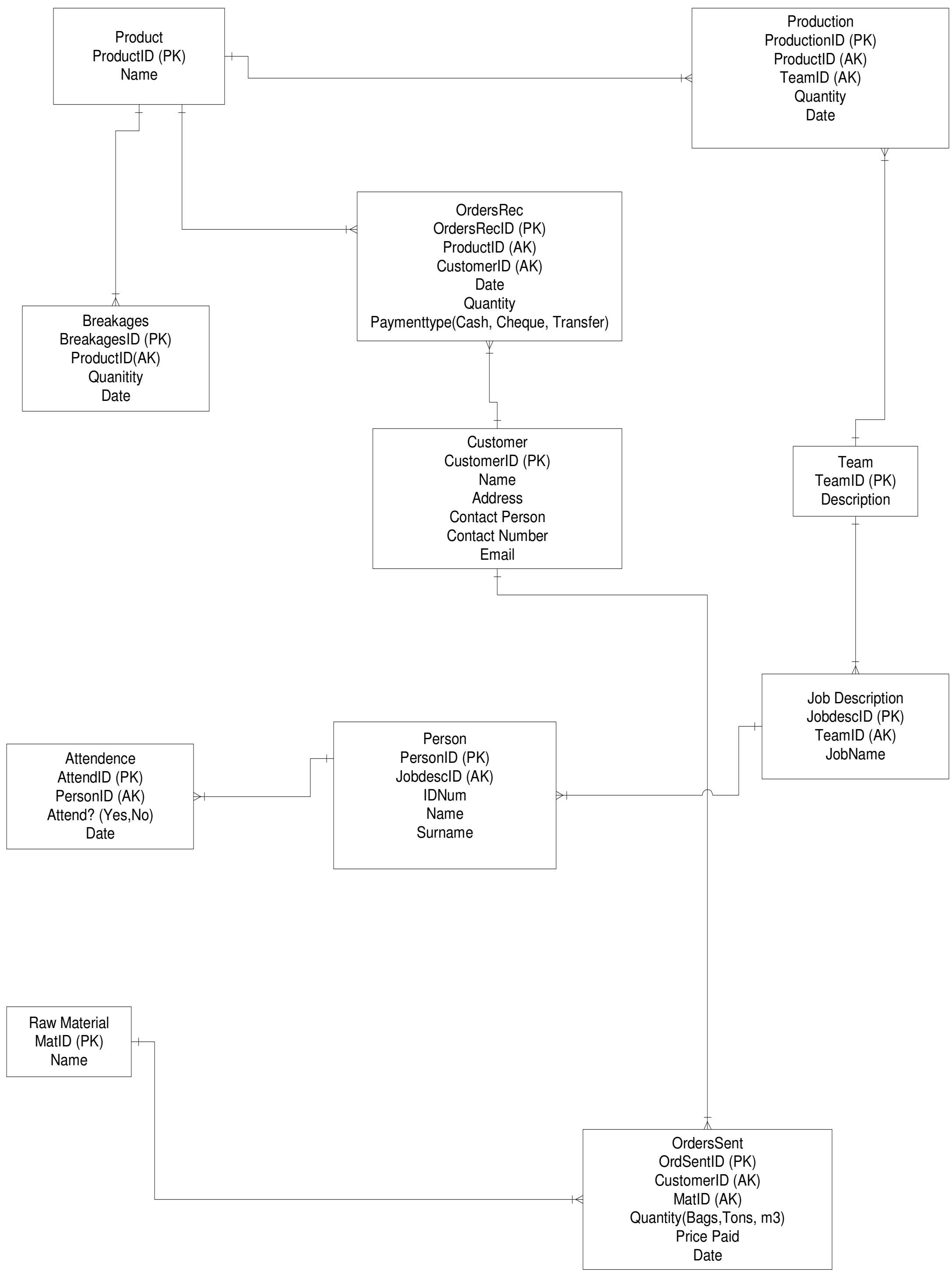
# Chapter 3: Design Stage

## 6. Main Design

### 6.1. Microsoft Access Database for use by the Onsite Manager

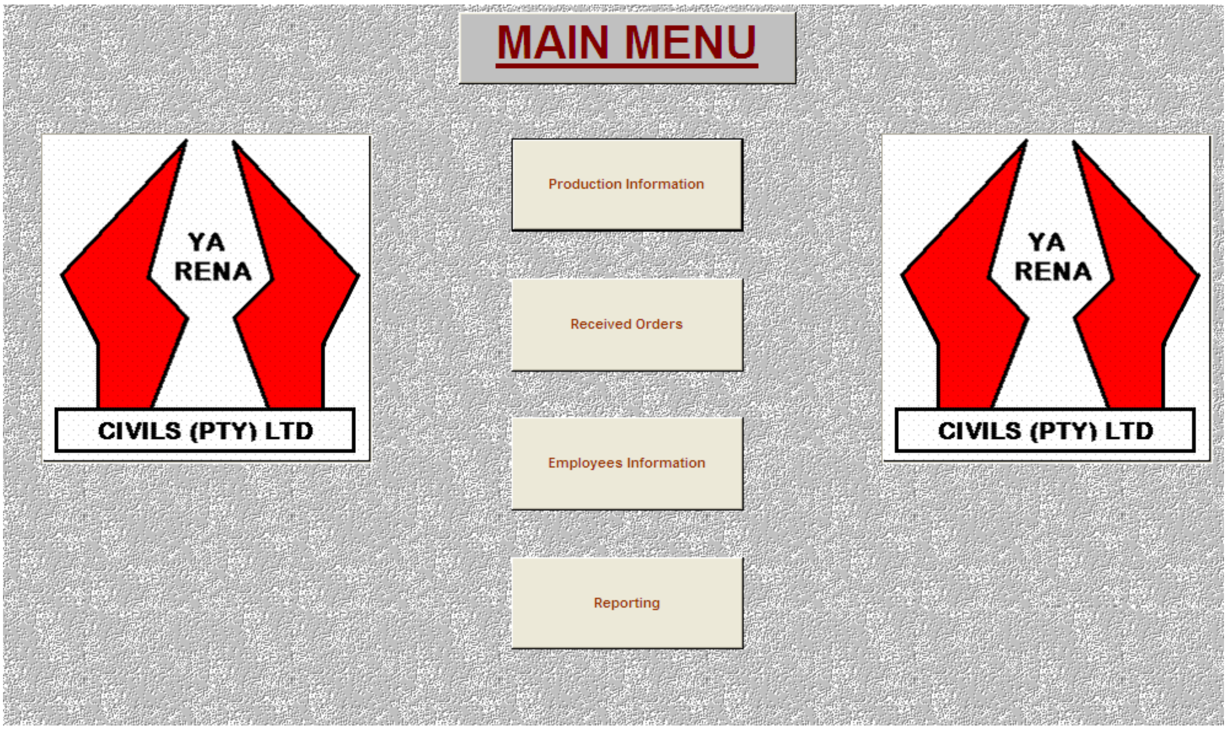
As a first step in developing the system an informal interview was held with the management of Ya Rena. The aim of this interview was to discover what functions the managers would like the Access Database to perform. All of the requirements were summarized and documented. An Entity Relationship Diagram (ERD) (Figure 1) was drawn up which would aided in the development of the program.

**Figure 1 - Entity Relationship Diagram**




The development of the Access Database took into account the ease with which the end user should be able to operate and make use of the program for its intended purpose. The database has four main groups (Figure 2) into which data can be stored or retrieved.

**Figure 2 - Database Main Menu Interface**




The first group, Production Information (Figure 3), which is probably the most important group, deals with all aspects of production. Within this group any outgoing orders (i.e. items which are purchased by the company) are recorded in the Outgoing Orders Form (Figure 4). The various suppliers information including email address, contact number, contact person and physical address are stored for future reference should any of this information be required. The item which is being ordered, the unit price and total quantity are stored and this information can be used at the end of the month to check where the expenses lie within the company.

The quantities of various products that are produced, the production 'team' which produced the products on the day and the breakages which occurred during production are noted on the Production form (Figure 5). Employee's attendances (Figure 6) indicate the number of hours worked on a daily basis by each employee. This information can be correlated with the clerk's month end time sheets to check for accuracy.

**Figure 3 - Production Information Interface**

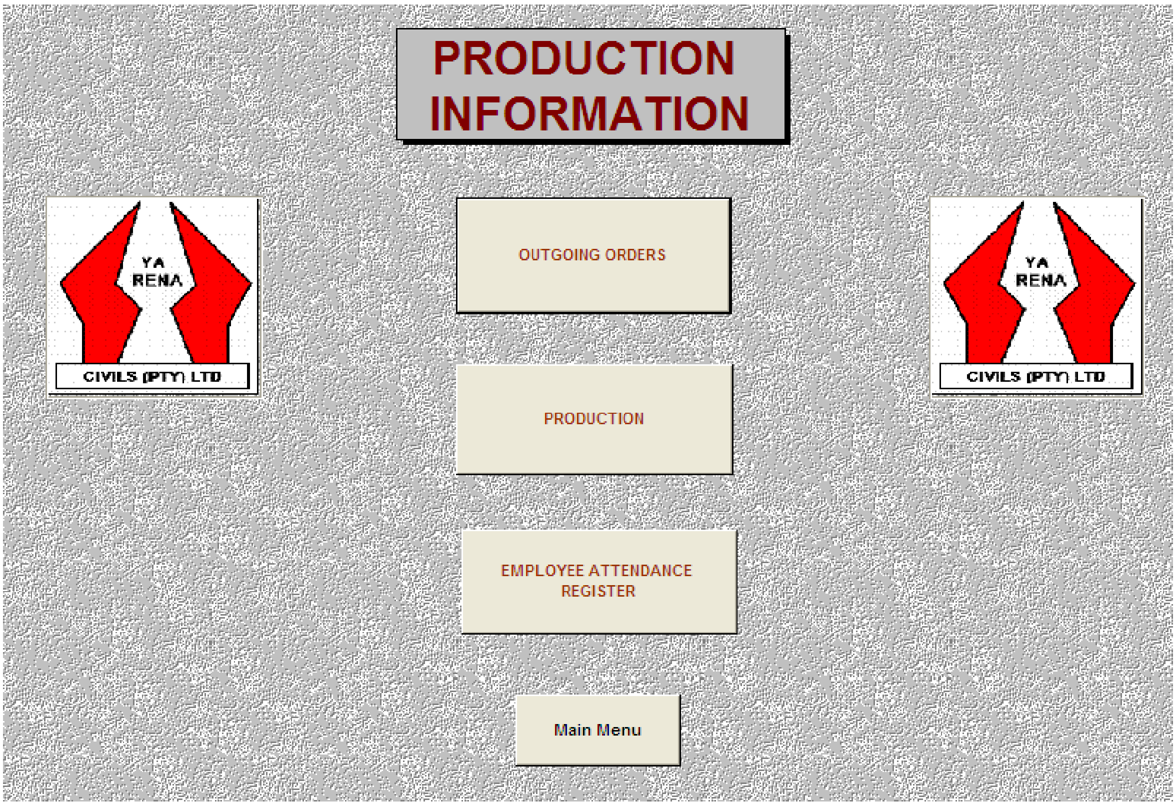



**Figure 4 - Outgoing Orders Interface**

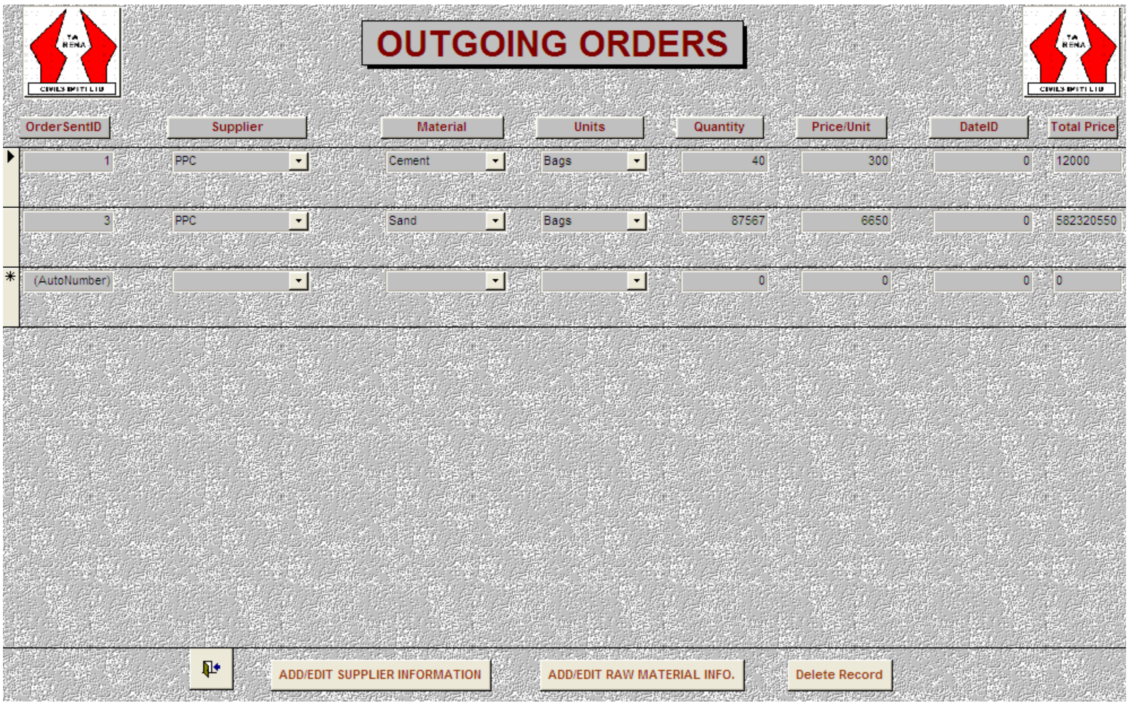
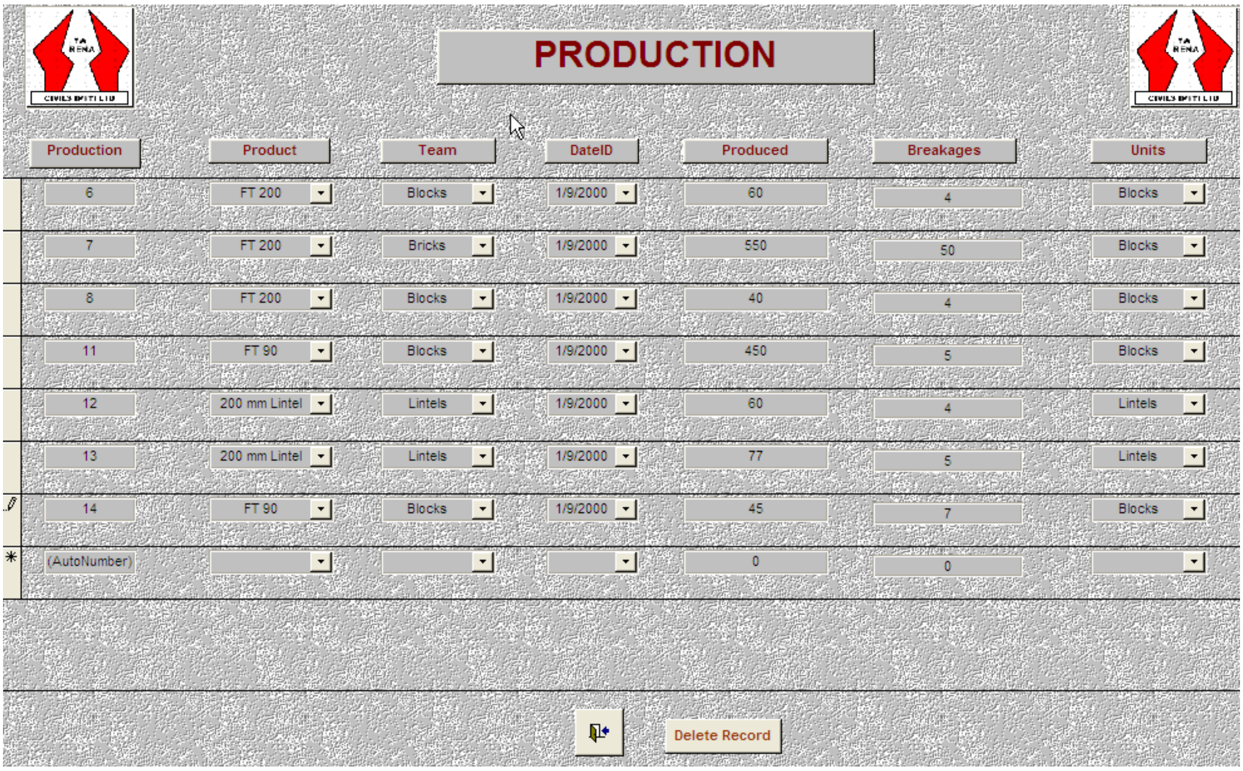


**Figure 5 - Production Interface**

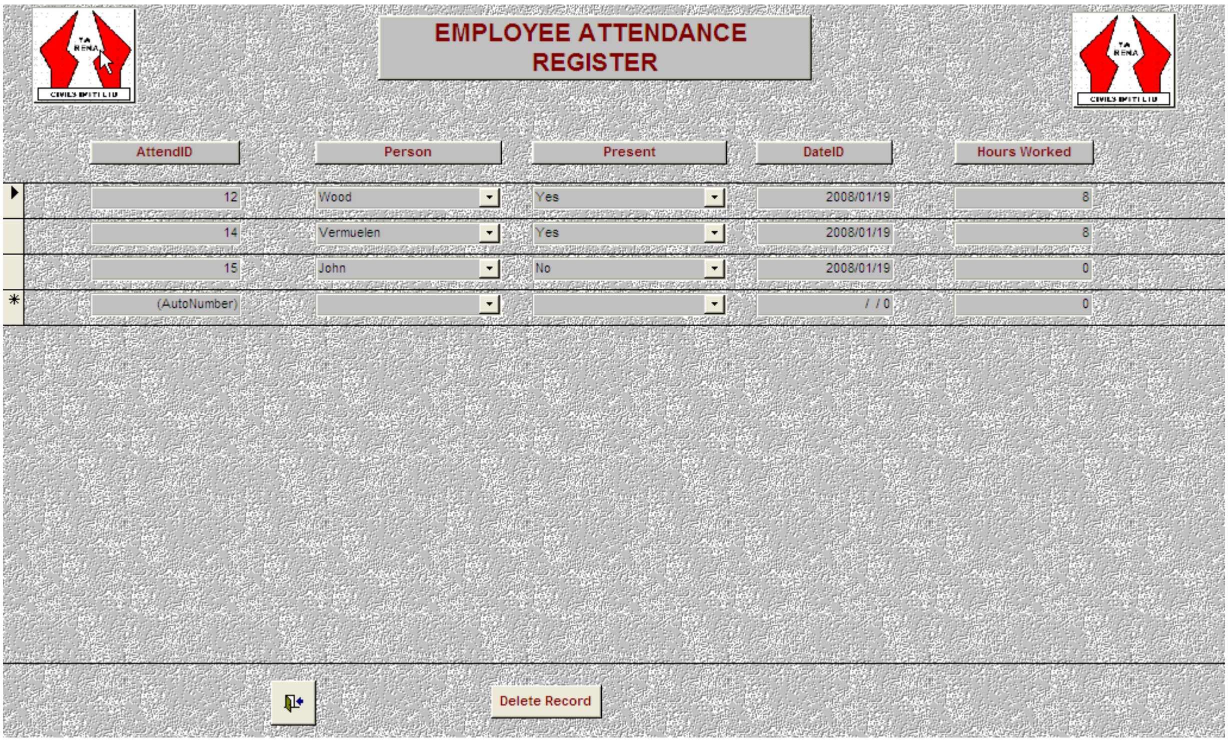


PRODUCTION

| Production | Product | Team | DateID | Produced | Breakages | Units |
|---|---|---|---|---|---|---|
| 6 | FT 200 | Blocks | 1/9/2000 | 60 | 4 | Blocks |
| 7 | FT 200 | Bricks | 1/9/2000 | 550 | 50 | Blocks |
| 8 | FT 200 | Blocks | 1/9/2000 | 40 | 4 | Blocks |
| 11 | FT 90 | Blocks | 1/9/2000 | 450 | 5 | Blocks |
| 12 | 200 mm Lintel | Lintels | 1/9/2000 | 60 | 4 | Lintels |
| 13 | 200 mm Lintel | Lintels | 1/9/2000 | 77 | 5 | Lintels |
| 14 | FT 90 | Blocks | 1/9/2000 | 45 | 7 | Blocks |
| (AutoNumber) | | | | 0 | 0 | |

Delete Record

**Figure 6 - Employee Attendance Register Interface**



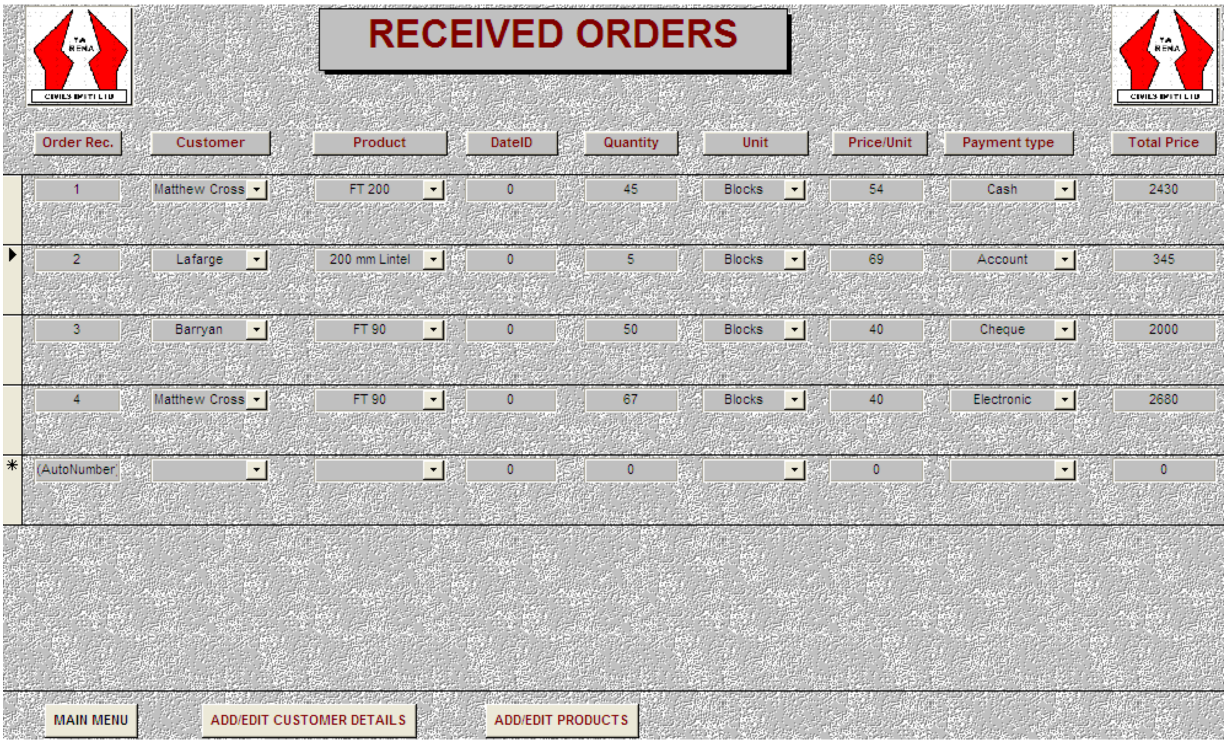
EMPLOYEE ATTENDANCE REGISTER

| AttendID | Person | Present | DateID | Hours Worked |
|---|---|---|---|---|
| 12 | Wood | Yes | 2008/01/19 | 8 |
| 14 | Vermuelen | Yes | 2008/01/19 | 8 |
| 15 | John | No | 2008/01/19 | 0 |
| (AutoNumber) | | | / / 0 | 0 |

Delete Record

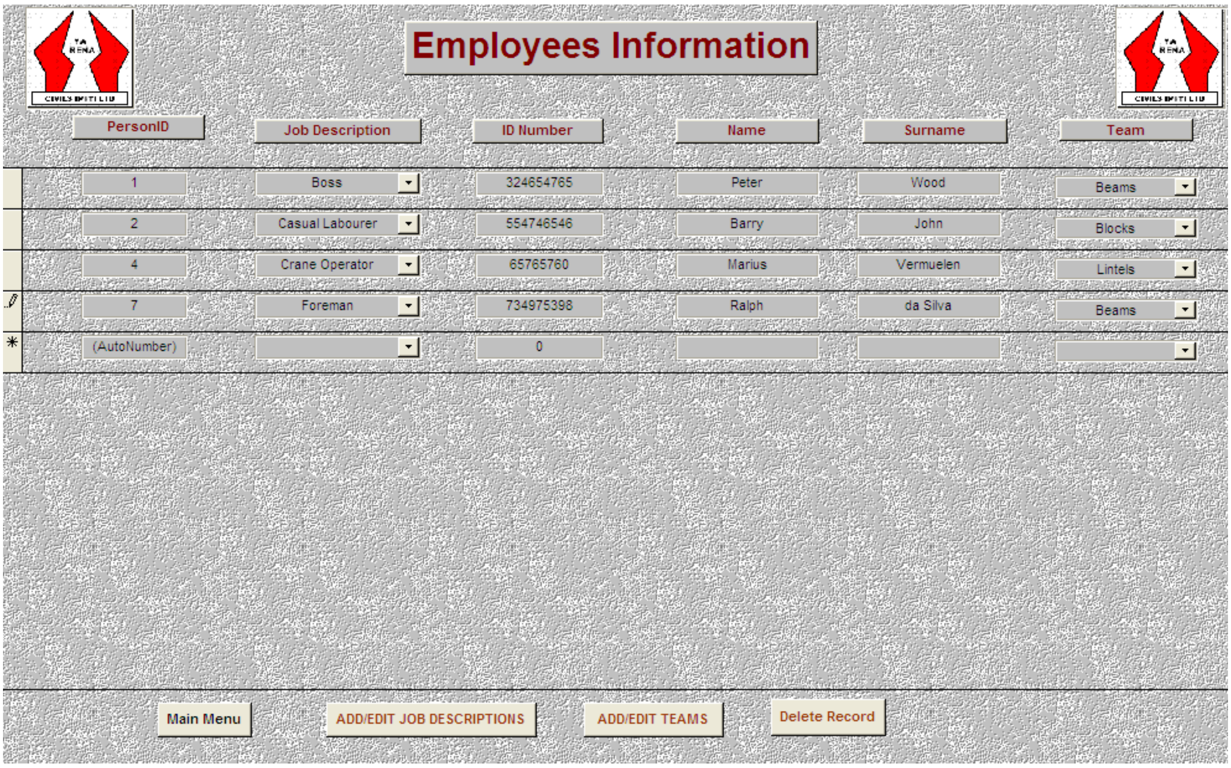
The second group (Figure 7) only deals with orders that were received (i.e. products sold from the plant to customers). The product which is being sold, the quantity and price of the specific units, the delivery date and the customer who made the purchase are all noted. This information can be used to see which products are the most popular as well as being able to see who the top customers are. Similarly, as with the supplier's information, so the customers information will be recorded.

**Figure 7 - Received Orders Interface**




The third group (Figure 8) allows the user to record an employees name, surname, identity number, job description and the team to which he/she belongs. It is essential to keep track of all this information regarding ones employees as to make sure that "ghost" individuals do not land up on the payroll.

**Figure 8 - Employees Information Interface**




The fourth group is the one in which management is the most interested in, the Reports Page (Figure 9). The reports which could be generated are:

- Attendance Report per Day
- Employee Details
- Monthly Production Figures
- Daily Production Figures
- Monthly Expense Report
- Total Hours Worked per Month By Each Employee
- Customer Sales Report
- Monthly Product Demand
- Daily Stock of Products on Hand

**Figure 9 - Reports Page**


The Access Database comes with a step by step user manual on how all of the features of the program work. This manual has been included as an attachment to the project.

It is believed that with all of the information that can be obtained from the database more informed decisions and governance over the operation of the plant can be made.

A CD disk has been attached to the project and contains the Access Database and the User Manual.

## 6.2. Production Planning

In the development of the production planning system for the precast plant it was noted that the system would be required to run on a daily basis to determine the production plan as the demand for various products will change regularly. For this reason LINGO, which would run the production planning algorithm, was interfaced with Microsoft Excel which would perform basic calculations. The information which the Excel spreadsheet will be using was imported from the Microsoft Access Database. This meant that all of the information, including the current product stock levels and the future demand for products would be based on true and current information.

The basis of the algorithm theory is to lower stock levels as far as possible yet insure that there will never be a shortage of the various products. There are a large variety of products that can be produced on limited pieces of machinery and moulds by a limited number of teams of workers.

The production planning model will be able to indicate which resources should be used on which day to produce a certain product. This should aid the production manager in his decision as to what his production plan should look like. It is not to say that the plan generated from the algorithm should be followed directly but it would give the production manager deeper insight into what steps he should follow.

The production plan algorithm is depicted below:

$openstock_i \equiv$ *The quantity of product i available at the beginning of the day*

$profit_i \equiv$ *The profit obtained from product i*

$$produce_{i,j,k} \equiv \begin{cases} 1 \text{ if product } i \text{ must be produced on day } j \text{ by plant } k \\ 0 \text{ otherwise} \end{cases}$$

$quantity_{i,j,k} \equiv$ *The number of units of product i to be produced on day j by plant k*

$changecost \equiv$ *The cost of changing moulds on a machine*

$productstock_{i,j} \equiv$ The *quantity of product i in stock on day j*

$maxunits_{i,k} \equiv$ *The maximum number of units of product i that can be produced on plant k*

$prodrates_{i,k} \equiv$ *The time in minutes it takes to produce one unit of product i with plant k*

$demand_{i,j} \equiv$ *The demand for product i on day j*

$change_{k,j} \equiv$ *The number of times a plant k changed products on day j*

$$\sum_{i=1}^{a}\sum_{j=1}^{b}\sum_{k=1}^{c} profit_i \times quantity_{i,j,k} - changecost \times \sum_{j}^{a}\sum_{k}^{c} change_{j,k} - (\sum_{i}^{a}\sum_{j}^{b} productcost_i \times productstock_{i,j}) \times 0.14$$

**s.t:**

$\sum_{i}^{a} prodrate_{i,k} \times quantity_{i,j,k} \leq 8 \times 60 - (60 \times change_{j,k}) \quad \forall j \in \{1,\ldots,b\}$ ..............................(1)

$\sum_{i=1}^{a}\sum_{j=1}^{b}\sum_{k=1}^{c} quantity_{i,j,k} \leq maxunit_{i,k} \times produce_{i,j,k}$ ........................................................(2)

$productstock_{i,1} = openstock_i + \sum_{k=1}^{c} quantity_{i,1,k} - demand_{i,1} \quad \forall i \in \{1,\ldots,a\}$ ...........................(3)

$productstock_{i,j} = productstock_{i,j-1} + \sum_{k=1}^{c} quantity_{i,j,k} - demand_{i,j}$
$\forall i \in \{1,\ldots,a\} \quad \forall j \in \{2,\ldots,b\}$ .................................................................................... (4)

$produce_{i,j,k} = \{0,1\}$

*a = the total number of product types in production*
*b = the total number of days being planned for*
*c = the total number of plants being used*

**Constraints:**

1. This constrains the quantity of units that can be produced against the time available in a day less an hour per mould change should it be required.
2. This constrains the quantity of units that can be produced against the max units that a plant can produce in a single day.
3. The available stock on hand at the end of day one is equal to the opening stock plus the quantity of units that were produced less the units that were sold on the day.
4. The stock on hand for the remaining days is equal to the quantity of units that were produced less the units that were sold on the day.

The 0.14 (14%) value represents the percentage which the capital cost of the products loses in terms of what it could be earning in other investments. It also takes into account the cost of actually storing the products on site. This value was determined through consultation with the managers of Ya Rena Precast.

In order to aid in making the production schedule easier to use an Excel spreadsheet (Figure 10) has been developed which interfaces with LINGO. This means that data can be entered into Excel with there having to be minimal changes to the code in the LINGO model.

**Figure 10 - Production Planning User Interface**

Ya Rena Precast Production Planning Data Interface

| | Product 1 | Product 2 | Product 3 | Product 4 |
|---|---|---|---|---|
| Profit | 1 | 2 | 4 | 5 |
| Production Cost | 0.7 | 1 | 3 | 2 |
| Change Over Cost | 10 | | | |

| Max Production per Product per Team | | | | |
|---|---|---|---|---|
| Team 1 | 50 | 50 | 50 | 50 |
| Team 2 | 50 | 50 | 50 | 50 |
| Team 3 | 50 | 50 | 50 | 50 |
| Team 4 | 50 | 50 | 50 | 50 |

| Production Rate (Minutes/product) | | | | |
|---|---|---|---|---|
| Team 1 | 3 | 4 | 3 | 5 |
| Team 2 | 3 | 4 | 3 | 5 |
| Team 3 | 3 | 4 | 3 | 5 |
| Team 4 | 3 | 4 | 3 | 5 |

| Demand per Product per Day | | | | |
|---|---|---|---|---|
| Team 1 | 40 | 40 | 40 | 40 |
| Team 2 | 40 | 40 | 40 | 40 |
| Team 3 | 40 | 40 | 40 | 40 |
| Team 4 | 40 | 40 | 40 | 40 |

| Opening Stock for Today | | | | |
|---|---|---|---|---|
| Day 1 | 100 | 100 | 100 | 100 |

Stock on Hand

| Product | Date | Sum Of Quantity |
|---|---|---|
| 1 | Wednesday, January 23, 2008 | 40 |
| 2 | Thursday, January 24, 2008 | 20 |
| 2 | Wednesday, January 23, 2008 | 45 |
| 3 | Thursday, January 24, 2008 | 10 |
| 4 | Thursday, January 24, 2008 | 30 |
| 5 | Saturday, February 23, 2008 | 2 |

Product Demand

| | | |
|---|---|---|
| FT 90 | Wednesday, January 23, 2008 | 325 |
| FT 90 | Wednesday, January 23, 2008 | 255 |
| FT 200 | Thursday, January 24, 2008 | 175 |
| FT 200 | Thursday, January 24, 2008 | 375 |
| FT 200 | Wednesday, January 23, 2008 | 151 |
| FT 200 | Wednesday, January 23, 2008 | 351 |
| 200 mm Lintel | Thursday, January 24, 2008 | 47 |
| 200 mm Lintel | Thursday, January 24, 2008 | 28 |
| 600 mm Lintel | Thursday, January 24, 2008 | 23 |
| 600 mm Lintel | Thursday, January 24, 2008 | 19 |
| Precast Stairs | Saturday, February 23, 2008 | 3 |
| Precast Stairs | Saturday, February 23, 2008 | -1 |
| Precast Stairs | Saturday, February 23, 2008 | 2 |

Data such as the profit which each product makes, the production cost of each product, the changeover cost which is incurred from changing production of one type of product to another, the time in minutes it takes to produce one unit of a product using a certain team and the maximum number of units of a product which can be produced by a team per day must be entered into the Excel Spreadsheet named "Precast". The data for the demand for products and the opening stock are generated automatically using data from the Access Database but this information needs to be placed into the set table in the Excel spreadsheet.

The only changes in the LINGO code which would need to be made occur if new products or plants are added/deleted from the system. Should this be the case then the first two lines of the code would need to have the value at the end changed to the total number of products or plants which are to be run by the system. This needs to correlate with the products and teams in the Excel Spreadsheet.

Once all of the information has been correctly entered into the system the LINGO file can be opened and run. The output which will be received will indicate what quantity of products should be produced over the next four days.

A Compact Disk had been included with this project and this contains the LINGO model and Excel Spreadsheet. An illustrative example has been set up but it should be noted that the values contained in the Excel Spreadsheet are random values and do not depict actual data which would be required to be entered by the user. In order to run the model copy the Excel spreadsheet labeled "Precast" to the 'C' drive of a computer and run the Lingo model.

## 6.3. Material Requirements Planning (MRP) & Optimisation of Production Lines

### 6.3.1 Model Overview

An ARENA simulation of the block forming production has been developed. The model has been split into two halves. The first section (Figure 9) represents the stockpile of the raw materials with order processing and delivery of materials included. The second section (Figure 10) represents the actual production of the blocks.

A Microsoft Excel Spreadsheet has been developed as the user interface for the simulation of the FT 90 and FT 200 blocks (Figures 11-14) allowing for various pieces of data to be placed in the spreadsheet. The ARENA simulation will read this data and, after the simulation is complete, give a report on the outcome. This can aid the production manager to run various scenarios for the block forming lines which can give him/her a better understanding of where problem areas are occurring.

The model depicts two actions which occur on site. The first being that of the raw material stock level and the second being that of the actual production. For the first section the production manager can simulate the current practices of when raw materials are ordered and from this can make alterations to determine what the lowest level the stockpiles can reach before an order needs to be placed. The second section will enable the production manager to simulate the production of the various products. The manager can see what impact various changes to the system can have before he/she actually implements them.

The model was constructed assuming that breakdowns don't occur on any of the machines. This was done to simplify the model and because the emphasis's of the project was to determine the optimal re-order points and optimizing of the line.

**Figure 11 - FT 90 User Interface (1)**

Ya Rena Precast Plant Simulation Model Interface

FT 90 Block Information

Buckets Required Per Mix

| | Sand | Crusher Dust | Stone |
|---|---|---|---|
| Number | 1 | 6 | 2 |

Delivery Time (Hours)

| | Sand | Crusher Dust | Stone |
|---|---|---|---|
| Min | 1 | 2 | 1 |
| Likely | 2 | 3 | 2 |
| Max | 3 | 4 | 3 |

Stockpile Information

| | Sand | Crusher Dust | Stone |
|---|---|---|---|
| Re-order Point | 820 | 820 | 820 |
| Total Buckets In Stockpile | 900 | 900 | 900 |

Raw Material Loading Info.

| | Sand | Crusher Dust | Stone | Cement |
|---|---|---|---|---|
| Time to Load Mixer | 1 | 3 | 2 | 2 |

Mixing Time (Minutes)

| | Time To Mix Raw Material |
|---|---|
| Min | 7 |
| Likely | 9 |
| Max | 10 |

**Figure 12 - FT 90 Simulation User Interface (2)**

Ya Rena Precast Plant Simulation Model Interface

| Batch Sizes | |
|---|---|
| | Value |
| Blocks/Mould | 8 |
| Percentage Broken | 98 |

| Pallet Information | | |
|---|---|---|
| | Mould Making Time | Stack Pallet |
| Mean | 3 | 1 |
| Std Deviation | 1 | 0.2 |

| % of Time That # of Blocks Are Produced | | | | | | (Must be 100%) |
|---|---|---|---|---|---|---|
| | 0 Block | 1 Block | 2 Block | 3 Block | 4 Block | Total % |
| % | 2 | 3 | 5 | 15 | 75 | 100 |

| Set Values (Not to Be Altered) | | | |
|---|---|---|---|
| | No Blocks | 1 Block | 2 Blocks |
| Duplicates | 3 | 2 | 1 |
| | | | |

**Figure 13 - FT 200 Simulation User Interface (1)**

Ya Rena Precast Plant Simulation Model Interface

FT 200 Block Information

Buckets Required Per Mix

| | Sand | Crusher Dust | Stone |
|---|---|---|---|
| Number | 1 | 6.5 | 2 |

Delivery Time (Hours)

| | Sand | Crusher Dust | Stone |
|---|---|---|---|
| Min | 1 | 2 | 1 |
| Likely | 2 | 3 | 2 |
| Max | 3 | 4 | 3 |

Stockpile Information

| | Sand | Crusher Dust | Stone |
|---|---|---|---|
| Re-order Point | 890 | 720 | 810 |
| Total Buckets In Stockpile | 900 | 900 | 900 |

Raw Material Loading Info.

| | Sand | Crusher Dust | Stone | Cement |
|---|---|---|---|---|
| Time to Load Mixer | 1 | 3 | 2 | 2 |

Mixing Time (Minutes)

| | Time To Mix Raw Material |
|---|---|
| Min | 6 |
| Likely | 8 |
| Max | 10 |

**Figure 14 - FT 200 Simulation User Interface (2)**

Ya Rena Precast Plant Simulation Model Interface

FT 200 Block Information

Buckets Required Per Mix

| | Sand | Crusher Dust | Stone |
|---|---|---|---|
| Number | 1 | 6.5 | 2 |

Delivery Time (Hours)

| | Sand | Crusher Dust | Stone |
|---|---|---|---|
| Min | 1 | 2 | 1 |
| Likely | 2 | 3 | 2 |
| Max | 3 | 4 | 3 |

Stockpile Information

| | Sand | Crusher Dust | Stone |
|---|---|---|---|
| Re-order Point | 890 | 720 | 810 |
| Total Buckets In Stockpile | 900 | 900 | 900 |

Raw Material Loading Info.

| | Sand | Crusher Dust | Stone | Cement |
|---|---|---|---|---|
| Time to Load Mixer | 1 | 3 | 2 | 2 |

Mixing Time (Minutes)

| | Time To Mix Raw Material |
|---|---|
| Min | 6 |
| Likely | 8 |
| Max | 10 |

### 6.3.2 Problem Background

The working day begins at 07:00 Monday to Friday where a safety meeting is first held and goals and tasks are set out for the day. Production thus starts at 7:30 until 12:00 when lunch is had for 30 minutes after which production work continues until 16:30. From this time until 17:00 the machines are cleaned, the tools are packed away and the wet products are covered with plastic to protect them. The overall production time for the plant is thus 8.5 hours which will be used for 1 day's simulation time.

The process for the production of the blocks runs as follows:

Whilst the conveyor is being loaded the mixer mixes the previous load. The time for the mixing varies due the operator having to add water and test the aggregate to achieve the required consistency.

While the mixer is mixing, the aggregate is placed into the moulds of the uni-stacker and compacted to produce the blocks of which there are 2 pallets produced per load from the mixer. Once the mixer is available for use the conveyor belt places all the raw materials into the mixer. The time for this process to occur is constant.

During the forming of the blocks in the moulds errors can occur i.e. breaks, cracks etc. An inspection of the blocks is performed and if a fault is detected the broken block is removed from the pallet and the aggregate is recycled and placed back into the mould machine.

The pallets containing the products which have been correctly made are laid out to dry. The process of moving the pallets varies in time as the distance which the pallets are carried changes. During the drying process some of the blocks crack, break or are damaged. These blocks are scraped and cannot be sold.

### 6.3.3 Development of Model

The production of the module is set to run for 8.5 hours a day for 30 days (255 hours). This time is the average time per day for which the plant is producing blocks.

The model firstly creates an entity which represents the loading of the conveyor belt with the various raw materials which results in the conveyor being loaded with 1 mixing unit. If a stockpile has reached its safety level an order is created and if a stockpile has run out the production stops until the material has been replenished.

The mixing unit is then fed from the conveyor to the mixer which then produces enough aggregate for 2 production runs of the product forming machine. Once the pallet has been emitted from the machine the numbers of incorrect blocks are removed from the pallet and the aggregate is fed back into the machine. The pallet containing the correct blocks is moved to a drying area. The model then duplicates the entities according to how many blocks are on the pallet and then separates the blocks which are damaged or broken during the curing process to a waste bin and the quantity of correct blocks made are recorded.

Once all the production information had been entered correctly into the model the current situation of the re-order point was simulated and the results were recorded. Due to the fact that the current situations re-order point was not optimal experimentation with the re-order points was done. Currently the size of the stockpiles for the crusher dust, sand and stone are as big as a 1 standard delivery truckload or 9 tons. Once the level of a stockpile reaches around 20% an order is placed for a delivery of that material. The delivery time of the materials vary due to availability of the material, delivery trucks and the distance which the supplier is located from the plant.

It is believed that with this model greater insight can be given into the quantity of raw materials which needs to be kept on hand, the re-order points, the safety limits, the rate at which the materials will be used and the production times which can be achieved.

### 6.3.4 Results

The model was run to simulate the current situation on-site for both the FT 90 block and the FT 200 block. The results that were obtained were not optimal which lead to further investigation into new re-order points were investigated. The tables depicted below show the correlation between the current situation and an optimal situation.

**Table 1 - FT 90 Simulation Results**

| | Current | Optimal | Difference | |
|---|---|---|---|---|
| | | | | |
| Sand Order Point (buckets remaining) | 80 | 20 | 60 | |
| Crusher Dust Order Point (buckets remaining) | 80 | 140 | 200 | |
| Stone Order Point (buckets remaining) | 80 | 70 | 10 | |
| Blocks Made | 16811 | 18023 | 1212 | 7.2% |
| # Sand Orders | 2 | 2 | 0 | |
| # Stone Orders | 5 | 6 | 2 | |
| # Crusher Orders | 13 | 13 | 0.0 | |
| # Of Times Production Stopped | 13 | 0 | -13 | |

**Table 2 - FT 200 Simulation Results**

| | Current | Optimal | Difference | |
|---|---|---|---|---|
| | | | | |
| Sand Order Point (buckets remaining) | 80 | 20 | 60 | |
| Crusher Dust Order Point (buckets remaining) | 80 | 180 | 100 | |
| Stone Order Point (buckets remaining) | 80 | 90 | 10 | |
| Blocks Made | 6229 | 6290 | 61 | 1.0% |
| # Sand Orders | 1 | 2 | 1 | |
| # Stone Orders | 3 | 4 | 1 | |
| # Crusher Orders | 8 | 11 | 3 | |
| # Of Times Production Stopped | 7 | 0 | 7 | |

From the results it is clear that the system has its advantages and with its use could improve production. The on-site manager could easily use the program through the Excel interface and with it run various scenarios which will ultimately give him/her more insight into what changes need to be implemented in order to receive better results.

**Figure 15 – ARENA Model of Raw Material Stock Level and Order Process**

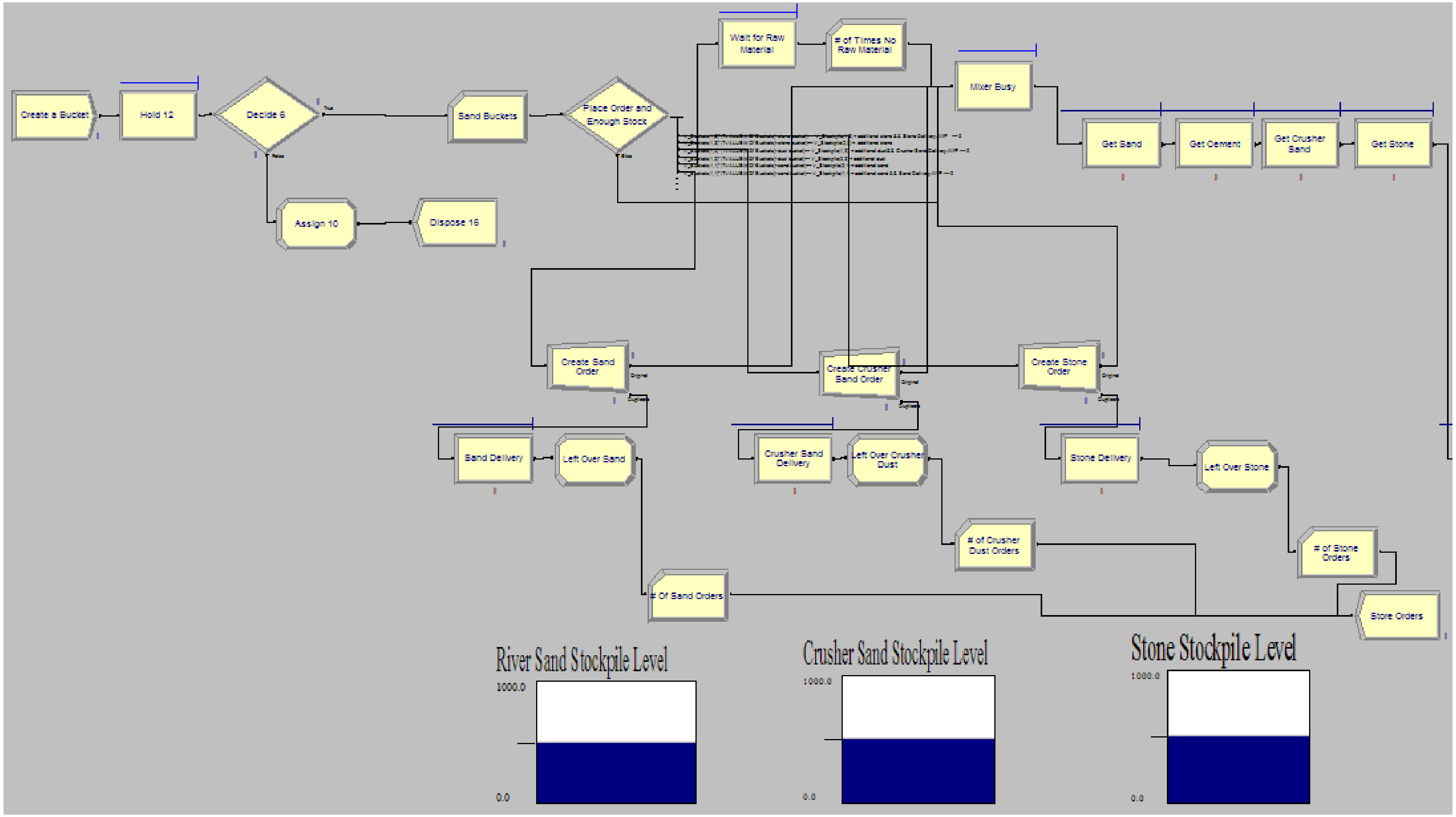
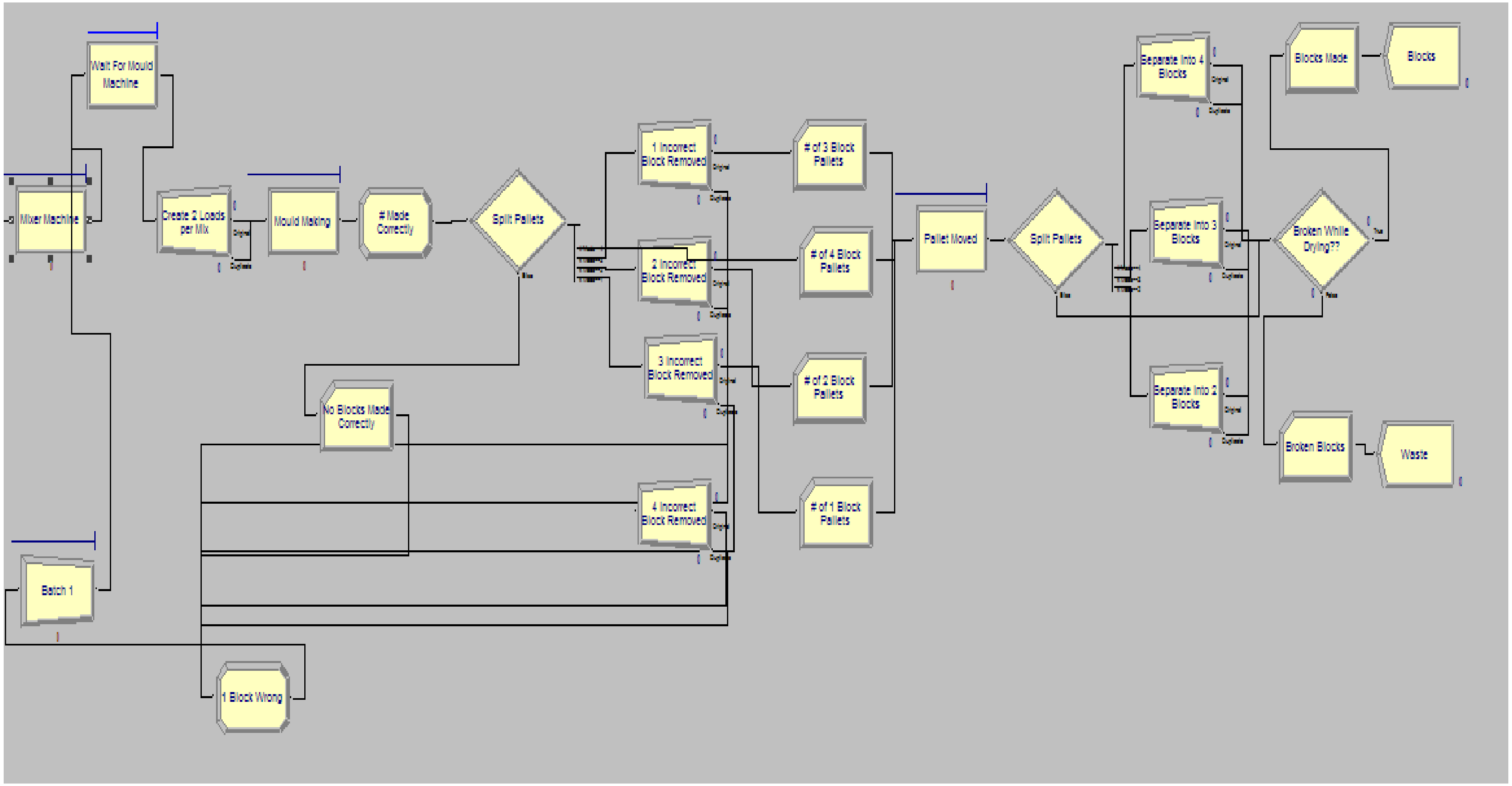


**Figure 16 – ARENA Model of Block Forming Production**



## 6.4 Onsite Ergonomics

### 6.4.1 Ergonomic Aid

After a site visit to the Ya Rena Precast facility it was clear that there were strict rules and regulations regarding the personal protective equipment (PPE) that was to be worn by all individuals entering the production area of the plant. The compulsory PPE which has to be worn includes hardhats, ear plugs, safety glasses, dust masks, gloves and safety boots. Overalls are provided to the labourers but are only compulsory to the labourers. It can be seen that the PPE which is issued to the labourers is fairly adequate and in most instances will provide sufficient safety.

As has been discussed earlier the majority of the workers handle raw materials and precast products by hand. The products are extremely heavy due to them being made from concrete which is a very heavy and an abrasive product. Through research based on sourced articles there are a few aids which could help certain labourers.

A study was conducted into the various types of jobs where labourers would be required to wear one of or a combination of back support (Figure 8), wrist support (Figure 9), elbow support (Figure 10), knee support or pads (Figure 11).

The table below depicts the various job types which are currently being used on the plant. These job types have been matched to the different aids which could be used as well as a reason for why the aids may be required.

**Table 3 - Job Description & Ergonomic Aid Correlation**

| Job Description | Ergonomic Aid | Reason |
|---|---|---|
| Form Block Handler | - Back Support<br>- Knee Support | This activity involves a lot of heavy lifting from a low level which places a large amount of strain on the back. Due to the weight being transferred through the body (Figure 21) whilst walking a knee guard would be recommended. |
| Raw Material Loader | - Back Support<br>- Wrist Support<br>- Elbow Support<br>- Knee Support | This job entails loading wheelbarrows with raw material by hand and pushing and then tipping the load into a mixer.<br>The action of loading the wheelbarrow places strain on the back, wrists and elbow.<br>By wheeling the load around a large amount of force is placed on the knees and the action of tipping the wheelbarrow requires all of the mentioned aids as this is a very strenuous activity. |
| Form Block Machine Operator | - Wrist Support | The operator has to slide the material from the mixer into the moulds which places strain on the wrists. |
| Curb Maker/Handler | - Back Support<br>- Knee Support | This job involves lifting curbs which are extremely heavy and stacking them. This causes a large amount of strain on the back as the products are lifted from a low position. |
| Lintel/Lattice Beam Producer | - Back Support<br>- Knee Pad | The labourers involved with the beam production do a variety of work. It is only in the removal of the beams from the moulds that a back support needs to be worn due to the weight of the product.<br>Due to the fact that a lot of kneeling is done it would relieve a lot of pressure on the knee caps if a pad was used to protect the knee. An example of this use is depicted in Figure 22 |
| Precast Stairs and Screed Railing | - Back Support<br>- Wrist Support | The production of these products is not a strenuous one but the removal and lifting of them out of the moulds entails a vast amount of strain as these items are very heavy and large. |

From the table above it is quite obvious that the general worker requires back support. This was to be expected as many of the products that are produced are extremely heavy and are required to be moved by hand after the drying process has been completed. The introduction of trolleys (figure 23), which aid in moving the products around, has already been implemented.

### 6.4.2 On-site Moral

Due to the fact that the workers are involved with very monotonous jobs the average moral of the worker is very low. This can lead to subconscious stress and a lack in concentration. These low levels of concentration often result in low quality of work and accidents within the workplace.

Two methods of combating these problems will now be discussed. The first solution to the problem at hand is to provide the worker with an incentive. Each product is produced by a team of workers. The idea would be to calculate a minimum quota which the team should strive to achieve during the production time in a day. Any additional product produced above this quota will result in an increase in pay per product produced above the quota.

By encouraging the labourers to work to achieve this quota the team should bond together where they would motivate each other to work harder to achieve the additional income. The labourers would have to think productively and work efficiently which would involve mental stimulation. The employer would obviously also benefit as they would be receiving more products for a days work and thus be more profitable. The employer needs to make sure that the minimum quota is set high enough so that they do not land up losing money on a day yet low enough that it is obtainable.

The second solution involves the job rotation of worker in a team on a weekly or monthly basis. By rotating the worker through different jobs he/she will experience an array of different work types. Each work type is different from each other and this would allow the worker to alternate his/her daily job in the light of providing more stimulation and excitement amongst the worker in participating on a different job type. The disadvantage to this though is that a worker who has been doing a certain job type becomes very good at what he/she is doing and by continuously rotating the workers the learning curve that each labourer would have to go through could mean that the overall production levels could be lower.

The final decision over which method, or even a combination of the methods, should be used lies in the hands of the employer yet it must be stated that something should be done to improve the moral of the on-site labourer.

# Chapter 4: Conclusion

The Ya Rena Precast Plant is still a relatively new business and so it will be expected that problems will arise within the organisation. The content of this project serves to address some of the issues but obviously not all of the problems.

The basis around the project is to supply the on site manager with tools which he/she can use on a daily basis. The user interface and user manuals will enable the on site manager to use of the program's supplied to him/her without a large amount of training or having the need to employ an Industrial Engineer to conduct the studies.

The use of the Microsoft Access Data Capturing System could prove to be an invaluable tool if used correctly. The information that can be retrieved from the reports can help management to pin point areas of concern as well as to give on overall view of the operations of the organisation. It must be stated that in order for the system to work correctly it needs to be updated everyday.

The production planning algorithm will give the onsite manager a better idea of what his production plan should look like. The program will point out the need to increase or decrease stock levels and aid the manager in knowing what the production demand for the near future will look like. The Excel user interface is fairly simple to use and is the only real centre where input data needs to be placed. This makes the program very user friendly and easy to use.

With use of the ARENA model depicting the production of the hollow form blocks the onsite manager should get a deeper understanding of where valuable time within the production can be made up. The system will allow him/her to run various scenarios and based on the results that can be obtained, give the manager confidence in knowing that a newly implemented change in the system will be a beneficial one. The calculation of the re-order points for the raw material stock piles will aid the manager in knowing exactly when an order for new material should be placed thus eliminating the guess work involved in the task.

It is vitally important that care of the onsite labour is taken. The image of the employer in supplying the labourers with the necessary ergonomic aids and incentive schemes will place the management in good light in the eyes of the workers. Although this is not the point of the implementation of the aids it is a definitely an advantage. Medical bills and loss in production time due to injured workers is currently a problem yet it is believed that with the aids this should not be a major issue in the future.

Overall the project has aimed at improving various functions at the precast plant and particularly in aiding the production manger and upper management of the plant. It is believed that with the implementation of the systems a great improvement to the organisation will be felt.

# Appendices

**Figure 17 – Back Support**

**Figure 18 – Wrist Support**

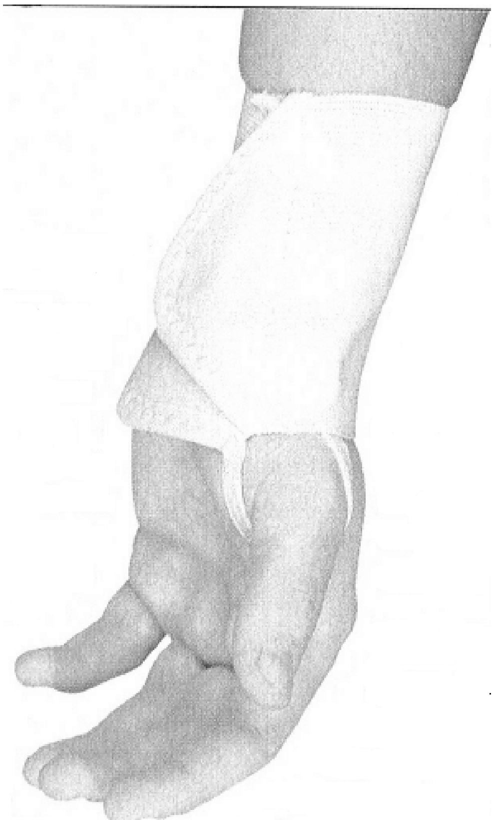


**Figure 19 – Elbow Support**

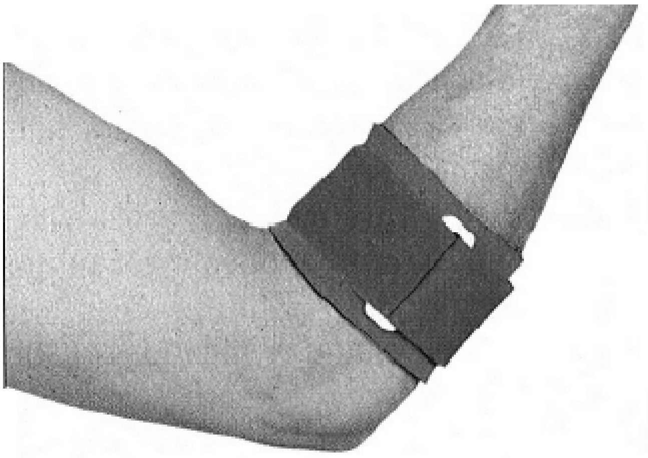


**Figure 20 – Knee Pads**

**Figure 21 - Lintel Production**


**Figure 22 - Overhead Crane and Lintel Production Line**


**Figure 23 - Curb Production**

**Figure 24 - FT 90 Block Production**


**Figure 25 - Curb Stock**


**Figure 26 - Block Production Shed**

**Figure 27 - Form Block Handler**

**Figure 28 - Lintel Labourers Kneeling**


**Figure 29 - Form Block Trolley**

**Table 4 - Production on 110 x Lintel Bays**

## Production On 110 x 70 Lintel Bays

**Concrete Cost (Material)** 14.55 kg/m

| | Rate/ton | | Weight kg (Per Block) | Quantity % | Wbarrow | Cost In R/m | |
|---|---|---|---|---|---|---|---|
| Crusher Sand | R 95.00 | | 2.87 | 19.70% | 1.3 | R 0.27 | |
| River Sand | R 108.33 | | 2.87 | 19.70% | 1.3 | R 0.31 | |
| Stone 6.7 mm | R 123.00 | | 0.00 | 0.00% | | R 0.00 | |
| Stone 9.5 mm | R 117.00 | | 0.00 | 0.00% | | R 0.00 | |
| Stone 13.2 mm | R 123.00 | | 4.41 | 30.30% | 2 | R 0.54 | |
| Water | R 1.50 | | 2.20 | 15.15% | 1 | R 0.00 | |
| Cement | R 960.00 | | 2.20 | 15.15% | 1 | R 2.12 | |
| | **1527.833333** | | **14.55** | 1 | **6.6** | R 3.24 | **R 3.24** |

**Phase Breakdown**

| **1st Phase - Strip** | Hour | Minutes | Seconds | Metre | Number | Hourly Rate | Daily Rate | Hours/day | Total | Total/metre |
|---|---|---|---|---|---|---|---|---|---|---|
| Bolt Cutter | | | | 15000 | | 90 | each | | 90.00 | 0.01 |
| Remove Lintel From Mould | 0.366666667 | 22.00 | 1320.00 | 50 | 5 | R 13.34 | R 120.06 | 9 | 24.46 | 0.49 |
| Stack Lintel On The Side | 0.166666667 | 10.00 | 600.00 | 50 | 7 | R 13.34 | R 120.06 | 9 | 15.56 | 0.31 |
| **Total** | | | | | | | | | | **0.80** |

| **2nd Phase - Clean Bays** | Hour | Minutes | Seconds | Metre | Number | Hourly Rate | Daily Rate | Hours/day | Total | Total/metre |
|---|---|---|---|---|---|---|---|---|---|---|
| Removal Of Large Pieces | 0.069444444 | 4.17 | 250.00 | 50 | 1 | R 13.34 | R 120.06 | 9 | 8.34 | 0.17 |
| Clean Bays Using Compressor (Labour) | 0.163888889 | 9.83 | 590.00 | 330 | 1 | R 13.34 | R 120.06 | 9 | 19.68 | 0.06 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Clean Bays Using Blower (Machine) | 0.163888889 | 9.83 | 590.00 | 330 | 1 | R 2.00 | R 18.00 | 9 | 0.33 | 0.00 |
| **Total** | | | | | | | | | | **0.23** |

| **3rd Phase - Oiling** | Hour | Minutes | Seconds | Metre | Number | Hourly Rate | Daily Rate | Hours/day | Total | Total/metre |
|---|---|---|---|---|---|---|---|---|---|---|
| Oil Bays | 0.366666667 | 22.00 | 1320.00 | 120 | 3 | R 13.34 | R 120.06 | 9 | 132.07 | 1.10 |
| Oil Cost | 5 | litres | 0.00 | 275 | 1 | R 6.60 | per liter | 0 | 33.00 | 0.12 |
| **Total** | | | | | | | | | | **1.22** |

| **4th Phase Wire Spacer Placement** | Hour | Wires | Seconds | Metre | Number | Hourly Rate | Daily Rate | Hours/day | Total | Total/metre |
|---|---|---|---|---|---|---|---|---|---|---|
| Pull 1 Stand Of Wire | 0.001388889 | 5.00 | 110.00 | 50 | 1 | R 13.34 | R 120.06 | 9 | 0.09 | 0.00 |
| Wire Cost | | 5.00 | | 50 | 1 | R 0.26 | per metre | | 1.30 | 1.30 |
| Place Wire Through Spacer | 0.005555556 | 5.00 | 20.00 | 50 | 1 | R 13.34 | R 120.06 | 9 | 0.37 | 0.01 |
| Measure Lengths | | | | | | | | | | |
| Place Spacer | 0.019444444 | | 70.00 | 40 | 1 | R 13.34 | R 120.06 | 9 | 0.26 | 0.01 |
| Tension Bay | 0.091666667 | 5.00 | 330.00 | 50 | 2 | R 13.34 | R 120.06 | 9 | 2.45 | 0.05 |
| **Total** | | | | | | | | | | **1.36** |

| **5th Phase - Pouring + Vibration** | Hour | Minutes | Seconds | Metre | Number | Hourly Rate | Daily Rate | Hours/day | Total | Total/metre |
|---|---|---|---|---|---|---|---|---|---|---|
| Mix Concrete (Labour) | 0.083333333 | 5.00 | 300.00 | 32 | 5 | R 13.34 | R 120.06 | 9 | 5.56 | 0.17 |
| Mix Concrete (Machine) | 0.083333333 | 5.00 | 300.00 | 32 | 1 | R 13.34 | R 120.06 | 9 | 1.11 | 0.03 |
| Concrete Cost (see above) | | | | | | | | | | 3.24 |
| Place In Bucket, Move and Empty ( Labour) | 0.083333333 | 5.00 | 300.00 | 60 | 2 | R 13.34 | R 120.06 | 9 | 2.22 | 0.04 |
| Crane Cost | 0.083333333 | 5.00 | 300.00 | 60 | 1 | R 13.34 | R 120.06 | 9 | 1.11 | 0.02 |
| Spreading Of Concrete | 0.083333333 | 5.00 | 300.00 | 32 | 3 | R 13.34 | R 120.06 | 9 | 3.34 | 0.10 |
| Vibration (Labour) | 0.083333333 | 5.00 | 300.00 | 32 | 3 | R 13.34 | R 120.06 | 9 | 3.34 | 0.10 |
| Vibration (Machine) | 0.083333333 | 5.00 | 300.00 | 32 | 1 | R 5.56 | R 50.00 | 9 | 0.46 | 0.01 |

| **Total** | | | | | | | | | | **3.73** |
|---|---|---|---|---|---|---|---|---|---|---|

| **6th Phase - Stacking + Strapping + Grinding** | Hour | Minutes | Seconds | Metre | Number | Hourly Rate | Daily Rate | Hours/day | Total | Total/metre |
|---|---|---|---|---|---|---|---|---|---|---|
| Removal Off Line By Manitou | 0.016666667 | 1.00 | 60.00 | 120 | 1 | R 120.00 | R 1,080.00 | 9 | 2.00 | 0.02 |
| Manitou Operator | 0.016666667 | 1.00 | 60.00 | 120 | 1 | R 157.50 | R 1,417.50 | 9 | 2.63 | 0.02 |
| Strapping Into Bundles | 0.05 | 3.00 | 180.00 | 120 | 2 | R 13.34 | R 120.06 | 9 | 1.33 | 0.01 |
| Strapping Cost ( Material) | | | | 8 | 20 | R 0.28 | per metre | | 2.24 | 0.11 |
| Grinder + Blades | | | | 30000 | | R 600.00 | | | | 0.02 |
| Grind Wires Off Ends | 0.083333333 | 5.00 | 300.00 | 40 | 1 | R 13.34 | R 120.06 | 9 | 1.11 | 0.03 |
| **Total** | | | | | | | | | | **0.21** |

**Theoretical:**

| | |
|---|---|
| Total Cost Per Metre | R 7.55 |
| Sale Price Per Metre | R 12.95 |
| Profit per metre | R 5.40 |
| Profit % | 71.43% |

**Table 5 - Production on 140 x 70 Lintels**

## Production On 140 x 70 Lintels

**Concrete Cost (Material)** 17.60 kg/m

| | **Rate** | | **Weight kg (Per Block)** | **Quantity %** | **Wbarrow** | **Cost In R/m** |
|---|---|---|---|---|---|---|
| Crusher Sand | R 95.00 | | 3.466666667 | 19.70% | 1.3 | R 0.33 |
| River Sand | R 108.33 | | 3.466666667 | 19.70% | 1.3 | R 0.38 |
| Stone 6.7 mm | R 123.00 | | 0 | 0.00% | 0 | R 0.00 |
| Stone 9.5 mm | R 117.00 | | 0 | 0.00% | 0 | R 0.00 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Stone 13.2 mm | R 123.00 | | 5.333333333 | 30.30% | 2 | R 0.66 | |
| Water | R 1.50 | | 2.666666667 | 15.15% | 1 | R 0.00 | |
| Cement | R 960.00 | | 2.666666667 | 15.15% | 1 | R 2.56 | |
| | **1527.833333** | | **17.6** | 100.00% | **6.6** | R 3.92 | **R 3.92** |

| **1st Phase - Strip** | Hour | Minutes | Seconds | Metre | Number | Hourly Rate | Daily Rate | Hours/day | Total | Total/metre |
|---|---|---|---|---|---|---|---|---|---|---|
| Remove Lintel From Mould | 0.3667 | 22 | 1320 | 50 | 5 | R 13.34 | R 120.06 | 9.00 | 24.46 | 0.49 |
| Stack Lintel On The Side | 0.1667 | 10 | 600 | 50 | 7 | R 13.34 | R 120.06 | 9.00 | 15.56 | 0.31 |
| **Total** | | | | | | | | | | **0.80** |

| **2nd Phase - Clean Bays** | Hour | Minutes | Seconds | Metre | Number | Hourly Rate | Daily Rate | Hours/day | Total | Total/metre |
|---|---|---|---|---|---|---|---|---|---|---|
| Removal Of Large Pieces | 0.0694 | 4.166666667 | 250 | 50 | 1 | R 13.34 | R 120.06 | 9.00 | 8.338 | 0.17 |
| Clean Bays Using Compressor (Labour) | 0.1639 | 9.833333333 | 590 | 330 | 1 | R 13.34 | R 120.06 | 9.00 | 19.68 | 0.06 |
| Clean Bays Using Blower (Machine) | 0.1639 | 9.833333333 | 590 | 330 | 1 | 2 | 18 | 9.00 | 0.328 | 0.00 |
| **Total** | | | | | | | | | | **0.23** |

| **3rd Phase - Oiling** | Hour | Minutes | Seconds | Metre | Number | Hourly Rate | Daily Rate | Hours/day | Total | Total/metre |
|---|---|---|---|---|---|---|---|---|---|---|
| Oil Bays | 0.3667 | 22 | 1320 | 120 | 3 | R 13.34 | R 120.06 | 9.00 | 132.1 | 1.10 |
| Oil Cost | 5.0000 | litres | 0 | 275 | 1 | R 6.60 | per liter | 0.00 | 33 | 0.12 |
| **Total** | | | | | | | | | | **1.22** |

| **4th Phase Wire Spacer Placement** | Hour | Wires | Seconds | Metre | Number | Hourly Rate | Daily Rate | Hours/day | Total | Total/metre |
|---|---|---|---|---|---|---|---|---|---|---|
| Pull 1 Stand Of Wire | 0.0014 | 5 | 110 | 50 | 1 | R 13.34 | R 120.06 | 9.00 | 0.093 | 0.00 |
| Wire Cost | | 5 | | 50 | 1 | R 0.26 | per metre | | 1.3 | 1.30 |
| Place Wire Through Spacer | 0.0056 | 5 | 20 | 50 | 1 | R 13.34 | R 120.06 | 9.00 | 0.371 | 0.01 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Measure Lengths | | | | | | | | | | |
| Place Spacer | 0.0194 | | 70 | 40 | 1 | R 13.34 | R 120.06 | 9.00 | 0.259 | 0.01 |
| Tension Bay | 0.0917 | 5 | 330 | 50 | 2 | R 13.34 | R 120.06 | 9.00 | 2.446 | 0.05 |
| **Total** | | | | | | | | | | **1.36** |

| **5th Phase - Pouring + Vibration** | Hour | Minutes | Seconds | Metre | Number | Hourly Rate | Daily Rate | Hours/day | Total | Total/metre |
|---|---|---|---|---|---|---|---|---|---|---|
| Mix Concrete (Labour) | 0.0833 | 5 | 300 | 32 | 5 | R 13.34 | R 120.06 | 9.00 | 5.558 | 0.17 |
| Mix Concrete (Machine) | 0.0833 | 5 | 300 | 32 | 1 | R 13.34 | R 100.00 | 9.00 | 1.112 | 0.03 |
| Concrete Cost (see above) | | | | | | | | | | 3.92 |
| Place In Bucket, Move and Empty ( Labour) | 0.0833 | 5 | 300 | 60 | 2 | R 13.34 | R 120.06 | 9.00 | 2.223 | 0.04 |
| Crane Cost (labour) | 0.0833 | 5 | 300 | 60 | 1 | R 13.34 | R 120.06 | 9.00 | 1.112 | 0.02 |
| Spreading Of Concrete | 0.0833 | 5 | 300 | 32 | 3 | R 13.34 | R 120.06 | 9.00 | 3.335 | 0.10 |
| Vibration (Labour) | 0.0833 | 5 | 300 | 32 | 3 | R 13.34 | R 120.06 | 9.00 | 3.335 | 0.10 |
| Vibration (Machine) | 0.0833 | 5 | 300 | 32 | 1 | R 5.56 | R 50.00 | 9.00 | 0.463 | 0.01 |
| **Total** | | | | | | | | | | **4.41** |

| **6th Phase - Stacking + Strapping + Grinding** | Hour | Minutes | Seconds | Metre | Number | Hourly Rate | Daily Rate | Hours/day | Total | Total/metre |
|---|---|---|---|---|---|---|---|---|---|---|
| Removal Off Line By Manitou (Machine) | 0.0167 | 1 | 60 | 120 | 1 | R 120.00 | R 1,080.00 | 9.00 | 2 | 0.02 |
| Manitou Operator | 0.0167 | 1 | 60 | 120 | 1 | R 17.50 | R 157.50 | 9.00 | 0.292 | 0.00 |
| Strapping Into Bundles | 0.0500 | 3 | 180 | 120 | 2 | R 13.34 | R 120.06 | 9.00 | 1.334 | 0.01 |
| Strapping Cost ( Material) | | | | 8 | 100 | R 0.28 | per metre | | 2.24 | 0.02 |
| Grind Wires Off Ends | 0.0833 | 5 | 300 | 40 | 1 | R 13.34 | R 120.06 | 9.00 | 1.112 | 0.03 |
| Grinder + Blades | | | | 30000 | | R 600.00 | | | | 0.02 |
| **Total** | | | | | | | | | | **0.10** |

**Theoretical:**

| | |
|---|---|
| Total Cost Per Metre | R 8.13 |

| | |
|---|---|
| Sale Price Per Metre | R 15.50 |
| Profit per metre | R 7.37 |
| Profit % | 90.76% |

**Table 6 - Production on FT 90 Blocks**

## Production On FT 90 Blocks

**Labour Cost**

| | Hour | Minutes | Seconds | Blocks | Labourers | Hourly Rate | Labour Daily Rate | Hours / day | Efficiency | Total | Total/ block |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Concrete Labour (Mixing) | 1 | 60 | 3600 | 240 | 2 | 13.33 | R 119.97 | 9 | 100.00% | R 26.66 | **R 0.11** |
| Placement Of Concrete Into Mould | 1 | 60 | 3600 | 240 | 1 | 13.33 | R 119.97 | 9 | 100.00% | R 13.33 | **R 0.06** |
| Placing Pallet | 1 | 60 | 3600 | 240 | 2 | 13.33 | R 119.97 | 9 | 100.00% | R 26.66 | **R 0.11** |
| Cleaning + Oiling | 1 | 60 | 3600 | 240 | 1 | 13.33 | R 119.97 | 9 | 100.00% | R 13.33 | **R 0.06** |
| Stacking Blocks Onto Pallet | 0.0583 | 3.5 | 210 | 10 | 1 | 13.33 | R 119.97 | 9 | 100.00% | R 0.78 | **R 0.08** |
| Manitou Removal + Stacking | 0.1 | 6 | 360 | 50 | 1 | 120 | R 1,080.00 | 9 | 100.00% | R 12.00 | **R 0.24** |

**Concrete Cost** 17.7 kg

| | Rate | Weight kg (Per Block) | Quantity % | Buckets | Cost In Weight per Block |
|---|---|---|---|---|---|
| Crusher Sand | R 95.00 | 10.34157303 | 0.5842697 | 6.5 | R 0.98 |
| River Sand | R 108.33 | 1.591011236 | 0.0898876 | 1 | R 0.17 |
| Stone 6.7 mm | R 123.00 | | 0 | | R 0.00 |
| Stone 9.5 mm | R 117.00 | | 0 | | R 0.00 |
| Stone 13.2 mm | R 123.00 | 3.182022472 | 0.1797753 | 2 | R 0.39 |

| | | | | | |
|---|---|---|---|---|---|
| Water | R 1.50 | 1.591011236 | 0.0898876 | 1 | R 0.00 |
| Cement | R 910.40 | 0.994382022 | 0.0561798 | 0.625 | R 0.91 |
| | **1478.233333** | **17.7** | **1** | **11.125** | **R 2.45** |

| | Blocks |
|---|---|
| **Mould + Pallet Wear** | R 0.10 |

**Theoretical:**

| | | | |
|---|---|---|---|
| Total Cost Per Block | **R 3.20** | | |
| Sale Price | R 5.07 | | |
| Profit per block | R 1.87 | | |
| Profit % | 58.20% | | |
| For Profit Of | 40.00% | Sell At | R 4.49 |
| Pallets | 350 | | |
| Blocks Per Day | 1400 | | |
| Expense Per Day | R 4,486.83 | | |
| Sales Per Day | R 7,098.00 | | |
| Profit Per Day | R 2,611.17 | | |
| Profit Per Month | R 57,445.76 | | |

**Table 7 - Production on FT 200 Blocks**

## Production On FT 200 Blocks

### Labour Cost

| | Hour | Minutes | Seconds | Pallets | Labourers | Hourly Rate | Labour Daily Rate | Hours / day | Efficiency | Total | Total/ block |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Concrete Labour (Mixing) | 1 | 60 | 3600 | 150 | 3 | 13.33 | R 119.97 | 9 | 100.00% | R 39.99 | **R 0.27** |
| Placement Of Concrete Into Mould | 1 | 60 | 3600 | 150 | 3 | 13.33 | R 119.97 | 9 | 100.00% | R 39.99 | **R 0.27** |
| Placing Pallet | 1 | 60 | 3600 | 150 | 2 | 13.33 | R 119.97 | 9 | 100.00% | R 26.66 | **R 0.18** |
| Cleaning + Oiling | 1 | 60 | 3600 | 150 | 1 | 13.33 | R 119.97 | 9 | 100.00% | R 13.33 | **R 0.09** |
| Stacking Blocks Onto Pallet | 0.0583 | 3.5 | 210 | 10 | 3 | 13.33 | R 119.97 | 9 | 100.00% | R 2.33 | **R 0.23** |
| Manitou Removal + Stacking | 0.1 | 6 | 360 | 50 | 1 | 120 | R 1,080.00 | 9 | 100.00% | R 12.00 | **R 0.24** |

**Concrete Cost** 18 kg

| | Rate | Weight kg (Per Block) | Quantity % | Buckets | Cost In Weight per Block |
|---|---|---|---|---|---|
| Crusher Sand | R 95.00 | 9.957447 | 0.55319149 | 6.5 | R 0.95 |
| River Sand | R 108.33 | 1.531915 | 0.08510638 | 1 | R 0.17 |
| Stone 6.7 mm | R 123.00 | | 0 | | R 0.00 |
| Stone 9.5 mm | R 117.00 | | 0 | | R 0.00 |
| Stone 13.2 mm | R 123.00 | 3.06383 | 0.17021277 | 2 | R 0.38 |
| Water | R 1.50 | 1.531915 | 0.085106 | 1 | R 0.00 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | 38 | | | |
| Cement | R 45.52 | 1.914894 | 0.106382 98 | 1.25 | R 0.09 | |
| | **613.3533333** | **18** | **1** | **11.75** | **R 1.58** | **R 1.58** |

| | |
|---|---|
| **Mould + Pallet Wear** | R 0.10 |

| | | | |
|---|---|---|---|
| Total Cost Per Block | **R 2.95** | | |
| Sale Price | R 4.50 | | |
| Profit per block | R 1.55 | | |
| Profit % | 52.47% | | |
| For Profit Of | 40.00% | Sell At | R 4.13 |
| Blocks Per Day | 800 | | |
| Expense Per Day | R 2,361.04 | | |
| Sales Per Day | R 3,600.00 | | |
| Profit Per Day | R 1,238.96 | | |
| Profit Per Month | R 27,257.04 | | |

**Table 8 - Production on Lattice Beams**

## Production on Lattice Beams

**Concrete Cost (Material)** 17.48 kg/m

| | Rate | | Weight kg (Per Block) | Quantity % | Wbarrow | Cost In R/m |
|---|---|---|---|---|---|---|
| Crusher Sand | R 95.00 | | 2.99043 | 17.11% | 1.3 | R 0.28 |
| River Sand | R 108.33 | | 2.99043 | 17.11% | 1.3 | R 0.32 |
| Stone 6.7 mm | R | | 0 | 0.00% | | R 0.00 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 123.00 | | | | | | |
| Stone 9.5 mm | R 117.00 | | 0 | 0.00% | | R 0.00 | |
| Stone 13.2 mm | R 123.00 | | 4.60066 | 26.32% | 2 | R 0.57 | |
| Water | R 1.50 | | 2.30033 | 13.16% | 1 | R 0.00 | |
| Cement | R 48.00 | | 4.60066 | 26.32% | 2 | R 0.22 | |
| | **615.833** | | **17.4825** | 1 | **7.6** | R 1.40 | **R 1.40** |

**Phase Breakdown**

| **1st Phase - Strip** | Hour | Minutes | Seconds | Metre | Number | Hourly Rate | Daily Rate | Hours /day | Total | Total/ metre |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| Remove Lintel From Mould | 0.36667 | 22 | 1320 | 50 | 5 | R 13.34 | R 120.06 | 9 | R 24.46 | R 0.49 |
| Stack Lintel On The Side | 0.16667 | 10 | 600 | 21 | 7 | R 13.34 | R 120.06 | 9 | R 15.56 | R 0.74 |
| **Total** | | | | | | | | | | **R 1.23** |

| **2nd Phase - Clean Bays** | Hour | Minutes | Seconds | Metre | Number | Hourly Rate | Daily Rate | Hours /day | Total | Total/ metre |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| Removal Of Large Pieces | 0.06944 | 4.166666667 | 250 | 50 | 1 | R 13.34 | R 120.06 | 9 | R 8.34 | R 0.17 |
| Clean Bays Using Compressor (Labour) | 0.16389 | 9.833333333 | 590 | 330 | 1 | R 13.34 | R 120.06 | 9 | R 19.68 | R 0.06 |
| Clean Bays Using Compressor (Compressor) | 0.16389 | 9.833333333 | 590 | 330 | 1 | R 250.00 | R 2,250.00 | 9 | R 40.97 | R 0.12 |
| **Total** | | | | | | | | | | **R 0.35** |

| **3rd Phase - Oiling** | Hour | Minutes | Seconds | Metre | Number | Hourly Rate | Daily Rate | Hours /day | Total | Total/ metre |
|---|---|---|---|---|---|---|---|---|---|---|

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Oil Bays | 0.36667 | 22 | 1320 | 120 | 3 | R 13.34 | R 120.06 | 9 | R 132.07 | R 1.10 |
| Oil Cost | 5 | litres | 0 | 275 | 1 | R 6.60 | per liter | 0 | R 33.00 | R 0.12 |
| **Total** | | | | | | | | | | **R 1.22** |

| **4th Phase Wire Spacer Placement** | Hour | Wires | Seconds | Metre | Number | Hourly Rate | Daily Rate | Hours /day | Total | Total/ metre |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| Pull 1 Stand Of Wire | 0.00167 | 6 | 110 | 50 | 1 | R 13.34 | R 120.06 | 9 | R 0.13 | R 0.00 |
| Wire Cost | | 6 | | 50 | 1 | R 0.26 | per metre | | R 1.56 | R 1.56 |
| Place Wire Through Spacer | 0.00556 | 6 | 20 | 50 | 1 | R 13.34 | R 120.06 | 9 | R 0.44 | R 0.01 |
| Measure Lengths | | | | | | | | | | |
| Place Spacer | 0.01944 | | 70 | 40 | 1 | R 13.34 | R 120.06 | 9 | R 0.26 | R 0.01 |
| Tension Bay | 0.09167 | 6 | 330 | 50 | 2 | R 13.34 | R 120.06 | 9 | R 2.45 | R 0.05 |
| **Total** | | | | | | | | | | **R 1.63** |

| **5th Phase - Pouring + Vibration** | Hour | Minutes | Seconds | Metre | Number | Hourly Rate | Daily Rate | Hours/ day | Total | Total/ metre |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| Mix Concrete (Labour) | 0.08333 | 5 | 300 | 32 | 5 | R 13.34 | R 120.06 | 9 | R 5.56 | R 0.17 |
| Mix Concrete (Machine) | 0.08333 | 5 | 300 | 32 | 1 | R 13.34 | R 120.06 | 9 | R 1.11 | R 0.03 |
| Concrete Cost (see above) | | | | | | | | | | R 1.40 |
| Place In Bucket, Move and Empty ( Labour) | 0.08333 | 5 | 300 | 60 | 2 | R 13.34 | R 120.06 | 9 | R 2.22 | R 0.04 |
| Crane Cost | 0.08333 | 5 | 300 | 60 | 1 | R 13.34 | R 120.06 | 9 | R 1.11 | R 0.02 |
| Spreading Of Concrete | 0.08333 | 5 | 300 | 32 | 3 | R 13.34 | R 120.06 | 9 | R 3.34 | R 0.10 |
| Vibration (Labour) | 0.08333 | 5 | 300 | 32 | 3 | R 13.34 | R 120.06 | 9 | R 3.34 | R 0.10 |
| Vibration (Machine) | 0.08333 | 5 | 300 | 32 | 1 | R 13.34 | R 120.06 | 9 | R 1.11 | R 0.03 |
| **Total** | | | | | | | | | | **R 1.91** |

| 6th Phase - Stacking + Strapping + Grinding | Hour | Minutes | Seconds | Metre | Number | Hourly Rate | Daily Rate | Hours/ day | Total | Total/ metre |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| Removal Off Line By Manitou | 0.01667 | 1 | 60 | 120 | 1 | R 120.00 | R 1,080.00 | 9 | R 2.00 | R 0.02 |
| Manitou Operator | 0.01667 | 1 | 60 | 120 | 1 | R 157.50 | R 1,417.50 | 9 | R 2.63 | R 0.02 |
| Strapping Into Bundles | 0.05 | 3 | 180 | 120 | 2 | R 13.34 | R 120.06 | 9 | R 1.33 | R 0.01 |
| Strapping Cost ( Material) | | | | 8 | 20 | R 0.28 | per metre | | R 2.24 | R 0.11 |
| Grind Wires Off Ends | 0.08333 | 5 | 300 | 40 | 1 | R 13.34 | R 120.06 | 9 | R 1.11 | R 0.03 |
| **Total** | | | | | | | | | | **R 0.19** |

**Theoretical:**

| | |
|---|---|
| Total Cost Per Metre | R 6.17 |
| Sale Price Per Metre | R 12.00 |
| Profit per metre | R 5.83 |
| Profit % | 94.41% |

**Table 99 - Lintels Monthly Production**

| MONTH | DESCRIPTION | METRES |
|---|---|---|
| May '07 | Lintels 110mm | 13 200,0 |
| June'07 | Lintels 110mm | 12 600,0 |
| July'07 | Lintels 110mm | 8 400,0 |
| Aug '07 | Lintels 110mm | 8 400,0 |
| Sept'07 | Lintels 110mm | 7 800,0 |
| Oct '07 | Lintels 110mm | 8 400,0 |
| Nov '07 | Lintels 110mm | 12 600,0 |
| Dec '07 | Lintels 110mm | 4 200,0 |
| Jan '08 | Lintels 110mm | 3 600,0 |
| Feb '08 | Lintels 110mm | 13 200,0 |
| Mar '08 | Lintels 110mm | 12 000,0 |
| Apr '08 | Lintels 110mm | 12 000.0 |

**Table 100 - FT 90 Monthly Production**

| MONTH | DESCRIPTION | UNITS |
|---|---|---|
| May '07 | FT 90 Block | 8 800 |
| June'07 | FT 90 Block | 9 000 |
| July'07 | FT 90 Block | 7 000 |
| Aug '07 | FT 90 Block | 8 000 |
| Sept'07 | FT 90 Block | 9 200 |
| Oct '07 | FT 90 Block | 9 000 |
| Nov '07 | FT 90 Block | 9 000 |
| Dec '07 | FT 90 Block | 4 000 |
| Jan '08 | FT 90 Block | 3 000 |
| Feb '08 | FT 90 Block | 6 000 |
| Mar '08 | FT 90 Block | 9 000 |
| Apr '08 | FT 90 Block | 8 800 |

**Table 11 -FT 200 Monthly Production**

| MONTH | DESCRIPTION | UNITS |
|---|---|---|
| May '07 | FT 200 Block | 3 850 |
| June'07 | FT 200 Block | 4 000 |
| July'07 | FT 200 Block | 3 600 |
| Aug '07 | FT 200 Block | 4 100 |
| Sept'07 | FT 200 Block | 3 800 |
| Oct '07 | FT 200 Block | 4 600 |
| Nov '07 | FT 200 Block | 4 800 |
| Dec '07 | FT 200 Block | 1 600 |
| Jan '08 | FT 200 Block | 1 000 |
| Feb '08 | FT 200 Block | 3 600 |
| Mar '08 | FT 200 Block | 4 100 |
| Apr '08 | FT 200 Block | 2 750 |

**Table 112 - Curb Monthly Production Figures**

| MONTH | DESCRIPTION | MASS/kg |
|---|---|---|
| May ‘07 | Curbs | 27 500 |
| June’07 | Curbs | 30 000 |
| July’07 | Curbs | 27 500 |
| Aug ‘07 | Curbs | 85 000 |
| Sept’07 | Curbs | 85 000 |
| Oct ‘07 | Curbs | 65 000 |
| Nov ‘07 | Curbs | 80 000 |
| Dec ‘07 | Curbs | 30 000 |
| Jan ‘08 | Curbs | 30 000 |
| Feb ‘08 | Curbs | 65 000 |
| Mar ‘08 | Curbs | 100 000 |
| Apr ‘08 | Curbs | 100 000 |

# References

Bentley, L.D. & Whitten, J.L., 2007. *Systems Analysis & Design for the Global Enterprise.* 7th ed. Mcgraw-Hill: Purdue University, West Lafayette, IN

Dawood, N.N. & Neale, R.H., 1990. A Survey of Current Production Planning Practices in the Precast Industry. *Construction Management and Economics* [Online] 8, p365-383
Available at: http://www.scholar.google.co.za/ [accessed 13th May 2008]

Dawood, N.N., 1994. Developing a Production Management Modeling Approach for Precast Concrete Building Products. *Construction Management and Economics* [Online] 12, p 343 – 383
Available at: http://www.scholar.google.co.za/ [accessed 13th May 2008]

Babontin-Bravo, E., 1990. Simulation of Large Precast Operations. *Proceedings of the 1998 Winter Simulation Conference*. D.J. Medeiros, E.F. Watson, J.S. Carson and M.S. Manivannan, eds. [Online] p1311 – 1317
Available at: http://www.scholar.google.co.za/ [accessed 13th May 2008]

Tiong, R.L.K., et al. 2007. Simulation Based Planning for Precast Production with Two Critical *Resources. Proceedings of the 2007 Winter Simulation Conference* S. G. Henderson, B. Biller, M.-H. Hsieh, J. Shortle, J. D. Tew, and R. R. Barton, eds. [Online] p 2104 - 2111
Available at: http://www.scholar.google.co.za/ [accessed 15th May 2008]

Branton, P. 1969. A Field Study of Repetitive Manual Work in Relation to Accidents at the Work Place. *The International Journal of Production Research 197, Vol 8 No 2* [Online] p 93 -107
Available at: http://www.scholar.google.co.za/ [accessed 15th May 2008]

Donald, F.R., 1953. Work Satisfaction and Social Reward Quota. *American Sociological Review*, Vol. 18, No. 5, (Oct., 1953), [Online] pp. 507-514

Available at: http://www.jstor.org/stable/2087434

Bao, S., 2004. Hand-Intensive Jobs. *Professional Safety.* 49, 1; ABI/INFORM Global [Online] p 28 – 34
Available at: http://www.scholar.google.co.za/ [accessed 15th May 2008]

Copeland, J., 2003 Ergonomic Aids for Industrial Workers. *Occupational Hazards.* 65, 12; ABI/INFORM Global [Online] p 50 - 52
Available at: http://www.scholar.google.co.za/ [accessed 15th May 2008]

Microsoft Office - Word 2007

Microsoft Office - Visio 2000

Rockwell Simulation – ARENA 10.0