Relocation Feasibility Study and Communication Improvement of Microgreen Production at PicoGro CC

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at the

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DECLARATION OF ORIGINALITY

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Declaration

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EXECUTIVE SUMMARY

The aim of this project is to determine the feasibility of the relocation of greenhouses at PicoGro CC. Edible greens called microgreens are produced at Pico 1, a farm located three kilometres away from where the microgreens are packaged and shipped. Microgreens are highly sensitive to their environment and can easily be damaged during harvesting or if handled incorrectly. Because microgreens are harvested while they are young, they need to be kept at precisely the correct temperatures to extend their short shelf life. Pico1 is experiencing problems with the management of microgreen production. The internal supply chain from sowing to shipping is frequently interrupted by poor communication and coordination. Orders are often fulfilled late or low-quality produce is supplied due to poor information flow. Other scheduling problems relating to the sowing and cutting of the produce that contribute to late delivery and low-quality product are also present.

This project aims to consider three alternative options, namely greenhouse relocation, implementation of an information system and taking no action. The feasibility of relocating the greenhouses from Pico1 to the main farm so that unnecessary handling can be eliminated was investigated. The savings associated with the relocation included labour, overtime wages and fuel costs. The total cost of relocating the greenhouses was calculated to be R2 195 970,00 and the Net Present Value for this project was calculated as -R576 000,00, with the negative value indicating a loss.

An additional solution that was considered was the implementation of an information system. The basic information system was designed using several diagrams and techniques resulting in the compilation of an entity relationship diagram. The information system is best suited for use in a *Microsoft Access* database which was compared to *Microsoft Dynamics 365* and found to be a better option due to price and customisability. An extension of this option was suggested in which a visual information dashboard is integrated into the information system using *Microsoft Visio*. The dashboard would allow employees to record data in real time and from their location in the greenhouse using a portable device. The resulting data could be analysed and used to improve operations.

The three options were compared and scored according to financial feasibility, effectiveness in addressing the problem and ease of implementation. It was suggested that the best option would be to implement an information system as it is the least risky option and allows for future development. The information system should be developed further and linked to systems regarding other aspects of the company to form a useful management tool.

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ACRONYMS AND NOTATION

LANGUAGE

The language of the report is English (South Africa).

All numerical values are given according to the convention in South Africa, which uses a ‘comma’ to designate real numbers (i.e., R2.345,12 or R2 345,12), instead of the ‘dot’ as in many other countries (i.e., R2,345.12).

ACRONYMS

SCOR: Supply Chain Operations Reference

SCC: Supply Chain Council

BPMN: Business Process Model and Notation

WBS: Work Breakdown Structure

NPV: Net Present Value

GRN: Goods Received Note

ERD: Entity Relationship Diagram

GIS: Geographic Information Systems

Chapter 1

Introduction

1.1 Background

PicoGro CC Began in 1995 as a company in the agricultural sector that produced a range of edible flowers and essential oils. Located in the Western parts of Midrand in Johannesburg, the company started as a single piece of land where the owner installed greenhouses to grow her crops. The company quickly became a supplier to many high-end restaurants and fresh food retailers.

Because of the rapid growth of the company, the original farm, now called Pico1, became too small and expansion was needed. Expansion proved challenging however, as no land was available directly next to the existing farm. Land had to be purchased about 1,3 kilometres away from the original farm to facilitate the required growth. Over time newer, larger green houses were built on the new farms: Pico2, 3 and 4. The new farms became the hub for the produce and the main offices and packaging facilities were moved there, thus the produce needed to be transported from Pico 1 to the main farm for storage and packaging. Transportation of produce is done via cooler-boxes packed in the bed of a truck with a canopy. Figure 1 shows the distance between Pico1 and the main farm labelled PicoGro CC on the map.

Figure 1: A map showing the distance between Pico1 and the main offices situated at PicoGro CC. Image courtesy of Google Maps.

Currently the major output of Pico 1 is microgreens. Microgreens are leafy greens produced from a variety of vegetable, herb and grain plants, harvested prematurely while the plant is still tender (Kyriacou et al., 2016). The microgreens are pre-planted into trays before being transferred into a greenhouse. One of the biggest challenges faced in the expansion of microgreen farming is the sensitivity to harvesting and post harvesting conditions. Microgreens need to be handled with care during the harvesting process and transportation. Because the nature of microgreen farming is that the harvest is done when the plant is very young, the crops begin to die as soon as they are cut. Because of their rapid deterioration, microgreens have a very short shelf life in comparison to most vegetables.

Recently, PicoGro has been experiencing managerial problems with Pico1. Because of the rapid expansion, Pico1 is currently running without an on-site manager. The absence of a manager has caused the coordination in the supply of microgreens to deteriorate, causing loss of stock and frequent miscommunications between Pico1 and the sales department. The microgreens are often handled or packed incorrectly for transportation, fridge temperatures are set incorrectly and due to the condition of the road, transportation from Pico1 to the main farm results in damaged produce. Orders are often filled late because of poor communication, causing missed flights, penalties, and poor product quality. Some orders are not filled because of inaccurate perceived stock levels.

A proposed solution to this problem is to eliminate the need to transport the produce over the short distance by relocating the greenhouses to the main farm. Relocation would potentially reduce the miscommunications along the supply chain and allow a shorter lead time between harvesting and packaging. The relocation of the greenhouse could potentially be an expensive process and insight is needed into whether this will be a feasible option. Some alternative solutions also need investigation.

1.2 Problem Statement

Pico1 is currently running without an on-site manager. Communication between the farms has been flagged as an issue, making it difficult for Pico1 to supply the main farm with the required stock on time and in the correct quantities. Lack of supervision and communication has also taken a toll on the quality of the product. Because of the lack of management many of the specific conditions required for transportation and storage are not met. When orders are placed, the supervisor uses intuition and memory to determine if the product is available, often leading to incorrect amounts of product being promised to customers or available product not being sold. The communication problems also cause delays in the harvesting of produce at Pico1 which disrupts packaging operations and often leads to employees working overtime to prepare orders for customers.

The conditions under which Pico1 is being run have been causing frustrations, financial losses and a decrease in the quality of microgreens produced. To overcome the current limitations, it was suggested that the greenhouses at Pico1 be relocated to Pico4. The owner wishes to know what the current losses are and if it would be feasible to relocate the greenhouses. It is also required to investigate possible alternative solutions to the management problems causing the supply issues.

Areas that will need to be taken into consideration are as follows:

- Deconstruction and reconstruction of greenhouse structure.
- Refrigeration storage of microgreens.
- Transportation logistics of microgreens.
- Coordination and communication between farms and possible improvements.
- The possible uses for Pico 1 if relocation takes place.
- Advantages and disadvantages towards the strategic location of the greenhouse.
- Impact of relocation and other improvements on the work force.

1.3 Project Aim

An investigation needs to be done to compare the advantages and disadvantages of the relocation of the greenhouses from Pico1 to Pico4, considering the cost, the effect on the supply chain and the social impact. Alternative management solutions should be identified to overcome the existing constraints and improve communication, scheduling and coordination in the production of microgreens.

1.4 Project Approach

This project will be broken up into 4 phases as shown in Table 1 below. Each phase addresses an important stage of the project necessary to achieve the project aim.

Table 1: The four phases of the project approach.

Phase I	1.1 Data collection 1.2 Literature study
Phase II	2.1 Supply chain model 2.2 Areas of concern 2.3 Impact of relocation on supply chain 2.4 Impact of relocation on operations 2.5 Key success factors
Phase III	3.1 Calculations and financial considerations 3.2 Comparison and feasibility
Phase IV	4.1 Investigation of alternatives 4.2 Final recommendations 4.3 Report submission

Phase I: Literature study and data collection

1.1 Collect data on current operations, procedures and systems, to gain a better understanding of the current state of production and management techniques.

1.2 Conduct literature studies on the following topics:

- Farm relocation
- Greenhouse construction
- Supply chain and logistics management techniques such as location planning
- The application of such techniques to the agricultural industry
- Facilities planning principles
- Production costing
- Land utilisation
- Simulation modelling techniques
- Information system design techniques
- Cold chain logistics

Phase II: Supply Chain Evaluation

2.1 Model the current internal supply chain network for the production of microgreens from planting to shipping and map out supply chain links to give a clearer picture of interconnections among the farms and highlight communication channels.

2.2 Identify areas that hinder supply chain flow and investigate these areas to determine the focal points along the supply chain that will be critical to improvement. The links will be flagged as problematic.

2.3 Evaluate how the relocation of the greenhouse will affect the internal supply chain and consider the strategic advantages and disadvantages of having the greenhouse in a new location.

2.4 Evaluate how the relocation of the greenhouse will affect the production operations and identify important factors to consider.

Phase III: Comparisons

3.1 Calculate current production losses, potential gains due to relocation and cost to relocate. Comparing the total losses and gains will provide a picture of the financial impact on the company. Engineering economics and costing principles will be used.

3.2 Compare costs and make a conclusion about the feasibility of the relocation of the greenhouse. Considering the costs will give an indication of whether the project is financially feasible. A conclusion can then be made, and recommendations given.

3.3 Investigate potential social impacts and provide a summary.

Phase IV: Recommendations and Report

4.1 Investigate possible management techniques that could be implemented as alternative solutions to the problem areas identified earlier, including the application of supply chain and process management techniques.

4.2 Make final recommendations as to whether the project is worth completing, comparing the various alternatives and making a conclusion.

4.3 Compile the project report document and prepare oral presentation and poster.

1.4.1 Assumptions and Scope

Some assumptions will be made to clearly define the boundaries of the project scope. Only the internal supply chain will be considered as far as is reasonable without affecting the accuracy of results. The focus will be on the management of the supply chain in relation to information flow and logistics. Very little attention will be given to the technical processes or methods of operations involved as far as it does not affect the management systems involved.

Chapter 2

Literature Review

The problem stated in the previous chapter touches on a range of different aspects. Various engineering techniques need to be investigated to fully understand the problem and its possible solutions as well as gain insight into which solution best solves the problem and how best to design the solution to suit the needs of the company. Academic literature was consulted on each of the topics and the findings thereof summarised below.

2.1 Post-harvest Conditions Affecting Shelf Life

Microgreen vegetables are a range of leafy greens that have become more popular in recent years for their use in high end culinary culture and for their health benefits. The specific range of vegetable leaves are grown from the seeds of vegetables, grains and various herbs, and are harvested while at an immature stage of their development, usually between 7 and 21 days (Kyriacou et al., 2016). Because the leaves are still extremely tender during harvesting, microgreens are known to have an extremely short shelf life and tend to deteriorate at a high rate.

Shelf life of any fruit or vegetable is dependent on several factors depending on the type, and its preferred conditions. The factors that are most relevant to this project are the post-harvest mechanical damage and temperature. As more of these factors are introduced, the rate of deterioration increases (Alice, 1999). To increase shelf life, these factors need to be controlled and monitored, and their effect on the produce minimised. In the case of microgreens many of the effects of poor post-harvest conditions only become apparent towards the end of the products life, making it extremely difficult to manage quality by inspection alone.

2.1.1 Temperature

High temperature is considered the biggest factor influencing the deterioration of fruit and vegetables. It has thus become common practice for many fruit and vegetable types to be frozen for transportation and packaging as this reduces their metabolism rate, the rate at which reactions and energy transfers take place within the plant cells. It is extremely important to begin the cooling of the produce as soon as possible after harvesting as deterioration begins immediately (Jongen).

The success of freezing and thawing vegetables in a way that maintains the consumer’s standard of freshness depends largely on a property called turgor (Kennedy). Turgor refers to the retention of water inside the plant’s cells. During freezing, water inside the plant cells expands due to the molecular properties of water, this can lead to the rupturing of the cells which causes water loss and has a direct impact on quality.

There are several ways that the effect of temperature on fruit and vegetables can be reduced after being harvested, these include:

- Precooling: reducing the temperature of the produce to between 3 and 6 °C in preparation for transport. Precooling is usually done using cold air.
- Icing: placing a layer of crushed ice on top of the produce.
- Room cooling: placing the produce in a refrigerated room. This is the most economical method.
- Hydro-cooling: the produce is cooled using cold water instead of air.

Pico1 is in the western parts of Midrand, Johannesburg, experiencing average maximum temperatures of 28° C in the spring and summer seasons. The relatively high temperatures make the microgreens vulnerable to increased metabolism and thus faster deterioration.

2.1.2 Mechanical Damage

Mechanical damage refers to the physical wounds inflicted on the produce through poor handling or transportation methods. Because of the sensitive nature of microgreens, even the slightest mishandling can influence the quality of the product received by the customer. The most critical stages are those between harvesting and storage. If the crop is harvested incorrectly, handled incorrectly after harvesting or packed incorrectly for transportation the shelf life can be drastically decreased.

Mishandling can cause damage to the surface of the produce which in turn may lead to bruising, water loss and pathogen infection (Jongen), all of which decrease the quality of the produce. Fruit and vegetables can be placed in several types of containers after harvesting to reduce mechanical damage. Some containers include polyethylene bags, plastic and wooden crates and bulk bins (Simson and Straus, 2010). After harvesting, the produce is usually packed in refrigerated trucks for transport however such trucks are not always available and often open trucks are used. The use of open trucks may lead to produce falling off the truck during transit.

2.2 Cold Chain Logistics

As stated above it is critical for produce to be maintained at the appropriate temperature throughout the journey from harvest to consumer to maintain freshness. The supply chain of produce maintained at low temperature is called a cold chain and requires smooth transitioning between the stages of distribution to the customer. (Burnson (2015)) mentions several focus points that should be considered when evaluating and improving a cold chain:

- Number of movements a product goes through
- Co-location of facilities and their effects on the number of movements
- Accessibility of operations to cold chain technology
- Accessibility of locations to cold chain technology
- Proximity to markets
- Flexibility

2.2.1 Co-location of Facilities

Co-location refers to multiple competitors, locating near one another. Possible increased efficiencies that are associated with co-location are described below (van den Heuvel et al., 2014).

- Locating multiple facilities near one another tends to have the advantage that the required labour is within proximity. A larger market pool implies that specialised labour is more readily available.
- Knowledge and information become cheaper and more available over shorter distances. Being located near other facilities allows information to be shared more efficiently. Informal knowledge is also transferred through actions and culture.
- Locating near members of the supply chain makes maintenance and repairs more efficient due to reduced travel time and shared facilities.
- Proximity also means reduced transportation costs because of lower fuel usage.

Some possible disadvantages if co-location are also mentioned by van den Heuvel et al. (2014):

- Co-location may lead to road congestion. Impacting transportation time and costs.
- High demand for desirable land may cause property costs to increase making co-location costly.

A study was commenced by van den Heuvel et al. (2014) on the above topics in an attempt to conclude if they carry any weight in application to the real world. The study was not able to draw any conclusions. Although these factors are implied to be relevant to large scale co-location, and limited research has been done into their practical application, they may still form points to take into consideration when evaluating the effects of relocation from a supply chain perspective.

2.2.2 Transportation Cost

One of the main factors to consider when selecting a site as part of evaluating and planning a supply chain is the transportation cost. The cost of moving goods between facilities has a big impact on choice of location since these costs directly increase the cost of supplying goods to the customer. The formula for calculating transportation cost according to Matsuoka et al. (2017) is given as:

$$C_p = \sum_{s=1}^{S} R_s C_s + C_m \tag{1}$$

Where:

$C_p \triangleq the\ transportation\ cost\ to\ location\ p$

$R_s \triangleq the\ number\ of\ trips\ from\ location\ s$

$C_s \triangleq the\ cost\ per\ trip\ from\ location\ s$

$S \triangleq the\ number\ of\ pick\ up\ locations$

$C_m \triangleq the\ maintenance\ cost$

The cost C_s incorporates the cost of fuel and tolls. The above model takes into consideration multiple pickup and delivery locations in a geographical area. The formula can be used as the basis for calculating the transportation cost. (Matsuoka et al. (2017)) also provides a formula for calculating the fuel cost which can be adjusted to form:

$$C_f = P_f \left(\sum_{i=1}^{I} \frac{d_i}{f_i} \right) \tag{2}$$

Where:

$P_f \triangleq the\ price\ of\ fuel$

$d_i \triangleq the\ length\ of\ road\ i \in I$

$f_i \triangleq the\ fuel\ consumption\ on\ road\ i \in I$

2.2.3 Supply Chain Operations Reference Model

The Supply Chain Operations Reference (SCOR) model is a standardised model that serves as a reference for planning and evaluating the configuration of a supply chain. It was developed by the Supply

Chain Council (SCC) in an effort to combine business process re-engineering, benchmarking, and process measurement (Li et al., 2011).

The SCOR model has five categories that focus on different aspects for each section of the supply chain as shown in Figure 2. The Plan category overarches the other four categories. Each of these categories cascade in to four levels, for the scope of this document only the top two levels (Top level and Configuration Level) taken from (Bolstorff and Rosenbaum (2003)) will be explored. Each category and level have a code attached, given in parentheses. They are:

- **Plan** (P)
    - The supply chain (P1)
    - Sourcing (P2)
    - Making (P3)
    - Delivering (P4)
    - Returning (P5)
- **Source** (S)
    - Stocked product (S1)
    - Make-to-order product (S2)
    - Engineer to order product (S3)
- **Make** (M)
    - Made-to-stock (M1)
    - Made-to-order (M2)
    - Engineer-to-order (M3)
- **Deliver** (D)
    - Stocked product (D1)
    - Make-to-order product (D2)
    - Engineer-to-order product (D3)
    - Retail product (D4)
- **Return** (R)
    - Source return defective product (SR1)
    - Deliver return defective product (DR1)
    - Source return MRO product (SR2)
    - Deliver return MRO product (DR2)
    - Source return excess product (SR3)
    - Deliver return excess product (DR3)

Figure 2: Map of SCOR categories in the supply chain (Li et al., 2011).

Along with the categories some metrics that have been designed to help manage the performance of the supply chain, given in Table 2 below.

Table 2: Performance metrics for SCOR level 1 categories (Bolstorff and Rosenbaum, 2003).

Level 1 Metrics	Performance Attributes				
	Customer-Facing			Internal-Facing	
	Reliabilty	Responsiveness	Flexibility	Cost	Assets
Perfect Order Fulfillment	✔				
Order Fulfillment Cycle Time		✔			
Upside Supply Chain Flexibility			✔		
Upside Supply Chain Adaptability			✔		
Downside Supply Chain Adaptability			✔		
Supply Chain Management Cost				✔	
Cost of Goods Sold				✔	
Cash-to-Cash Cycle Time					✔
Return on Supply Chain Fixed Assets					✔
Return on Working Capital					✔

The SCOR model was constructed for use in developed countries and as such it is limited in its ability to satisfy the needs of companies and supply chains in developing countries (Georgise et al., 2017). As a result, companies are customising the SCOR model to suit their personalised supply chain needs.

2.3 Greenhouse Construction

A greenhouse is a structure that is designed to take advantage of the so-called greenhouse effect to aid in the growth and survival of various types of plants. There are a number of greenhouse types that can be classified according to shape, construction, utility and covering materials (Radha and Igatidnathane, 2007). The classifications that are relevant to this project are even span, truss framed and plastic film greenhouses. Even span refers to the symmetrical lengths and slopes of the roof of the greenhouse, truss framed identifies the design used to support the structure and the covering over the greenhouse is made of polyethylene film. Each of these aspects play a role in the ease of construction and deconstruction of the greenhouse. The polyethylene film is the most economical covering; however, it has an estimated life span of only 4 years.

According to (Hanan et al. (1978)), the materials required for construction of a greenhouse, and thus the capital required, vary largely depending on the size of the greenhouse to be constructed. Because of the variety of types of greenhouses, cost estimation for relocation and reusable materials depends heavily on circumstances. Some considerations are highlighted, namely the location relative to the market, water supplies, availability of utilities, vehicle accessibility and layout design.

2.4 Work Flow Modelling

An important stage of analysing and improving any system is mapping the system in a way that represents the different aspects simply and accurately. Work flow modelling aims to achieve an accurate map through the application of standard modelling procedures (Chinosi and Trombetta, 2012). Business Process Model and Notation (BPMN) is considered the most prevalent modelling language.

2.4.1 Business Process Model and Notation

Business Process Model and Notation (BPMN) was designed to model business processes in a way that most people involved could understand without technical training (Chinosi and Trombetta, 2012). BPMN is a standardised system that uses symbols and icons to represent business processes and is a versatile tool for modelling interactions within a business process and across different departments. For example, the processes carried out by the Agent and Traveller in their respective swim lanes are shown in Figure 3 below.

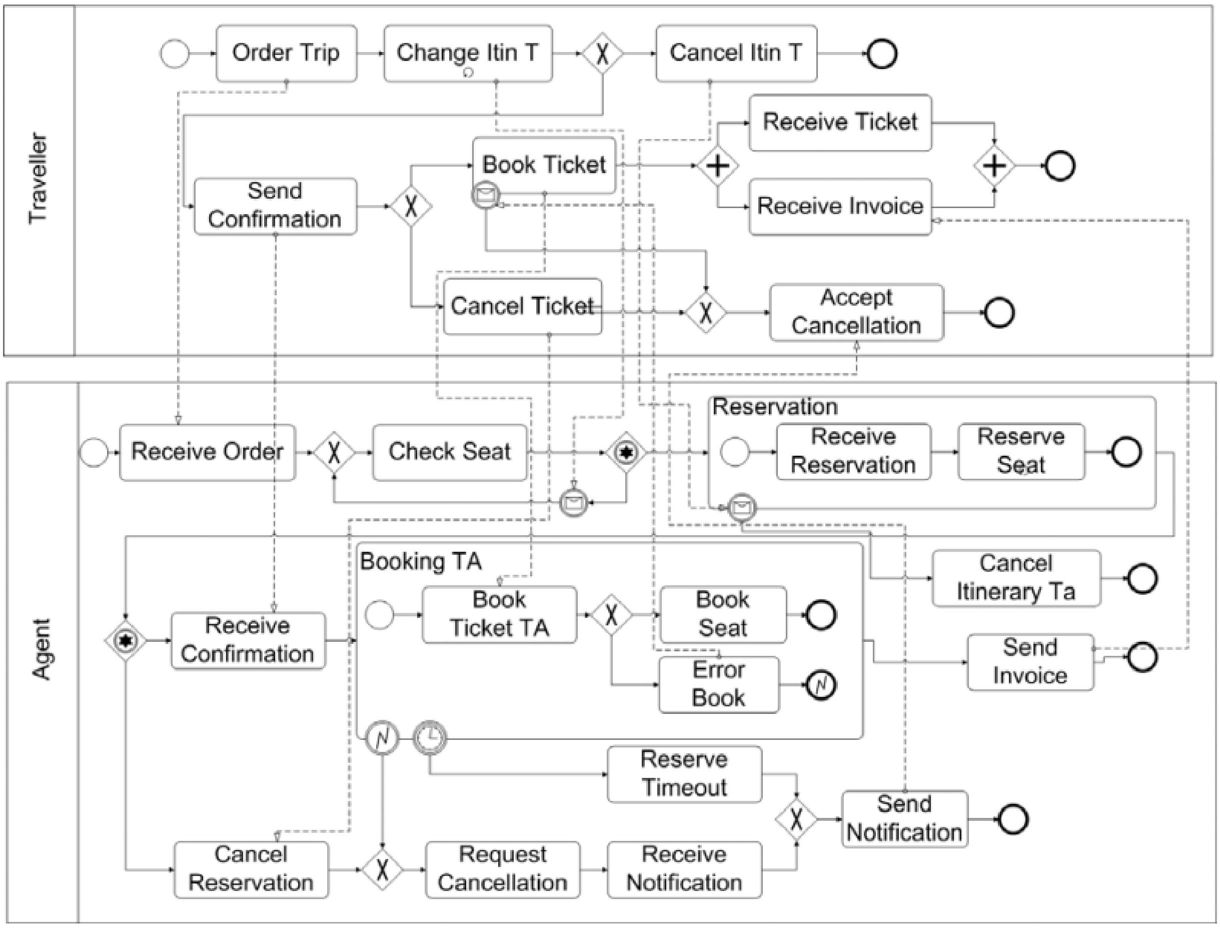

Figure 3: An example of a BPMN model of interactions between a travel agent and a traveller (Wong and Gibbons, 2011).

In the latest set of standards (BPMN 2.0) several items exist for use in the BPMN system including tasks to represent activities that need to take place, gateways that represent decisions, start and end items and intermediate items that represent different circumstances that may arise within the system. There are a broad range of functionalities that are summarised in Appendix D.

Some criticisms have been raised however about the limitations of BPMN models, namely that although certain tasks are implied to be compulsory, this is not always obvious or explicitly stated in the model (Natschläger et al., 2015). Another criticism of BPMN is that it lacks formalisation and thus becomes ambiguous in certain circumstances (Wong and Gibbons, 2011). Natschläger et al. (2015) and Wong and Gibbons (2011) have both ventured to create extensions to the standard BPMN model to overcome these limitations. For the sake of this project however, BPMN will be sufficient to model the communications within the process.

2.4.2 Information Flow

The flow of information between departments and people within those departments plays an important role. There are three levels that make up the flow of information they are data, information and knowledge (Silva and Agustí i Cullell, 2008).

Data represents the most basic level where no manipulation or organising has taken place. Data comes straight out of reality. Information is the usefulness of this data with respect to what the data represents. Knowledge is the result of consideration of the information, it is the application of what the information represents and usually helps in making decisions

There are a number of philosophies concerning which is the best way to view information, two of these approaches are the subjectivist approach and the objectivist approach (Silva and Agustí i Cullell, 2008).

Both approaches view reality as the basis for information, the objectivist approach however sees data as inherent in nature where the subjectivist approach only recognises data once it has been extracted from realty. The philosophy that is most appropriate for this project is the subjectivist approach as the data only becomes useful for decision making once it is extracted from reality.

2.5 Project Management

An important aspect of improving working conditions and communication is the execution of the implementation. Since the project is a technical solution that needs to be used by a range of skilled and unskilled individuals, the manner in which the project is carried out has a significant impact on its success. The conflict that naturally arises when individuals interact needs to be handled skilfully to avoid complete breakdowns in collaboration. Some tools exist to aid in planning effective execution of a project.

2.5.1 Work Breakdown Structure

A Work Breakdown Structure (WBS) is a management and planning tool used to visually present the components of a project that need to be completed. A typical WBS is comprised of multiple levels of tasks and objectives that cascade into greater detail as one passes through the levels.

A WBS has both advantages and disadvantages. Since the WBS is limited to encompassing only the given project, it is useful for defining the boundaries of the project and establishing exactly what is important and what is not (Pmi). A WBS is meant to help managers direct and plan projects and as such the degree to which it covers detail depends on the individual producing it (Taylor, 2004). The subjective aspect of how the WBS is constructed may thus affect how well it is interpreted. Both advantages and disadvantages are present in this case. The WBS suits the needs of the manager using it but may cause confusion for team members who may interpret it differently.

Chapter 3

Problem Investigation

The current production system was assessed in its condition and weighed up against management methods explored in the previous chapter. The methods researched were applied to identify and focus on a possible solution. The solutions considered are the relocation of the greenhouses to the new location, eliminating the need for excess handling and transportation, and improvement of the cold chain from harvest to packaging phase so that quality can be maintained, and orders filled on time. The two approaches are discussed below.

3.1 As-Is Analysis of Processes

Additional data gathering was done to build a better picture of the current processes being carried out at Pico1. A narrative for the current processes was written as a starting point for understanding the flow of information.

3.1.1 Narrative

The sowing schedule tells the supervisor which varieties and how many trays of each should be sown. The supervisor ensures that there is enough seed to meet the sowing schedule requirements. If there is not enough seed on hand, the supervisor requests for more seed to be sent from the pack house. When the crops are sown, the Goods Received Note (GRN) number for each item on the sowing schedule is recorded. The GRN number is used to trace the quality of crops from supplier to customer. The Variety, quantity and location of each item is also recorded by the sower.

Certain varieties require chemical treatment after which the crop is withheld from being cut for a specified period. If the crop is cut and then allowed to regrow, it is said that the crop has been cut back. During chemical treatment, also known as spraying, the chemical, application date, cut back date and withholding period is recorded by the sprayer. Crops can only be cut back a limited number of times.

After sowing each variety can only be cut within a period of time between the leaves reaching the appropriate size and the leaves growing too large or losing their value. The time period differs according to the plant variety and the season. The supervisor keeps track of which crops are ready for harvest, how much each crop can yield and how long each crop can be kept before exceeding the maximum time period.

Orders for produce arrive via email and WhatsApp. For email orders the order manager at Pico2 prints the order and places it on a clipboard. A photograph of the order is posted on the internal WhatsApp group specifically for Pico1 and the physical copy of the order is given to the driver to deliver to Pico1. Orders received via WhatsApp are forwarded to the internal WhatsApp group. Orders are required to be retrieved and packaged within 24 hours of their arrival.

When orders arrive from the pack house, the supervisor determines the quantity and location of available stock as well as if the stock is within the specified period of time. If no stock is available the supervisor negotiates with the order manager to substitute or cancel the order. The supervisor then deploys cutters to cut the appropriate amounts of each crop. The amounts cut are then recorded by the cutters according to the customer order and plant variety. The product is then placed into plastic bags to be transported to the pack house at Pico1.

The order manager considers the cutting and sowing records and consults with the supervisor to gauge demand for the coming period. The sowing records are adjusted to account for variation in customer demand and seasonality.

3.1.2 BPMN Model

From the above narrative, the basic BPMN diagrams shown in Figure 4, 5 and 6 were constructed. Several problems have been identified between the sowing of crops and the collection of harvests that affect a range of factors. Problems include:

- The Supervisor monitors product availability by memory which often leads to inaccuracies in the perceived amounts of produce available.
- Frequent additions and changes to orders are passed on through the internal WhatsApp group complicating harvesting procedures.
- Orders are often filled late due to delays in the cutting.
- Delays in the cutting forces packers at the pack house to work overtime.
- Driver locations being unknown results in confusion as to driver utilisation.
- Crops are not being packed onto cooler boxes, possibly caused by time pressure to deliver crops or limited space in cooler boxes.
- Cooler boxes are not being packed onto the truck correctly, usually cooler box lids are neglected for convenience or time sake, exposing the crops to the heat of the sun.
- Crops are being delayed at Pico1 because of new orders; to utilise truck capacity employees delay return trips while orders are being harvested so that less trips are necessary and truck loads are fuller.
- Records of sowing and cutting not kept up to date. Random inspection of records revealed that records were being neglected during activities and then filled in from memory later once inspection was done. Filling in forms from memory may cause further inaccuracies in the stock levels.

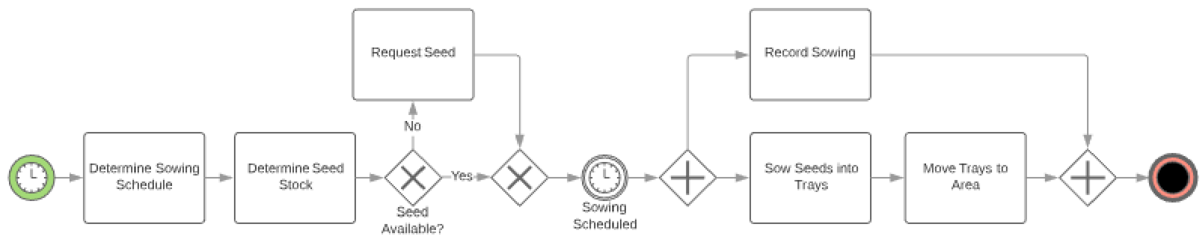

Figure 4: The BPMN diagram for the sowing of seed.

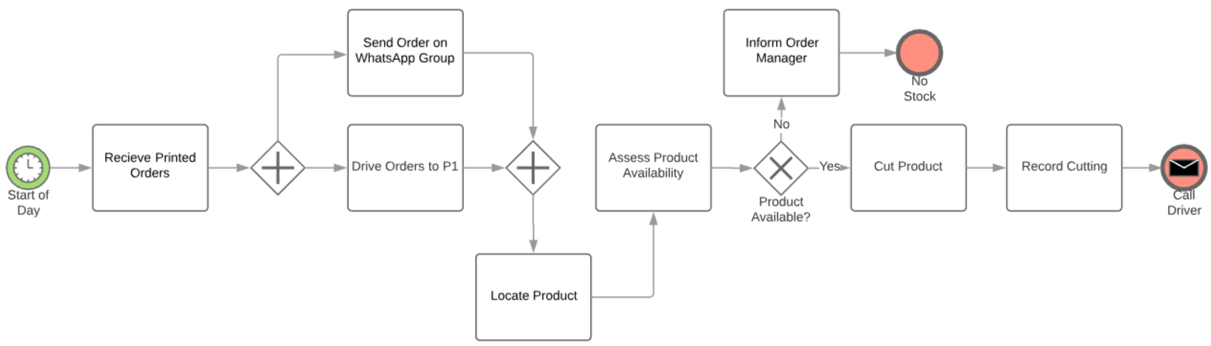

Figure 5: BPMN diagram for the filling of orders at Pico1

Figure 6: BPMN diagram for the transportation of product from Pico1

3.1.3 Cold Chain Capabilities

In this section, the capabilities of PicoGro CC in respect to its cold chain will be assessed. The cold chain should begin as soon as the crops are harvested. In order to maintain the highest degree of quality consistently, the produce must be transported and stored at the correct temperature at all stages of the supply chain.

The facilities at Pico1 have a cold room in which the crops can be placed immediately after they have been harvested, allowing them to be room cooled. No procedure is currently in place to monitor the temperature or time that crops remain in the refrigerated room, and thus no standards are in place. Crops may remain in the room overnight or for less than an hour, causing a large variability with respect to the produce packed onto the trucks. The precooling of produce is not carried out properly. Incorrect or improper precooling may lead to a decrease in the quality and shelf life of the produce.

The transportation trucks are only equipped with an open bed, no cooling facilities exist for the transportation of crops from Pico1 to Pico2. The use of cooler boxes is essential for maintaining the low temperatures during transportation and thus when used incorrectly major damage can be caused to produce. Standard procedures are in place for the securing of crops during transportation, however these standards are not being enforced since Pico1 is currently without an on-sight manager.

Once the crops reach the pack house at Pico2 they are offloaded into the refrigerated rooms where they are packaged. The packaging is done inside the refrigerated rooms to maintain low temperatures while preparing either for the supplier to pick up the produce or to be packed into refrigerated trucks and transported to customers.

3.2 SCOR Assessment

To highlight areas that require improvement, the current internal supply chain can be assessed using the SCOR model and its various categories. Each category will be discussed, and the current supply chain will be assessed according to each category. For clarity, the internal supply chain that will be assessed is that of the microgreen crops produced at Pico1 only, from the arrival of orders until the delivery of crops at Pico2. The codes discussed in chapter 2 will be used to refer to the category and its level.

3.2.1 Plan

Planning overarches all the other categories in that each category requires a level of planning outside of itself. For P1, little can be said about planning the supply chain, as any planning occurs at long intervals. For P2, no standards are in place for the level of quality that is to be expected from Pico1, this may be because of the requirements for products not being defined and communicated clearly. The resources required to achieve a certain level of quality are then also not monitored or planned. In P3 the production of crops has been planned to some degree as the requirements for sowing of crops are determined regularly. Production resources have been identified but are often missing or delayed because of poor resource planning. Balancing production resources with the planned requirements is unstable because of delays. P4 is an important area of focus for the problem as it includes the management and scheduling of the transport.

3.2.2 Source

Source refers to the requesting, procurement and payment of resources required for production. Since the crops are grown in advance and only harvested once an order is received, this production system can be seen as a Make-to-Order system. Only S2 applies to Make-to-Order Systems. The procurement of seed and trays for the sowing of crops are not planned but are only received once requested. No systems are in place for the assessment of the requested resources.

3.2.3 Make

As previously stated, this system is Make-to-order and thus only M2 applies. Production activities are planned 1-3 weeks in advance and production begins before any orders are received. The production schedule is assumed to be used as a product issuing document. Once the produce is harvested, no formal testing is done to determine its level of quality. No metrics have been chosen to form the basis for testing. The product is packed into plastic bags for delivery to Pico2, however mishandling is common at this stage and no controls are in place for the prevention of damage.

3.2.4 Deliver

Only D2 applies to this supply chain. Inquiry and quotes are handled by the offices at Pico2 and thus no systems are in place for quoting orders that arrive at Pico1, orders are thus already configured and validated upon their arrival. Orders are required to be delivered within 24 hours of arrival. The resources required for delivery are assumed to be available upon request. No delivery scheduling is currently in place. A highly informal system is in place for monitoring the progress of deliveries. If deliveries are late the Pico2 can inquire about them via a WhatsApp group. Because of a low number of pickup points and destinations, routing is not done as part of regular delivery processes. One route is chosen for all deliveries. Picking is straightforward as only one product exists for transport. Some damage often occurs during packing as there is a procedure for packing, but these procedures are not enforced.

3.2.5 Return

Since the nature of microgreens and fruit and vegetable production in general is that defective products cannot be reworked or corrected, and the shelf life limits the time available to return products, the return category is largely irrelevant. The defective product is usually reused as part of compost or fertiliser for future products.

3.2.6 Metrics

Very few metrics are recorded or measured as part of the supply chain management, thus it is difficult to monitor the productivity and effectiveness of everyday production. In not knowing how the supply chain is performing, it is impossible to keep track of improvements. At this point it may be useful to identify the SCOR level 1 metrics that are most relevant to the problem.

- Perfect Order Fulfilment: The combination of many inefficiencies leads to production and order fulfilment delays. Delays often lead to customer dissatisfaction and penalties incurred by the larger company due to missed flights and late deliveries. Missed appointments also mean lost produce since the short shelf life causes produce to deteriorate quickly. Perfect order fulfilment as a metric covers the aspect of consistency and reliability in filling customer orders.
- Order Fulfilment Cycle time: One of the standards that have been set in placed is the time between order arrival and order fulfilment. It is required for orders to be filled within 24 hours. The 24-hour standard has not been enforced or measured. Since it is already partially being used it may be helpful for the motivation of employees and for monitoring the time delays that cause deterioration.

3.3 Greenhouse Relocation

The determination of whether to relocate the greenhouses at Pico1 depends largely on the trade-off between the cost of relocation, which includes the cost of materials, cost of hiring experts to ensure standards, legal expenses and the utilisation of the vacant land, and the benefits that arise. Possible benefits may include reduced transportation costs, income from selling the unused land and possible future office space. The focus of this project is the effect relocation will have on the efficiency of production and order fulfilment. Elimination of the distance between Pico1 and Pico2 will allow microgreens to be harvested closer to the time of their distribution, which will decrease the amount of deterioration that could have occurred before reaching the customer. It can also allow more flexibility in packaging with respect to work scheduling.

When considering the economics of greenhouse relocation, it is difficult to make an estimation as to which materials can be reused and which will need to be bought, how much it will cost and how long it will take to complete, since these variables depend on specific greenhouse types and sizes as discussed in chapter 2. PicoGro CC is however currently undergoing a similar greenhouse relocation on another section of the farm. The costs and details associated with the relocation project will be gathered and used to estimate a possible price range for future projects.

Chapter 4

Solutions

After investigation of the problem and research done on various engineering tools and disciplines, three possible solutions were identified that could be implemented to solve the stated problem. The possible solutions are described as follows:

- Option A: Relocate the greenhouse to available land at Pico4.
- Option B: Implement new management and information systems at the current Pico1 farm.
- Option C: Do nothing, continue operations as is.

4.1 Option A: Relocate

The relocation of the greenhouse is a complicated procedure with several variables playing a role. Only four variables however were considered major in comparing different options and were chosen based on their measurability and in light of the scope of the project. The variables considered are discussed below.

4.1.1 Overtime Wages

One of the major frustrations in managing the communication between the farms is the difference of pace in which the workers fulfil orders at each farm. Because of the poor information flow, workers and supervisors at Pico1 are left to make assumptions as to the intentions of the order manager. Any assumptions made may not represent reality and thus Pico1 quickly loses contact with what is required of them.

For example, Pico1 may receive an order that is required to be ready at five o'clock in the afternoon. In the eyes of the pack house this means that the client will be arriving at five o'clock to pick up the order from the pack house. The product must thus be cut well before five o'clock providing enough time for the driver to pick the product up and transport it to the pack house where it can be packaged and prepared for the client. However, since the supervisor assumes that the cutting of that specific product needs to be completed by five o'clock, the transportation and packaging is left to be done after five o'clock which is outside of the specified working hours.

Because of the lack of clarity in terminology and poor communication, the linking of the cutting of product to the transportation and packaging of the product in time for the client to pick it up is not realised. Constant changes and additions in the orders throughout the day may push workers to spread the work out evenly leaving a large portion to be done in the final hours of the shift. Since often times the client is waiting at the pack house by the time the produce arrives for packaging, the work load cannot be moved to the next day, forcing pack house workers to put in overtime hours to meet demands.

4.1.2 Fuel Costs

The movement of the produce between Pico1 and the pack house is achieved through the use of a Mitsubishi Colt with a canopy. The driver transports seed and trays to Pico1 and cut product from Pico1 to the pack house over a distance of 1.3 km for every one-way trip. The operation of the Colt requires fuel. The constantly increasing price of fuel combined with the high fuel consumption of the Colt, assumed to be because of its age, makes the cost of fuel a major variable in the considering the relocation of the greenhouses.

4.1.3 Regular Wages

Relocating the greenhouses would introduce a number of efficiencies since certain systems would be merged with those already present at Pico2. One of the systems that form efficiencies is the manual operation of cleaning the polystyrene trays after the produce has been harvested from them, to prepare them for reuse. If the greenhouses were to be relocated to Pico4 then the need for additional tray cleaners would fall away. The used trays could be added to the existing washing system. Furthermore, idle cutters would be able to move quickly to aid if large orders are received, increasing overall utilisation. For this section however, only the tray washers will be considered.

Currently there are 3 workers assigned to washing the trays at Pico1. It is assumed based on the current systems in place at Pico4 that the current tray washers at Pico1 would become unnecessary if the greenhouses were to be relocated. Reducing the work force by three workers would add to the savings in the long term.

There are however ethical questions that arise when considering the dismissal of employees, such as whether or not an individual and potentially their family should be put at risk for the sake of improving the financial position of an organisation. It is in all cases preferred that no employees be dismissed as a solution to inefficiencies and as such it may be possible to reintegrate the redundant tray washers into the organisation as cutters or in another area of the organisation. Although the employees will not be dismissed and a direct saving will not take place, the company is growing, opening new positions for employment. The human resources department will not need to hire new workers as there will already be an excess. In addition, the excess workers may help to improve the time to fill orders.

4.1.4 Net Present Value Calculation

The three factors discussed above were assessed and quantified using historical data. The average monthly cost of each variable was determined, and this average was used to calculate the net present value of relocating the greenhouses. The variables manifest themselves as monthly savings when compared to option C. Since no direct increase in revenue will be experienced, this option is classified as a service project. The lifespan was chosen to be 10 years. The initial investment is not exactly known because the cost of relocation of a greenhouse depends on a large range of factors, these factors would need to be taken into account by an expert or professional contractor. For the sake of this project however, the costs were estimated using a similar project. The total Net Present Value (NPV) of future potential savings will provide a reasonable estimation of the value of relocation. If the calculated NPV falls below zero, then the relocation cannot be justified.

Although only microgreen herbs are grown in the greenhouses at Pico1, there are other varieties of edible flowers that are grown under shade netting. In order to take full advantage of the efficiencies provided by relocation, these crops will also need to be relocated. Using the costs of a similar project shown in Table 3, the total relocation costs were calculated as shown in Table 4 and came to a total of R 2 195 970.

Table 3: The estimated cost of each type of covering and the additional components.

Cost	R/m^2
greenhouse	670
rain shelter	325
shade net	100
irrigation including control panel	80
electronics	40

Table 4: A summary of the total cost of relocation of Pico1.

Greenhouse	m^2	Cost
Ferdi	567	R447 930,00
Mozart	600	R474 000,00
Handel	600	R474 000,00
Sabastian	180	R142 200,00
Bach	360	R284 400,00
Stravinsky	1260	R277 200,00
West of Ferdi	20	R2 400,00
East of F,M,H	320	R38 400,00
North of Handel	60	R7 200,00
North of Handel	60	R7 200,00
South of Bach	24	R2 880,00
East of Stravinsky	90	R10 800,00
Triangle 1	24	R2 880,00
Triangle 2	168	R20 160,00
North of Office	36	R4 320,00
Total	**4369**	**R2 195 970,00**

The fuel savings was calculated using records of fuel bought specifically for the Colt over a four-month period. The values were sorted into monthly spending and the average monthly spending was then calculated. The average fuel cost amounted to R 1736,85 per month.

Regular wages relevant to the relocation option were calculated by using the minimum farm wage provided by the government given as R 3169,19 and multiplying it by the total number of workers that would not be necessary if relocation took place (3), giving a total of R 9507,57 per month.

The average weekly overtime was calculated by multiplying the average number of picking workers that work overtime in a week (3) by the average number of hours of overtime worked per picker in a week (4), giving a total of 12 hours per week for pickers. Likewise the average number of workers that work overtime in the pack house in a week (6) was multiplied by the average number of hours of overtime worked per packer in a week (6), giving a total of 36 hours a week for packers. The average hours per week were then divided by 7 days in a week and multiplied by 30 days in a month to find the average overtime hours in a month. The average overtime hours were then multiplied by the given hourly picking wage (R 16,25) and the given hourly packing wage (R 17,10) respectively. The resulting values were then multiplied by 1,5 as required by law for overtime wages. The average overtime wages cost in a month came to R 5249,57 per month.

The annual inflation rate of the minimum farm wage in South Africa is given as 5,6%. In order to determine the net present value, an interest rate is required. Standard practice is to use the Minimum Acceptable Rate of Returns (MARR) decided by the company. PicoGro however, does not use a standard decided rate, and thus the inflation rate with an additional 1% will be used instead. The nominal interest rate then becomes 6,6%. The interest rate will be compounded monthly since the payments for each expense, except for the initial investment, are made on a monthly basis. The monthly wage amount increases by 5,6% each year due to inflation. It is assumed that the relocation will take a year to be completed thus for the first year no savings are incurred. Figure 7 shows the monthly cash flow of the first 3 years of option A, with the savings forming an annuity that increases each month, the monthly wages and fuel cost form an annuity.

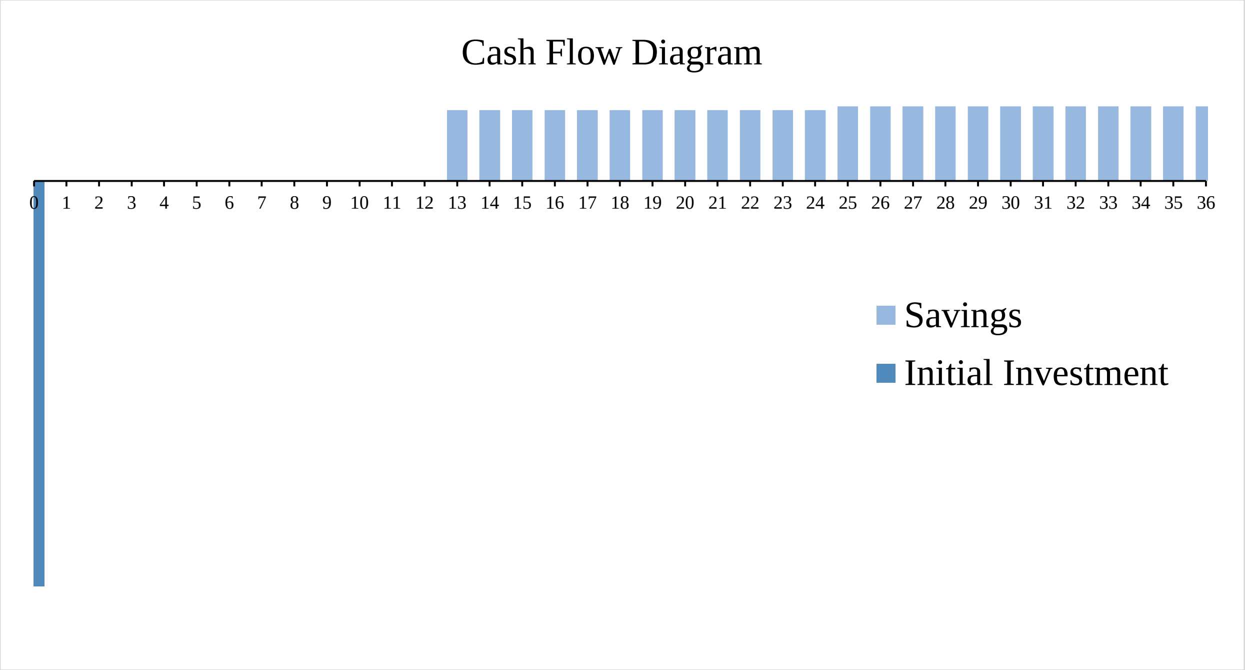

Figure 7: Cash flow diagram of the first 3 months of option A.

To calculate the NPV the annuity for each year was calculated individually and the equivalent present value for each of the resulting future values was calculated. The formula for a present value given an annuity is as follows:

$$P = A\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right] \tag{3}$$

Where P is the present value, A is the annuity, i is the MARR and n is the number of periods. The formula for a present value given a future value is:

$$P = F\left[\frac{1}{(1+i)^n}\right] \tag{4}$$

Where F is the given future value. Assuming the cost of relocation was incurred at the beginning of period 1, there is no factor used to multiply the total cost. Because the interest rate is an annual rate compounded monthly, the interest rate needs to be divided by 12 months to find the monthly interest rate. For a 10-year period there are 120 months in total and thus the number of periods n is equal to 120. The total monthly annuity paid is equal to the sum of all individual variables, this comes to a total of R 16 493,99 per month.

The calculations were coded into *RStudio* for ease of calculation and if any variables were to change, the result could be quickly analysed. See Appendix B for the exact code used.

The NPV was calculated to be - R 575 839,08. Since this value is below zero, the project is infeasible over 10 years. The remaining unused land can however be sold to increase the NPV and make the project feasible. The minimum value the land can be sold for to make the NPV zero is calculated to be R 613 844,46 assuming that the land will be sold at the end of the first year.

4.1.5 Considerations and Assumptions

Some other variables were also considered but were not included in the assessment of this option. The cutting speed depending on the number of workers was not included because this would need further examination into manual cutting processes, the variation of cutting speeds and yield amounts, which vary greatly depending on greenhouse conditions, quality of seed, individual cutter and variety of plant. Because of the detail of the manual processes, these processes were outside of the scope of this project.

An assumption was made regarding the level of management occurring at each farm. Since Pico2 and Pico3 do not face the same challenges concerning the late arrival of product to the pack house, it is assumed that the relocation will allow the management team at Pico2 and Pico3 to apply the same principles to the new greenhouses and thus many of the management problems will be decreased if not eliminated completely.

The loss of product and credit supplied to the customer as a result of this was not quantifiable given the resources and time period available. It is expected that the improvement in management due to the relocation would decrease this expense but a reasonable estimation of its impact to the NPV was not reached. It can however be said that the reduction of credit awarded to the customer will result in a favourable increase in the NPV as calculated above.

It should be noted that further efficiencies or inefficiencies may arise that are not so clear at first glance. These further efficiencies could influence the NPV calculation and produce a value different to the one calculated above. The Workers variable in *RStudio* was seen to be especially sensitive to change, with a single additional worker becoming unnecessary resulting in the NPV increasing to - R 206 608,35 when all other variables remained the same. The number of 3 workers that was chosen for the calculation was the maximum number of workers that could confidently be considered unnecessary, this value may however be different in reality.

Maintenance costs with regards to the regular repairs of the greenhouses and their facilities were not included in the calculation since the greenhouses will need to be maintained regardless of their geographical location, these costs would therefore have no effect on the NPV calculation.

The data for the variables mentioned above were then collected and used to calculate monthly averages. One limitation in this data was that records of these specific variables were only available for the four months prior to their collection. Data from earlier months was either never recorded or was lost between old employees leaving and new employees starting work at PicoGro. The limited data thus does not account for seasonality trends and peak periods. The variables used however, are not expected to be majorly impacted by seasonality and peak periods.

The fuel usage of the Colt is expected to remain reasonably constant even if the volume of the produce and equipment transported between the two farms increases. The Colt runs between 5 and 8 trips in a day and is currently not being filled to capacity on every trip, with utilisation of bed space estimated to be between 10% and 30% per trip. If the volume of produce were to increase within a reasonable range, the Colt would still have the capacity to carry the additional produce without any major modifications and, because of the low density of microgreens packed into plastic bags and polystyrene trays, the increase in volume would not necessarily increase the weight of the load significantly enough to impact the fuel consumption of the Colt.

4.2 Option B: New Systems at Pico1

The second option is to implement new management and information systems at Pico1 to improve the flow of information across the organisation and reduce errors made by employees. As an alternative to relocation, a more feasible solution may lie in redesigning the systems that facilitate the flow of information. For example, the monitoring of available stock is one aspect where the system has been a major hindrance to meeting targets. The supervisor is left to keep track of crops by thought. When the supervisor is unsure they then need to walk to the relevant areas and estimate by eye how much of each product is available. The use of new systems may help improve conditions throughout the farm.

4.2.1 Information System Design

Information plays a vital role in the coordination of business processes. Many of the systems required to carry out everyday operations rely on information flow from one department to another. The design of an information system seeks to create a platform to easily and efficiently gather and store data for use in management. Although many Enterprise Resource Planning (ERP) systems do exist, they are often expensive and do not always meet the specific needs of the user. For the scope of this project, only the processes from sowing seed and receiving orders at Pico1 to the delivery of the product to the pack house will be considered, although ERP systems often include sections for client and vendor management as well as accounting modules.

The information system design often begins with a description of the system in the form of a narrative. For this section, the same narrative that was used in the problem investigation will be reused. The ontological actions have been made bold and the actor roles have been underlined to better extract the relevant information from the text.

(1) The sowing schedule tells the supervisor which varieties and how many trays of each should be sown. The <u>supervisor</u> **ensures that there is enough seed to meet the sowing schedule requirements**. If there is not enough seed on hand, the <u>supervisor</u> **requests for more seed to be sent from the** <u>pack house</u>. When the **crops are sown**, the GRN number for each item on the sowing schedule is recorded. The GRN number is used to trace the quality of crops from supplier to customer. **The Variety, quantity and location of each item is also recorded** by the <u>sower</u>.

(2) Certain varieties require chemical treatment after which the crop is withheld from being cut for a specified period. If the crop is cut and then allowed to regrow, it is said that the crop has been cut back. During chemical treatment, also known as spraying, the chemical, application date, cut back date and **withholding period is recorded** by the <u>sprayer</u>. Crops can only be cut back a limited number of times.

(3) After sowing each variety can only be cut within a period of time between the leaves reaching the appropriate size and the leaves growing too large or losing their value. The time period differs according to the plant variety and season. The <u>supervisor</u> **keeps track of which crops are ready for harvest**, how much each crop can yield and how long each crop can be kept before exceeding the maximum time period.

(4) Orders for produce arrive via email and WhatsApp. For email orders the order manager at Pico2 prints the order and places it on a clipboard. A photograph of the order is posted on the internal WhatsApp group specifically for Pico1 and the physical copy of the order is given to the driver to deliver to Pico1. Orders received via WhatsApp are forwarded to the internal WhatsApp group. Orders are required to be retrieved and packaged within 24 hours of their arrival.

(5) When orders arrive from the <u>pack house</u>, the <u>supervisor</u> **determines the quantity and location of available stock** as well as if the stock is within the specified period of time. The supervisor then deploys cutters to cut the appropriate amounts of each crop. **The amounts cut are then recorded by** the <u>cutters</u> according to the customer order and plant variety.

(6) The <u>manager</u> **considers the cutting and sowing records and consults with the supervisor to gauge demand for the coming period.** The sowing records are adjusted to account for variation in customer demand and seasonality.

From the narrative, 7 transaction kinds were identified with 5 actor roles. The actor roles identified are those roles that carry out the actions linked to them as shown in Table 5 below.

Table 5: The list of transaction kinds taken from the narrative.

	Transaction kinds	Actor
T01	Seed stock maintenance	Supervisor
T02	Seed stock acquisition	Supervisor
T03	Sowing record maintenance	Sower
T04	Spraying Record maintenance	Sprayer
T05	Cutting Record maintenance	Cutter
T06	Product availability maintenance	Supervisor
T07	Sowing Schedule evaluation	Manager

For example, the supervisor is the one responsible for carrying out seed stock maintenance and seed stock acquisition, the sower is the one responsible for carrying out sowing record maintenance etc. Although the pack house does play a role in the narrative, the actions it carries out are not on an ontological level, that is that there are no decisions being made when the orders arrive from customers or when seed stocks need to be replenished at Pico1. The pack house is treated as an external entity and any complex decision making on the pack house side falls outside of the scope of this project.

From Table 5, a use case diagram was constructed representing the system, its functions and the way in which each of the actor roles utilise the system, shown in Figure 8. Once again, the pack house is not considered part of the specific production process at Pico1, but it is still included in the diagram as it makes use of the system by receiving requests and sending orders. The availability of stock first needs to be checked by the supervisor so that the order manager at the pack house can confirm the order to the client. The pack house serves a role similar to that of a customer.

In the diagram certain transactions depend on one another. For example, the sowing schedule depends on the sowing record, the cutting record and the spraying record as all three of these records are taken into consideration when determining the sowing schedule.

The use case diagram was used in combination with the transaction table to construct the OCD diagram shown in Figure 9. Each rectangle represents an actor role and each circle with a diamond shape inside represents a transaction kind linking to Table 5. The origin of the solid arrows represents the actor role making a request for the specific transaction. The arrow heads point towards the individual executing the transaction and the dotted lines represent the sharing of information. The information shared between the manager and transactions T3, T4 and T5 mirror the connections in the use case diagram in determining the sowing schedule. In Figure 9 it becomes clear how the pack house plays a role in the system but is not part of the system, rather it can be considered an external factor interacting with the system.

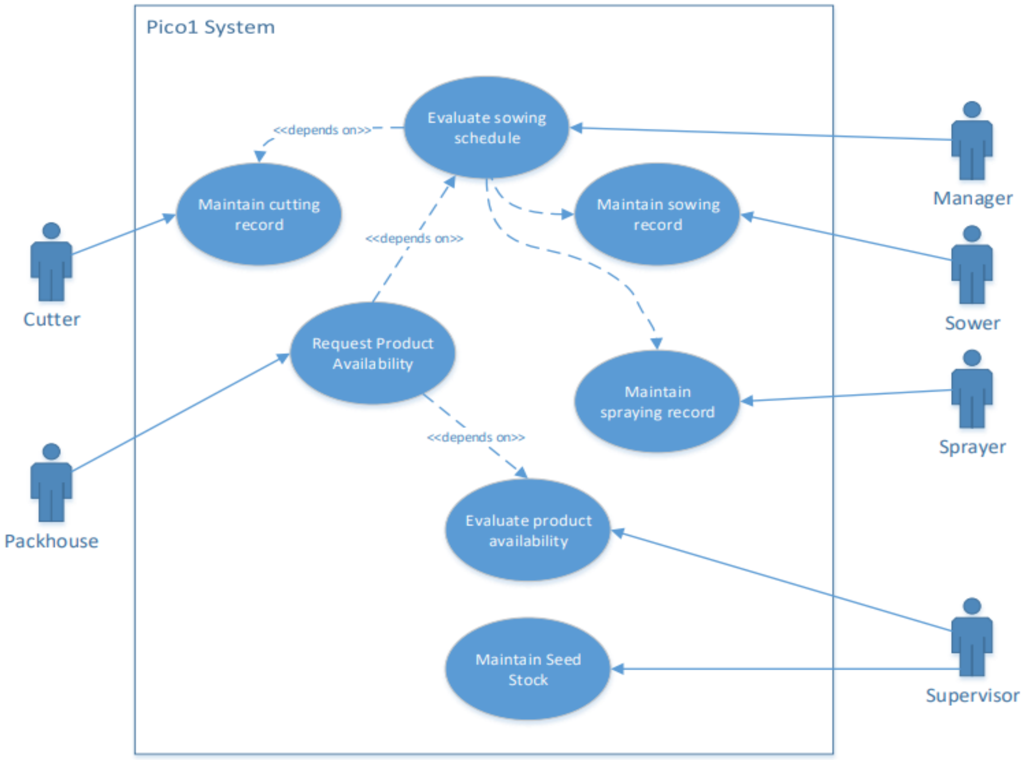

Figure 8: Use case diagram of the proposed information system at Pico1.

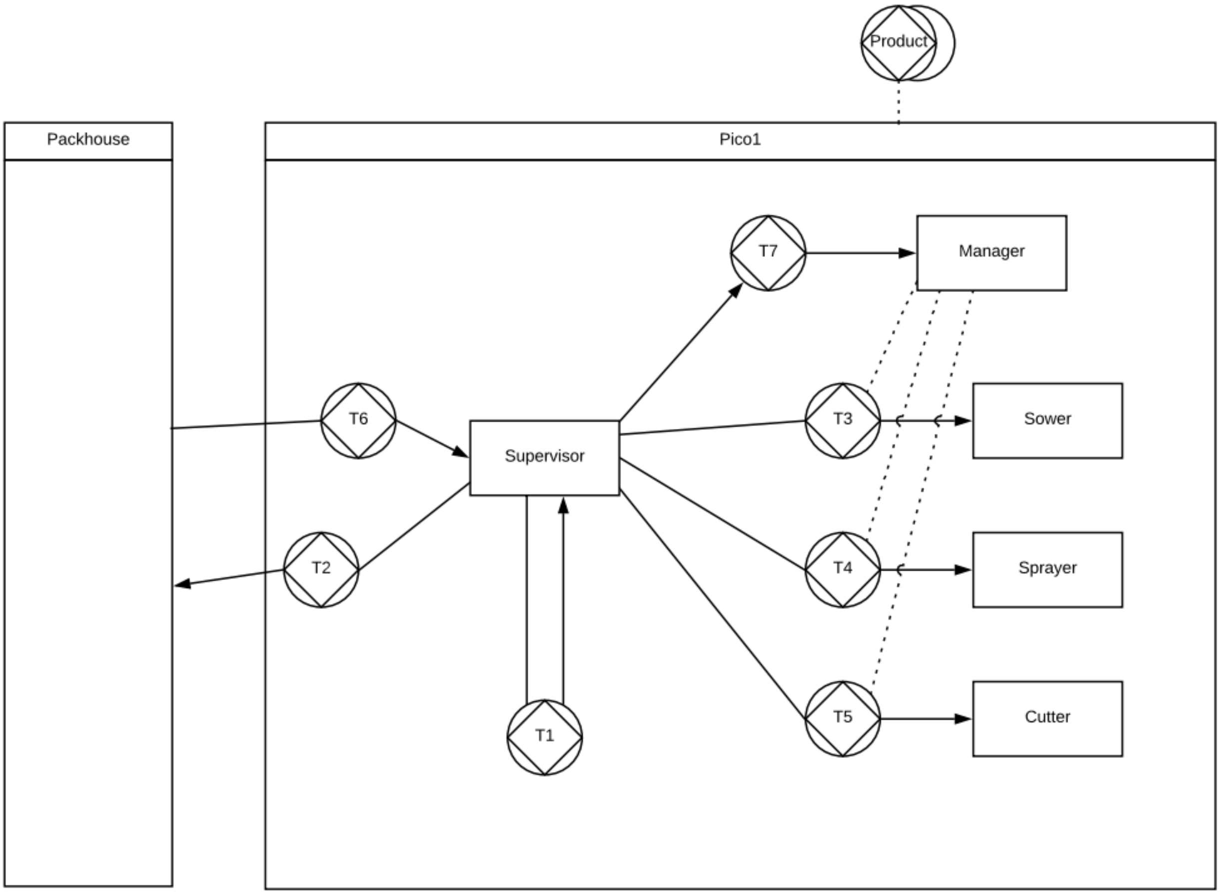

Figure 9: OCD diagram of Pico1 system.

Having a clear picture of the system layout and interactions, the requirements laid out by PicoGro specifically relating to the stated problem, were considered. The specific system requirements include the following:

- The system must keep record of which crops are sown, when they are sown, where the trays are grown, how many trays are sown, which type of tray is used and the responsible person. Each bag of seed has a specific code called the GRN number. The GRN number is used to trace the movement of products. If at any stage the product is found to be damaged or defective, it can be traced back to the original bag of seed and supplier to determine the cause.
- Each crop's age must be monitored to ensure that the crops can be harvested on time. If the crop is approaching the end of its availability, the crop must be identified so that it can be cut and the produce can be marketed aggressively in order to sell it.
- The system should monitor the seed stock levels and notify the supervisor if seed stock levels are low, and if that specific variety is scheduled to be sown soon.
- The system should contain each variety of microgreen and the specific conditions under which they need to be kept as well as the minimum and maximum growing days within which the crop will be available for harvest.
- The system should keep track of the number of trays cut from each crop to maintain an accurate stock level. The responsible person should be noted, and the yield of each harvest should be recorded.
- A record of which trays have been sprayed with which chemicals and when they were sprayed should also be kept on the system. After the crop has been sprayed it is held back from being harvested for a period depending on the chemical used and the variety of crop. A record of the chemical and the withholding period should be kept, and the user should be notified when the withholding period expires.
- The system should be used to bring relevant information together to aid in the compilation of the sowing schedule.
- Each area should be monitored by the system to determine which areas contain which crops.

The system requirements were then applied to the system layout to form the Entity Relationship Diagram (ERD) shown in Figure 10. *Microsoft Access* was used to compile the ERD. Each box represents a table with the contents of that box representing the coulombs in that table. The lines joining the boxes are the relationships between different tables in the system.

The ERD is best described from a starting point. Beginning from the *Variety* box, each variety has a name, a description, minimum and maximum growing times (measured in days) and the basic requirements for its growth. The primary key or identifier of the table, that is the coulomb used to identify specific records, is the variety name. Only one record exists for each variety name in the *Variety* table.

The *Variety* table is linked to the *SeedStock* table via a one to many relationship. A *SeedStock* record can only be of one variety but a variety can have many *SeedStock* records. When a new bag of seed is received, a new *SeedStock* record is created by selecting the variety name from the Variety table and inputting the GRN number stamped on the bag. The date that the bag is received is also recorded in the *SeedStock* table.

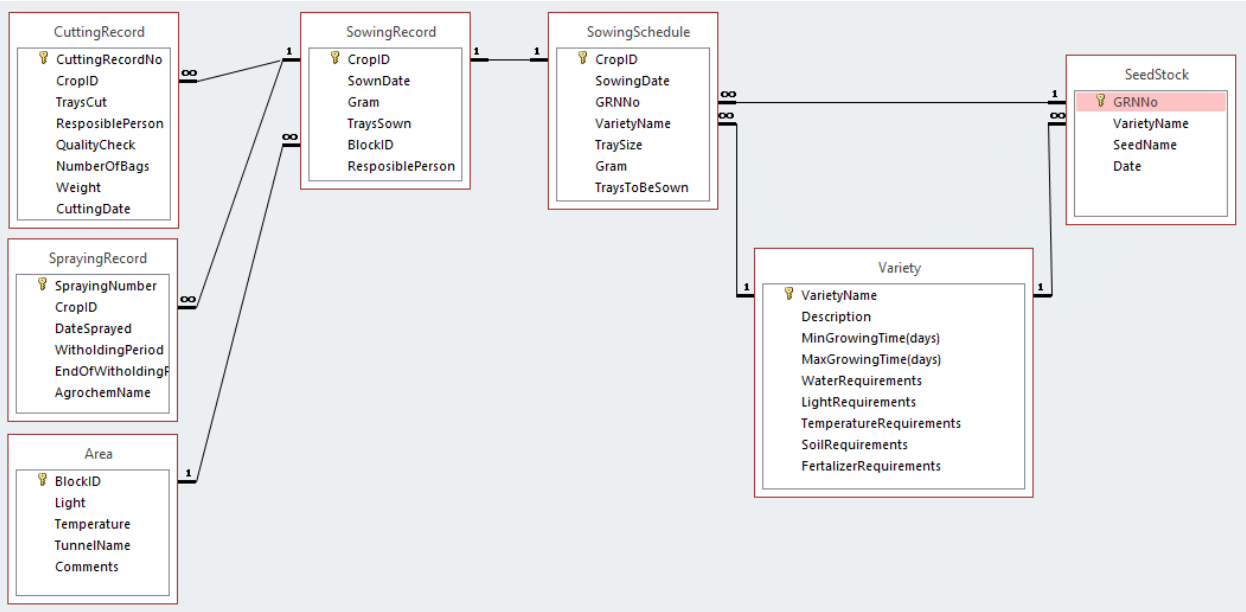

Figure 10: Entity Relationship Diagram of the Pico1 system.

The *SeedStock* table is linked to the *SowingSchedule* table via the GRN number. It is in the *SowingSchedule* table that a crop ID is assigned to each individual crop that is scheduled to be sown. The variety name and the GRN number is noted for each crop as well as how many trays should be sown, which type of tray should be used, how many grams of seed should be used and the date that the crop is to be sown.

Linking to the sowing schedule is the sowing record. The *SowingRecord* table requires the *SowingSchedule* table to function correctly. Only once a crop is scheduled to be sown will it allow the sowing of a crop to be recorded. Here the crop ID is passed from the *SowingSchedule*. The crop ID will be used to connect each cutting and spraying record to a specific crop. The actual number of trays sown, grams of seed used, and sowing date are also recorded for comparison with the scheduled sowing.

The *CuttingRecord SprayingRecord* and *Area* tables are linked to the *SowingRecord* table. When trays are cut, the number of trays cut for each specific crop, the weight of the yield, the number of bags filled, and the cutting date are recorded. The responsible person is also noted. The date sprayed the chemical used and the withholding period are noted in the *SprayingRecord* table when a crop is prayed. When a crop is sown it is assigned a specific area where it will be kept and grown. The area is identified by a block ID which correlates to a specific location on the premises. The conditions and environment details of the area can be stored with each block ID. The data collected by the information system can be used to monitor specific metrics and focus improvement of key performance indicators.

4.2.2 Geographic Information Systems

Geographic Information Systems (GIS) make use of satellites and GPS to monitor geographic locations on the surface of the earth. Recently GIS systems have been used in the agricultural industry to monitor the conditions around farm land. The real time satellite images allow farmers to monitor weather conditions such as storms and temperatures, track farm vehicles while performing operations such as harvesting and spraying and catch infections and pests before they can cause serious crop damage. Many software companies have capitalised on GIS technology and have designed packages for off the shelf purchase.

The crops at Pico1 however are covered by greenhouse plastic and the conditions are monitored and controlled inside each greenhouse. The individual trays used are also far smaller than the hectares of land used by farmers. The principle however may be valuable if it can be adopted to suit Pico1's specific needs.

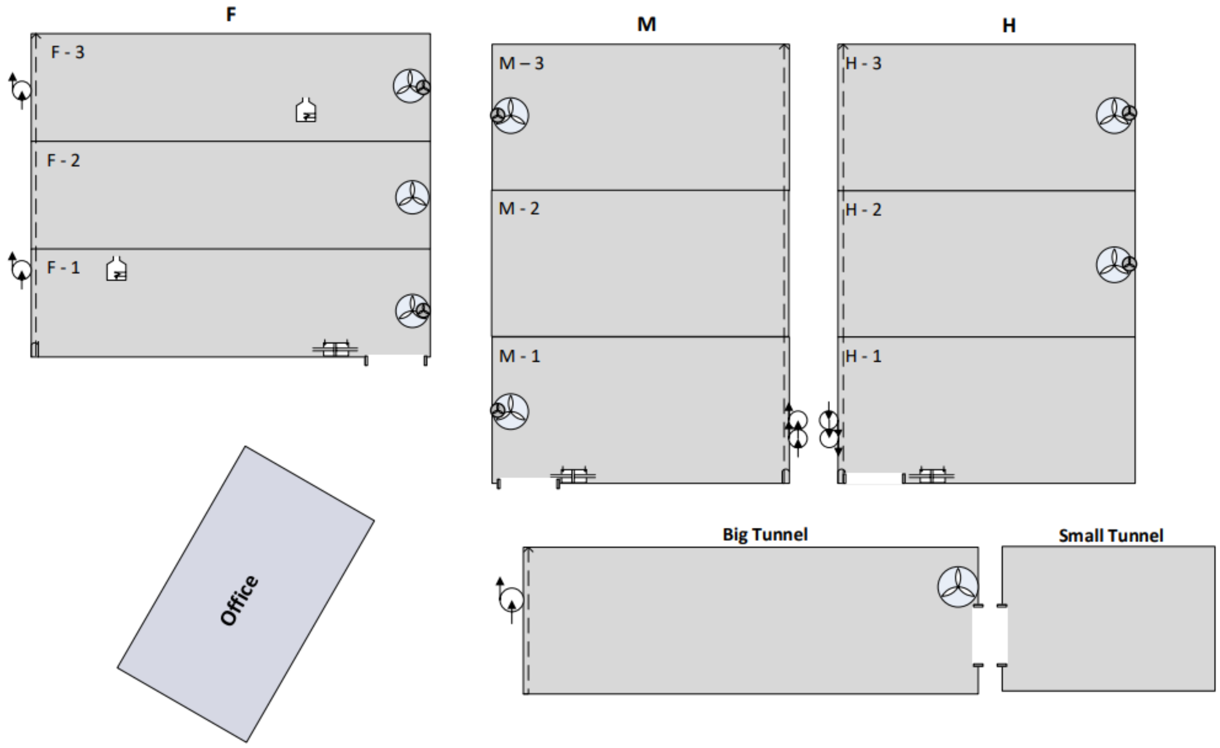

Figure 11: Layout of areas at Pico1.

Figure 11 shows the layout of Pico1 drawn on *Microsoft Visio*. The areas in Figure 11 can be divided even further according to the sections in which the trays are laid as shown in Figure 12. Although satellite imagery may not be possible for monitoring sections, Visio has the capability to link each section to multiple tables in Access. The information system above can be linked to the Visio representation and used as an interface for recording sowing, spraying and cutting according to the specific area. The database can hold data such as the variety of crop in each area, the number of available trays and the number of days before a crop is ready for harvest.

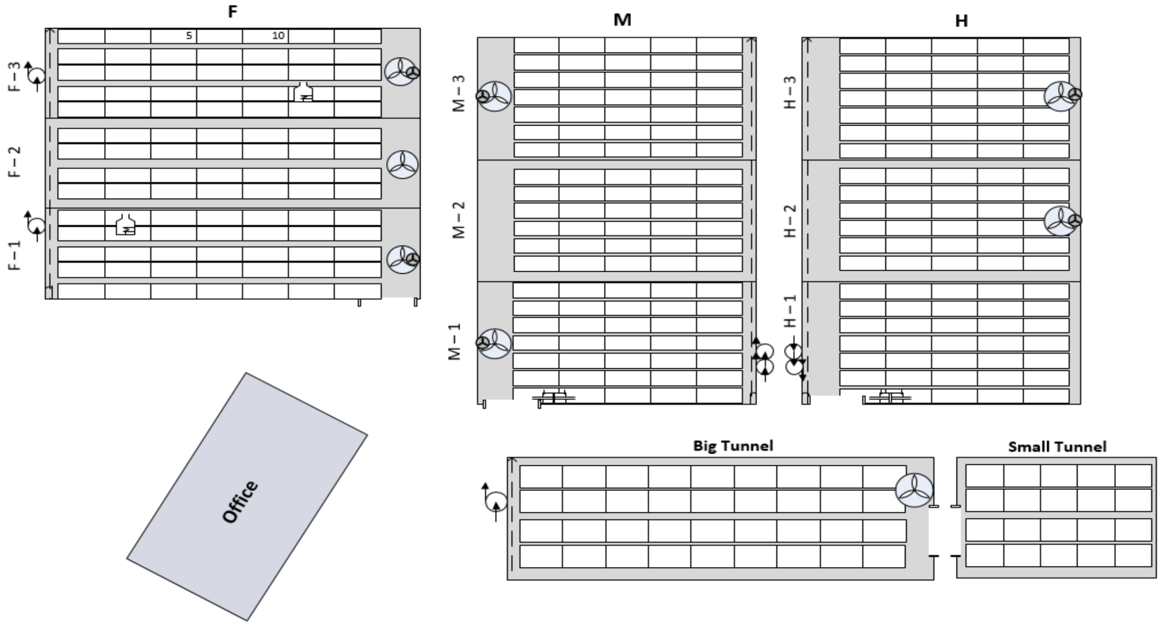

Figure 12: Layout of areas at Pico1 with designated sections.

The proposed integration of Access and Visio may allow managers, supervisors and possibly workers to move around in the greenhouses and record data as they sow, cut and spray crops. The Visio display could also be used as an information dash board to display availability of crops and possible problem areas to the supervisor, which would allow for faster response and better coordination. The development of this solution will require additional research.

4.2.3 Information System Costs

The information system described above was designed for use in a *Microsoft Access* database. The specific requirements for the database were built in using the design process and may not be the case for certain off the shelf systems, these are systems that can be bought from suppliers as a package and applied without much design involved. Off the shelf systems are however naturally more generic in nature and some required functionalities may not exist as part of the package. Additional modules can be custom ordered as part of the package, but this often costs extra and requires additional updates and maintenance.

An off the shelf system that may suit the needs of PicoGro CC is *Microsoft Dynamics*. *Dynamics* is an ERP system that was designed for the ease of managing and planning resources and interactions within an enterprise. *Dynamics 365* was given finance and operations functionalities specifically to suit production floors and better facilitate information flow in a production environment. The capabilities of *Microsoft Dynamics* are excessively large compared to the system at Pico1, the package goes as deep as customer service management. The custom package provided by *Microsoft* allows the owner to choose specific capabilities to suit their company's needs. The pricing for the custom package is upwards of R 585,20 per user per month. If only the manager, supervisor, and order manager use the system, the price totals a minimum of R 1755,60 per month resulting in an NPV of -R 153 922,44 over 10 years. The cost of *Microsoft Access* is lower than *Dynamics* costing R 107,30 per user per month. With the same number of users, the *Access* database results in an NPV of -R 28 222,62. Although the functionality will be less and the database will need to be maintained, the interface can be designed specially to suit use by employees that do not necessarily have experience with computers or information systems.

Additional costs would be incurred to purchase a computer system and tablets to run the information system as well as the cost to install an internet connection at Pico1, which would be necessary for the manager and order manager to gain access.

4.2.4 Validation

The proposed information system was compared to the requirements provided by the company to validate how well it suits the company's needs. Table 6 shows which capabilities are required and whether the requirement was met by the information system.

Table 6: The capabilities of the information system compared to requirements.

Capability	Requirement Met
When crops were sown.	Yes
Location as detailed as bays per greenhouse.	Yes
Number of trays sown.	Yes
The type of tray used.	Yes
Grams of seed per variety.	Yes
Each crop's age since time of harvesting.	Yes
The minimum and maximum growing days depending on the season.	Yes
Number of trays cut.	Yes
The yield of each tray.	Yes

Identify crops approaching maturity.	Yes
Notify the user when crops become available.	Yes
Monitor resource levels such as seed stock, fertilizer, growing medium, trays etc.	Yes
Maintain each variety of microgreen and the conditions under which they need to be kept.	Yes
Note the responsible person for each activity.	Yes
Record which trays have been sprayed with which chemicals and when.	Yes
Record the chemical and the withholding period when crops are sprayed.	Yes
Notify the user when the withholding period expires.	Yes
Bring relevant information together to aid in the compilation of the sowing schedule.	Yes
Monitor each area to determine which areas contain which crops.	Yes
Visually display crops in their respective locations.	Yes
Link orders received to orders filled.	No
Monitor cutting progress.	No
Be compatible with portable devices for ease of use.	Yes
Limit access to unauthorized data and data editing.	Yes
Monitor wastage and reason (poor quality crop, lowers sales than expected, etc.)	Yes

All except two requirements were met by the information system, namely the ability to link orders received to orders filled and the monitoring of cutting progress. A previous project completed at the company focused on the ordering system and an information system to facilitate orders, it was thus to avoid these projects overlapping that no further detail was explored in receiving orders from customers. The proposed information system can in future however be linked to the order system to facilitate the required functionality. The capability to monitor the progress of an order in real time required further investigation and may be a focus area for future projects.

4.2.5 Limitations to the Information System

The implementation of an information system can be costly and may require an experienced software developer to achieve the desired results. The implementation of such a system may require additional employee training and development courses on how to properly use the platform that facilitates the information system. Furthermore, the successful implementation of an information system may not lead to improvements if the source of the problem is not corrected, it can however help the user to identify such a core problem and its causes.

4.3 Option C: Do Nothing

The third option available to PicoGro CC is to continue operations and accept the current frustrations and losses as they are. If the previous two options are seen as impractical or infeasible, without any alternatives available, the best option may be to continue without change or to consider focusing efforts on smaller aspects to improve circumstances gradually in smaller steps. A benefit of option C is that no additional costs will be incurred apart from the existing losses. A disadvantage would be that the current frustrations and poor communication flow would continue to impact the organisation negatively and as time progresses these incorrect practices may become more ingrained in company culture making later improvements more difficult to implement.

4.4 Comparison

The three options A, B and C were compared to determine which would be the most beneficial course of action for PicoGro to follow. Three criteria were used to compare the alternatives against one another.

4.4.1 Finance

The financial aspect is important in determining which alternatives are possible and which alternatives will be beneficial for the company. Evaluation of the financial aspect of a project is often done by comparing the NPVs of different alternatives. Although the NPV of option A is the most negative of all the options at - R 575 839,08, the project opens opportunities for future gains by making the remaining land available for sale or for use in future projects. Selling the land at an appropriate price would bring the NPV up to at least zero.

The NPVs of the *Microsoft Dynamics* and *Microsoft Access* alternatives both fall below zero, meaning that neither will bring direct gains to the company. The *Microsoft Access* database provides the opportunity for more employees to make use of the system because of the lower cost in comparison to Dynamics. The decision of management whether the land should be sold in option A plays a role in the benefits of option B. If the land is not to be sold then option B is more feasible than option A since the NPV is higher although still negative. The NPV of option C is considered to be zero.

4.4.2 Effectiveness

Each option solves the problem to a different degree and will impact the company in a different way. Option A aims to eliminate the wasted movement between the farms and improve communication by improving the proximity between departments within the organisation. It is expected that closer proximity will allow for better management and transparency for employees to better understand the processes outside of their own department. Improved communication is expected to promote unity within the organisational culture.

The aim of option B is to improve the clarity of communication between management and employees through the introduction of a formal channel. The system would allow a platform for managers, supervisors and employees to have access to the same information by eliminating miscommunication and subjective interpretation. Better communication channels coupled with the ability to collect and store data would allow for more accurate instruction and action, particularly in sowing and harvesting the correct amounts to fill orders with minimum waste. The information system may not directly solve the management problems faced by Pico1 as this would require human decision making skills, however the data gathered can be analysed to aid in the decision making process and expose and quantify problems that may otherwise seem abstract. Option C offers no solution to the problems faced but takes the viewpoint that these problems are, at least for the moment, tolerable and as such do not require immediate attention.

4.4.3 Ease of Implementation

The best solution will need to be practically possible as any proposed solution that is limited by resources or technology will not benefit the company. While all options are possible given the company's resources, some options may be more effort to implement than others. Relocating the greenhouses may require effort in setting down the current facilities and setting up the new facilities. There may also be a period of discomfort for employees as they adjust to the new setting and become a part of a system with newer methods and equipment. Once this period is passed however, productivity can continue and possibly increase with no opportunity to revert back to the previous system. The scale of the project effects how easily it will be completed.

The implementation of an information system may be more challenging as employees will require training on new devices and new software that may at first increase their workload. The adjustment period for option B may be longer than that expected for option A as the human element of resistance to change may cause employees to constantly revert back to previous methods. It may take time for employees to get used to the new system and there is a risk that employees may reject the system completely and boycott its use in order to force the old system back into use. The adjustment period may be extended by any changes made to the information system while overcoming unforeseen technical problems that may arise in its use. Option C is by nature the easiest to implement as it requires zero effort. The continued frustration in current processes is however a deterrent and could be considered effort in choosing option C since it would require constant corrections and additional work to maintain.

The criteria were used to analyse the alternatives and score each option in each criteria based on a scale from 0 to 5 with 5 being the best possible result for the criteria and 0 being the worst. The outcome is summarised in Table 7.

Table 7: The scores achieved by the different options in each criterion.

	Option A	**Option B**	**Option C**
Finance	1/3	2	3
Effectiveness	4	3	0
Ease of Implementation	2	3	4
Total	**7/9**	**8**	**7**

The score given for option A in the Finance criterion was given first without the sale of the land and second with the sale of land separated by a forward slash, resulting in a total score with and without land sale.

Chapter 5

Conclusion

The aim of this project was to investigate possible solutions to management problems faced by PicoGro CC. PicoGro faces pressures to improve the systems and processes in use to better their service and product quality and remain competitive in the market as well as expand their business. Several industrial engineering techniques were researched to provide context to the problems faced by PicoGro.

The business processes were modelled using BPMN notation and the key problem areas were identified. The main causes of the poor communication was found to be the outdated communication mediums and the lack of a formal communication channel. The SCOR model was used as an effective tool in identifying areas to focus improvement efforts and for possible metrics to be put in place. Metrics will help in monitoring process performance and provide a platform for assessing the impact of future changes. Currently no quality control or inspection procedures are being implemented and enforced within the production process. The internal supply chain between sowing and packaging is currently running on informal systems that tend to cause inefficiencies and inaccuracies resulting in late order fulfilment and damaged produce.

Three options were proposed and compared, namely relocating the greenhouses at Pico1 nearer to the pack house at Pico2, the implementation of a formal information system and no action. The relocation would cost R 2 195 970,00 over the course of a year and would incorporate the breaking down of all greenhouses and shade netting at Pico1 as well as the moving of all offices and other facilities to Pico2, 3 and 4. The relocation option would eliminate the need for short distance transportation between farms, reduce the number of hours of overtime worked due to poor coordination and allow better utilisation of employees. The NPV of the relocation project was calculated to be - R 575 839,08 over a 10 year period. The negative value indicates that a loss would be made if the project was carried out. The loss could be reduced however by selling the remaining land. The value that the land will need to be sold for to reach a zero NPV was calculated to be R 613 844,46, assuming that the relocation will be paid for at the beginning of the first year and the land sold at the end of the first year with this period not generating any financial savings.

An information system was designed to facilitate the interaction between employees, supervisors and managers through a formalised structure. The system was designed to monitor specific aspects of day to day operations to allow data collection and analysis. *Microsoft Access* and *Microsoft Dynamics* were compared as alternatives and it was proposed that the information system could be linked to *Microsoft Visio* to form an information dashboard. The dashboard could be used to visually represent the layout of Pico1 and any important information that the user would require regularly to allow the user to remain up to date with operations in real time. Employees in the field could use the system on a portable device as they work in each area. Some additional costs such as internet connection and data usage would however need to be incurred to enable this system to work.

The third option is the choice to not take action. If none of the other options are feasible, the best course of action could be to continue operations as they currently are. Taking no action would imply that the current losses and wastages are acceptable and that it is not a priority to reduce them. Although no cost would be incurred, the risk of losing clients because of poor service delivery or poor product quality is present, as well as the continued frustration of the employees.

The three options were compared to one another by focusing on three criteria. The financial aspects of each option were considered to evaluate the feasibility, the overall impact and effectiveness in solving the identified problems was considered and the practical implications of carrying out each option were discussed. The options were then scored on a scale of 0 to 5 for each of the criteria and the total score for each option was determined by summing the individual scores. The relocation option was scored without selling the remaining land and with selling included.

5.1 Recommendations

The most economically feasible option is shown by the comparison to be dependent on the decision of PicoGro's management. If PicoGro decides to sell the land after relocation has taken place then the relocation may be feasible if the land is sold for an appropriate amount. If the land is not to be sold then the information system becomes the most economical solution. Although PicoGro will suffer a financial loss for these two options, the potential improved service and product delivery could yield intangible gains in terms of new clients, reduced wastages and better company culture.

All three options carry a measure of risk. Implementing a large scale change such as facilities relocation may lead to unforeseen challenges and circumstances that cannot be reversed. It is not guaranteed that any change will yield the desired results as social factors play a large role in determining success. It is therefore suggested that the information system be used to improve conditions at Pico1. The implementation of such a system may require changes and adjustments as the need arises, however this option seems to align the best with strategies already in place. The uncertainty in the effects of change on the productivity levels also favour the information system as it is more flexible than the relocation option while accomplishing more than the option to take no action.

5.2 Future Investigations

Several opportunities exist for further improvement. The proposed information dashboard would require further research into system functionality to determine the best layout for presenting data as well as the most ideal interface for use by employees. The real time functionality and interactions between users should be explored to create the most practical solution for PicoGro.

The information system should be refined and designed to best provide useful information as well as to statistically analyse the data collected from day to day use. The system should be used to aid further investigation into fluctuations and inconsistencies throughout processes. Other systems such as the ordering and delivery systems can be linked to the proposed system to increase capabilities and provide a better understanding of the enterprise as a whole. The system should be used to highlight wastes and better communicate organisation wide goals to all employees.

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Appendices

Appendix A

Faculty of Engineering, Built Environment and Information Technology

Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie / Lefapha la Boetšenere, Tikologo ya Kago le Theknolotši ya Tshedimošo

1956 – 2016 60 years of Engineering Education

Final Year Project Mentorship Form
2018

Introduction

An industry mentor is the key contact person within a company for a final year project student. The mentor should be the person that could provide the best guidance on the project to the student and is most likely to gain from the success of the project.

The project mentor has the following important responsibilities:

1. To select a suitable student/candidate to conduct the project.
2. To confirm his/her role as project mentor, duly authorised by the company by signing this **Project Mentor Form**. Multiple mentors can be appointed, but is not advised.
3. To ensure that the **Project Definition** adequately describes the project.
4. To review and approve the **Project Proposal**, ensuring that it clearly defines the problem to be investigated and that the project aim, scope, deliverables and approach is acceptable.
5. To review and approve all subsequent project reports, particularly the **Final Project Report** at the end of the second semester, thereby ensuring that information is accurate and the solution addresses the problems and/or design requirements of the defined project.
6. Ensure that sensitive confidential information or intellectual property of the company is not disclosed in the document and/or that the necessary arrangements are made with the Department regarding the handling of the reports.

Project Mentor Details

Company:	Pico - Gro CC
Project Description:	Relocation feasibility study and communication improvement of microgree operations.
Student Name:	Gareth Swart
Student number:	15106463
Student Signature:	
Mentor Name:	Yolandi le Roux
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E-mail:	yolandi@pico-gro.co.za
Tel No:	011 238 7170
Cell No:	0732274477
Fax No:	—
Mentor Signature:	

Figure 13: A copy of the signed industry mentorship form.

Appendix B

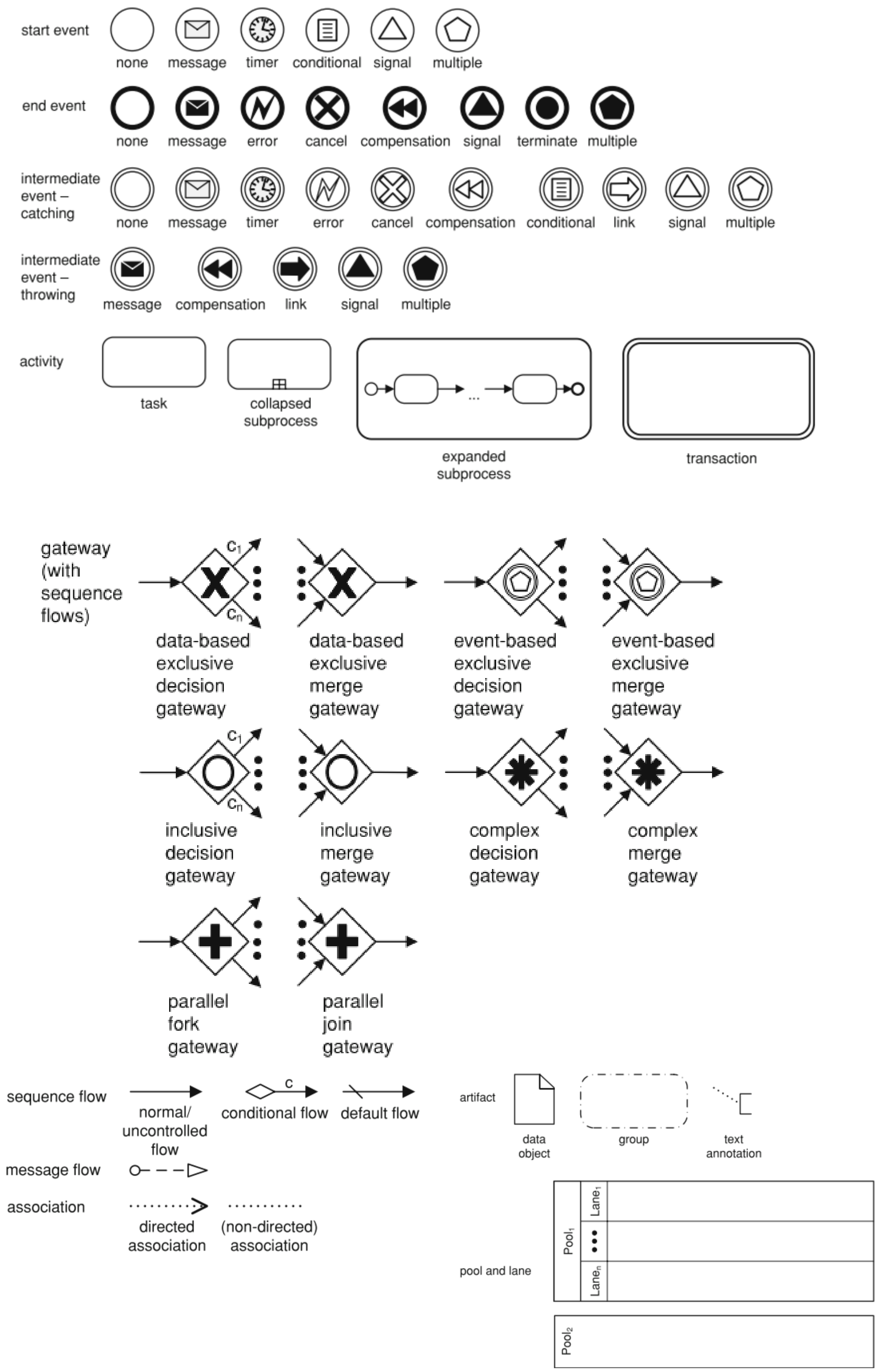

Figure 14: BPMN notation symbols summary (Lam, 2009).

Appendix C

Table 8: Fuel costs of Colt over 4 month period.

				Type	Date	Num	Name	Memo	Amount
Costs incurred for Production									
	Transport								
		Fuel							
			Colt Bakkie						
				Cheque	2018-03-02	18/03/02/05	Fuel - Production	COLT	447.47
				Cheque	2018-03-10	18/03/10/02	Fuel - Production	COLT	792.19
				Cheque	2018-03-27	18/03/27/02	Fuel - Production	Colt	837.14
				Cheque	2018-04-08	18/04/08/04	Fuel - Production	colt bakkie	852.41
				Cheque	2018-04-30	Apr18	ABSA	Colt	400.00
				Cheque	2018-05-01	18/05/01/01	Fuel - Production	COLT	807.09
				Cheque	2018-05-04	18/05/04/01	Fuel - Production	COLT	874.5
				Cheque	2018-05-31	18/05/31/03	Fuel - Production	COLT	450
				Bill	2018-06-07	I05264	Emfuleni Fuels (Pty) Ltd	COLT	755
				Cheque	2018-06-23	18/06/23/02	Fuel - Production	COLT	731.58
			Total Colt Bakkie						6947.38

Appendix D

```
#Fuel

Fuel = 6947.38/4 #pm

#overtime

OTRate_Pick = 16.75 * 1.5
workers_Pick = 3
hoursPWeek_Pick = 4

OTRate_Pack = 17.10 * 1.5
workers_Pack = 6
hoursPWeek_Pack = 6

OTWages_Month = (OTRate_Pick*workers_Pick*(hoursPWeek_Pick/7)*30)+(OTRate_Pack*workers_Pack*(hoursPWeek_Pack/7)*30)

#wages

minWage = 3169.19 #pm
Workers = 3
WagesSaved = minWage*Workers


f = 0.056              #Inflation rate
r = f + 0.01           #Nominal interest rate used as MARR
m = 12                 #Number of periods in a year
i = r/m
ia = (1+(r/m))**m - 1  #Effective interest rate per month

LifeSpan = 10                      #years
Rel_cost = 2195970.00              # cost of relocation
X1 = (OTWages_Month+WagesSaved) #combined wage variables
Incr = 1.056                       #Yearly increase of wages due to inflation

Nc = c()
N1 = 0 #NPV for combined wage variable
for (p in 2:10){
  N1 = N1 + (X1 * (Incr**(p-1)) *(  ( (1+i)**(m)-1 ) / ( i*(1+i)**(m) )   )*( 1/( (1+r)**(p-1) ) ))
  Nc[p] = N1
}

NPV = (Fuel * (  ( (1+i)**(m*LifeSpan)-1 ) / ( i*(1+i)**(m*LifeSpan) )   )) + N1 - Rel_cost #Total relocation NPV

landSale = (-NPV) / ( 1/((1+r)^1) ) #minimum cost land can be sold for

NPV2 = - 1755.60 * (  ( (1+i)**(m*LifeSpan)-1 ) / ( i*(1+i)**(m*LifeSpan) )   )    #NPV for MS Dynamics
NPV3 = - 107.30 * 3 * (  ( (1+i)**(m*LifeSpan)-1 ) / ( i*(1+i)**(m*LifeSpan) )   ) #NPV for MS Access
```

Figure 15: The code used to calculate NPV in *RStudio.*