

BPJ420: Final Project Report

Yolandi le Roux

11119854

Mentor: Dr. Jacomine Grobler

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Supply chain analysis and improvement

- towards high quality ripe and ready avocados

Executive Summary

This project considers the avocado supply chain of Bertie van Zyl (Pty) Ltd, more commonly known as ZZ2. ZZ2's avocado production is rapidly expanding and they are currently introducing "Ripe and Ready" avocados into the market. Ripe and ready avocados are avocados that have been ripened in ripening chambers at ZZFresh in Lanseria. There are however, added risks to ripening fruit. Since avocados only show bruising when they ripen, independent of where in the supply chain the bruising occurred, the fruit could show damage after the ripening process. According to research conducted by Ogunleye & Adefemi (2007) post-harvest losses are approximately 10-20% worldwide. It is therefore important for ZZ2 to limit post-harvest losses as far as possible

In order to successfully ripen avocados, a synchronized supply chain that can ensure the timely delivery of unbruised avocados is required. To achieve this, strict control over the post-harvest supply chain processes needs to be implemented. Since there are so many variables that influence agricultural practices, this can be a challenge. The aim of this project is to carefully analyse the supply to identify possible areas for improvements and develop suggested solutions for these problems.

Firstly existing literature from similar enterprises were researched. Six different Industrial Engineering Mechanisms that could help with the completion of this project were also researched and reviewed. These techniques include time studies, method engineering, business process modelling notation (BPMN), information systems design, supply chain operations reference (SCOR) and business model canvas (BMC). The results can be seen in the Literature review.

For the AS-IS analysis, time was spent carefully analysing each section of the supply chain. A batch of avocados was followed through the entire supply chain whilst time, temperature and humidity measurements were taken. The supply chain was also mapped with BPMN to help clearly understand all the processes and how they interact with each other.

Through the supply chain analysis two key problems were identified: Problem 1: Addressing damage caused to the trees during the picking process. Problem 2: Addressing the lack of information captured throughout the supply chain. These problems are addressed in two separate chapters. Each of the problems were carefully analysed and alternative solutions were developed. The alternative solutions were then evaluated against criteria and the optimal solution chosen.

For the first problem, the chosen solution to reduce the climbing of the trees is to improve the picking pole that the workers use to pick the fruit. A new picking pole was designed, developed and built. A time study was done to compare the new picking pole to the current design. The results show that the new picking pole picks avocados faster than the current picking pole, reducing the average picking time per fruit from 13.98 seconds to 7.04 seconds, a reduction of 49.65 %, almost cutting the picking time per fruit in half. The new pole is also more accurate. On average one in three tries (34.4%) with the current picking pole does not cut the fruit compared to only 12.96% missis from the new pole. This can be attributed to the fact that the new pole requires much less aiming than the new pole. Further improvements for the new design were also discussed. These improvements include increasing the ring diameter as well as the bag size, selecting the best material for the bag and increasing the length of the cutting blades.

The second problem is addressed in a separate chapter. To attempt to satisfy a growing demand for ripe and ready avocados, ZZ2 will need to utilise the ripening chambers at their full capacity. If the correct information could be captured, at the right times into a central database, the data could then be extracted from the database and used to calculate more accurately the ripening time and conditions required for each batch of avocados. Accurate and reliable information is therefore required throughout the supply chain.

To ensure all the information that is required is captured, a flow chart was developed that maps out each section of the supply chain. The flow chart lists at each section of the supply chain the data fields that need to be captured. This information is then used to construct an Entity Relationship Diagram (ERD). An ERD is a graphical representation of an information system that defines the relationship between people, objects and places that form a system (Rouse, 2014). Linking the correct entities for the ERD would also create a path of traceability, implying that a final product, such as a box of avocados, could be traced back through the supply chain. In addition to determining a more accurate ripening time, this would allow ZZ2 to answer questions such as who handled the fruit and from which field and when the fruit was harvested.

This project forms a full avocado supply chain analysis, looking at pre-harvest, harvesting and post-harvest operations. The information gathered through this project can aid ZZ2 in improving their avocado supply chain by eliminating problem areas in order successfully implement the ripening process at ZZFresh.

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List of Acronyms

BMC	- BUSINESS MODEL CANVAS
BPD	- BUSINESS PROCESS DIAGRAM
BPMN	- BUSINESS PROCESS MODELLING NOTATION
DFD	- DATA FLOW DIAGRAM
ERD	- ENTITY RELATIONSHIP DIAGRAM
KPI	- KEY PERFORMANCE INDICATOR
SCOR	- SUPPLY CHAIN OPERATIONS REFERENCE
XML	- EXTENSIBLE MARK-UP LANGUAGE
ZZ2	- COMMON NAME FOR BERTIE VAN ZYL (PTY) LTD

1. Introduction

1.1 Background to the company and problem

Bertie van Zyl (Pty) Ltd (more commonly known as ZZ2), is a farming company that operates mainly in the Limpopo province, specifically in Mooketsi, Politsi, Polokwane and Musina. They also operate in the Western Cape in Ceres and Riebeek-Wes as well as in Langkloof in the Eastern Cape.

Among the products that ZZ2 produces are tomatoes, avocados, mangos, onions, apples, pears and cattle. Tomatoes form the main crop. Annually up to 190 000 tonnes of tomatoes are produced by ZZ2, making them a world leader in tomato production. The focus of this project is on avocados. ZZ2's avocado production is rapidly expanding. Currently they have over 660ha of avocados producing more than 9200 tons per annum and they are planting more orchards each year.



FIGURE 1: NEW ZZ2 AVOCADO DEVELOPMENTS (ZZ2, 2014)

ZZ2 have over 79 different cultivars and 17 rootstocks to ensure they produce a year round supply of avocados. These varieties are split in two main categories, namely Hass and Green Skins. Hass avocados are distinct from green skins due to its rough dark green skin that turns darker as the fruit ripens. Some of the green skin varieties that ZZ2 grows include Fuerte, Pinkerton, Ryan, Reed and Queen.

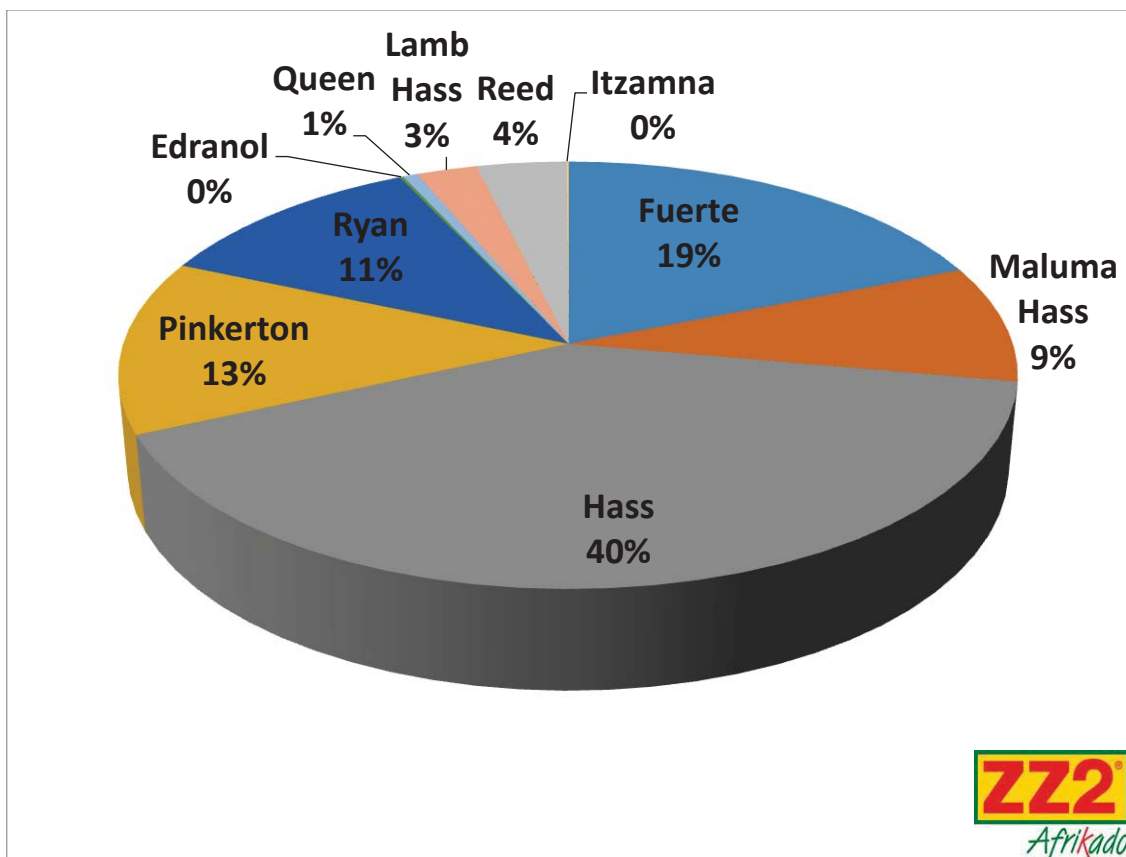


FIGURE 2: ZZ2 AVOCADO VARIETIES (ZZ2, 2014)

Avocados do not ripen on the tree. While avocados are on the tree the fruit remains hard, only softening and ripening after picking. This characteristic allows for some control over when the fruit ripens. After fruit is picked the fruit does not ripen immediately. Factors such as the maturity of the fruit when it was picked, temperature and ethylene gas exposure all influence the time that the fruit takes to ripen. By controlling these factors, the time until ripening can be used to the advantage of the company. In the case of exports, the fruit are kept cold throughout the supply chain, never breaking the cold chain. This ensures the fruit do not ripen before they reach the final location. For the demanding local market, ripening chambers can be used to control the ripening process.

Ripening chambers work by controlling temperature and ethylene gas levels. Ethylene gas is the natural gas that fruit gives off when it ripens. By adding ethylene into the room, the fruit is encouraged to give off its own gas, therefore triggering the ripening process (Mission, 2012). The fruit are then left in the ripening rooms and monitored for 2 to 5 days, depending on factors such as the maturity of the fruit and the level of ripeness required.

Marketing studies that ZZ2 conducted show that there is a growing demand for 'Ripe and Ready' avocados. Ripe and ready avocados will increase sales and overall customer satisfaction and ZZ2 has just completed the construction of an avocado ripening facility at their distribution centre near Lanseria, Gauteng.

There are however, added risks to ripening fruit. Since avocados only show bruising when they have ripened, independent of where in the supply chain the bruising occurred, the fruit could show damage after the ripening process. Handling of the ripe fruit must also be very gentle avoid additional bruising. In order to successfully ripen avocados, a synchronized supply chain that can ensure the timely delivering of unbruised avocados is required. To achieve this, strict control is required over the post-harvest supply chain processes. Since there are so many variables that influence agricultural practices, this can be a challenge. ZZ2 wants the Avocado supply chain to be carefully analysed, in order to identify possible areas for improvements.

1.2 Problem Statement, Project Aim and Rationale

As mentioned in the previous section, in order to successfully ripen avocados, a synchronized supply chain that can ensure timely delivery, as well as minimal fruit damage of avocados, is required. Fresh produce supply chains have countless uncontrollable factors that can influence the effectiveness of the value chain. If it rains, for example, avocados cannot be picked, as the avocados are more prone to nodule (the small bumps on the skin of the avocados) damage when the fruit are wet.

Avocados are also highly temperature sensitive and therefore it is important to maintain the cold chain throughout the supply chain. Furthermore avocados are sensitive to bruising. Bruising that occur throughout the supply chain, only become evident when the fruit ripens. When all these factors are taken into consideration, having a synchronized avocado supply chain that can ensure the timely delivery of unbruised avocados, is a difficult task.

To achieve such a supply chain, strict control is required over the post-harvest supply chain processes. To enable strict control, it will be necessary to understand the entire supply chain and to identify and address problems that occur throughout the supply chain, as all these problems will affect the ripening process. For fresh produce it is important to address both the handling as well as the duration of the processes since the fruit are bruise- and time-sensitive. To ensure traceability it is important to understand the flow of information throughout the supply chain. The aim of this project is therefore to analyse and improve the

avocado supply chain within ZZ2 and to eliminate all controllable variables in order to be able to successfully implement the ripening process. FIGURE 3 below shows an example of the basic outline of an agricultural supply chain and the different sections that will need to be analysed for the completion of this project.



FIGURE 3: AGRICULTURE SUPPLY CHAIN EXAMPLE (Produce Marketing Association, 2015)

Traditionally, avocados have been marketed in shops, stacked as large pyramids of hard fruit or sold in large quantities in boxes or bags. See FIGURE 4 for current ZZ2 packaging examples. This type of packaging would then leave the customer with the dilemma of buying large quantities of unripe fruit, not knowing when the fruit will ripen exactly. Chances are the fruit would not be ripe when the customer planned to consume it, or all the fruit would ripen simultaneously and most of the fruit would be discarded in the end.



FIGURE 4: EXAMPLES OF ZZ2 AVOCADO PACKAGING; BOXED TO THE LEFT, BAGGED TO THE RIGHT (ZZ2, 2014)

Having ripe fruit available in the shop, packaged in smaller, convenient quantities would eliminate the above mentioned problems for the consumers, increasing customer

satisfaction. See FIGURE 5 for a sample of ripe and ready packaging. Customers can buy avocados, knowing that the fruit will be ready for consumption within the next 2-3 days. According to Frontline Services (2014), consumers are rather shopping more often and purchasing lower quantities per shopping event. This proves that there is a growing market for ripe and ready avocados. If the ripe and ready program is implemented properly, it has the potential to increase avocado sales. According to Mission (2012), some suppliers have seen sales rise as much as 400%. The avocado market is continuously increasing and has enormous growth potential. With managed supply chains in place avocados can be very profitable.



FIGURE 5: 'RIPE AND READY' PUNNET AVACADO PACKAGING

1.3 Project Approach, Scope and Deliverables

Project Approach

The approach that will be followed (depicted graphically in FIGURE 6) will be to firstly analyse the entire post-harvest avocado supply chain. This will include briefly the pre-harvest maturity and ripeness tests to determine if fruit are ready to be harvested, the harvesting process itself, as well as a thorough discussion of post harvesting activities such as sorting, packing, transporting, ripening in the ripening facilities and transportation to the super markets. To understand all of these sections, time will be spent on all the different segments of the supply chain, completely analysing all the key activities. The aim is to identify possible areas for improvement.

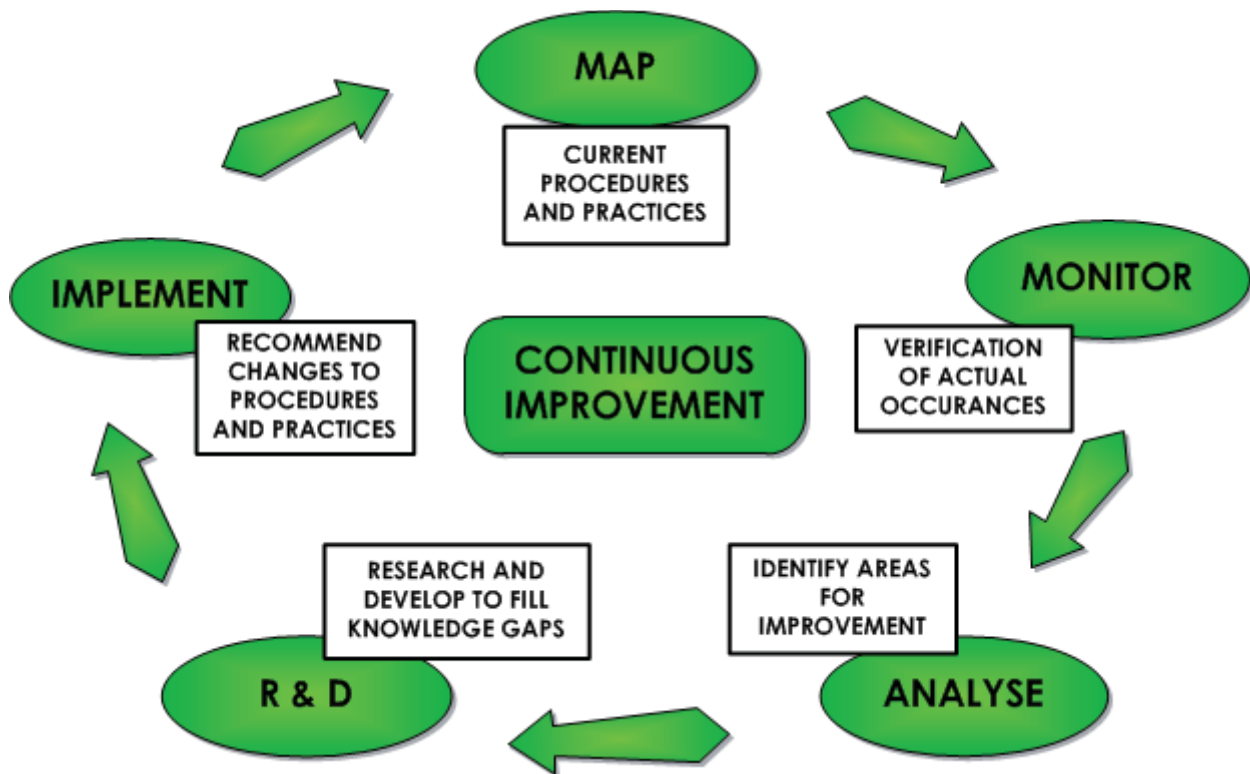


FIGURE 6: SUPPLY CHAIN ANALYSIS APPROACH, BASED ON (Badenhorst-Weiss & Nel, 2011)

The analysed supply chain will then be mapped with BPMN. Business Process Modelling Notation provides a universal language which enables all involved parties to communicate the processes clearly and completely (Bizagi Suite, 2014). BPMN defines the notation and semantics that is required for a Business Process Diagram (BPD). A BPD is a diagram similar to a flow chart and documents the sequence of activities that occur in a process graphically. As the entire supply chain is analysed, key problem areas will be identified. The focus will then shift to understanding these specific problem areas. Solutions for these problems will then be designed, implemented and the improvements measured.

In order to gather data to analyse and map all the activities an avocado undergoes as it works its way through the supply chain, a sample of avocados will be carefully monitored as the fruit makes its way through the supply chain. As the sample is being followed, temperature will be measured, any bruising of the fruit will be monitored and time studies will be completed to gather data. Information regarding the avocados that is currently being captured will also be analysed.

Project Scope

The project aims to deliver the following:

- A thorough literature review on avocado supply chains, avocado ripening facilities as well as Industrial engineering techniques that can be used.
- A complete supply chain analysis and mapping of the current supply chain.
- An analysis of the dataflow throughout the supply chain
- Identified problems and areas for improvements.
- Solutions to identified problems.
- Implemented solutions and quantified improvements.
- Improved throughput time by eliminating unnecessary practises or improving current practises

Project Deliverables

For the literature review, six different industrial engineering techniques is researched and reviewed in chapter 2. These techniques include time study, method engineering, business process modelling notation (BPMN), information systems design, supply chain operations reference (SCOR) and business model canvas (BMC). Section 3.1 gives a full avocado supply chain analysis, including an analysis of pre-harvest, harvesting and post-harvest activities. Section 3.2 contains graphical results of time temperature and humidity levels that were taken as a batch of avocados were followed through the supply chain. The entire supply chain is mapped with BPMN, shown in FIGURE 19 in section 3.3.

Through the analysis two main problem areas are identified and addressed in separate chapters. Chapter Problem 1: Addressing damaged caused to the trees during the picking process by developing and implementing a new picking mechanism. Section 5 addresses the lack of information captured throughout the avocado supply chain by developing a flow chart and ERD (Entity Relationship Diagram) to capture missing data fields.

2. Literature Review

Research was done on existing case studies, to determine what processes were followed in solving similar problems, and which of these processes were successful. Different Industrial Engineering Tools that can help to complete this project is also researched and reviewed.

2.1 Existing literature on similar enterprises

Improving the avocado supply chain

According to Campbell & Campbell, (2009) the aim of improving the avocado supply chain is to deliver value and satisfaction to the end customer whilst ensuring profitability for all chain members. To achieve this they focus on certain areas:

- Efficient logistics and distribution
- Delivering of the right product
- Improvement of knowledge and best practises
- Value creation and sharing
- Effective communication and relationships
- Customer focus

Since these goals are in line with the aim for this project, the methods and results achieved by this case study are worth further investigating. The process followed by Campbell & Campbell (2009) is one of continuous improvement in the supply chain. To achieve continuous improvement they followed these five steps:

- Step 1: Mapping: What are the current procedures and practices?
- Step 2: Monitoring: Verifying what is actually occurring.
- Step 3: Analysis: Identifying areas of improvement.
- Step 4: Research and Development: Fill the knowledge gaps.
- Step 5: Change in practice: Recommend changes to procedures or practices.

These steps can be very helpful in completely understanding the avocado supply chain and identifying problem areas, and therefore the same approach will be followed in the completion of this project, as discussed in section 1.2; project approach, scope and deliverables.

Campbell & Campbell (2009) determined that consumers want avocados that are free from flesh bruising, rots and skin spotting, so they specifically focused on these three types of defects and their causes. Skin spotting is caused by nodule damage. Avocados have a leathery type of skin and when the small bumps are bruised it results in skin spotting. These bruised places can be an entry point for disease. Since these bruises are mainly caused by

handling, skin spotting accumulates further down the supply chain. Flesh bruising is caused by mechanical damage due to rough handling, especially dropping of the fruit. To determine exactly where along the supply chain mechanical damage has the largest impact, Campbell & Campbell executed a commercial robustness test. This is done by dropping fruit of different ripeness levels, from different heights and examining the bruising that occurs. The result of the test showed that susceptibility to bruising increases as fruit ripens and drop height increases. The effects are shown in FIGURE 7.

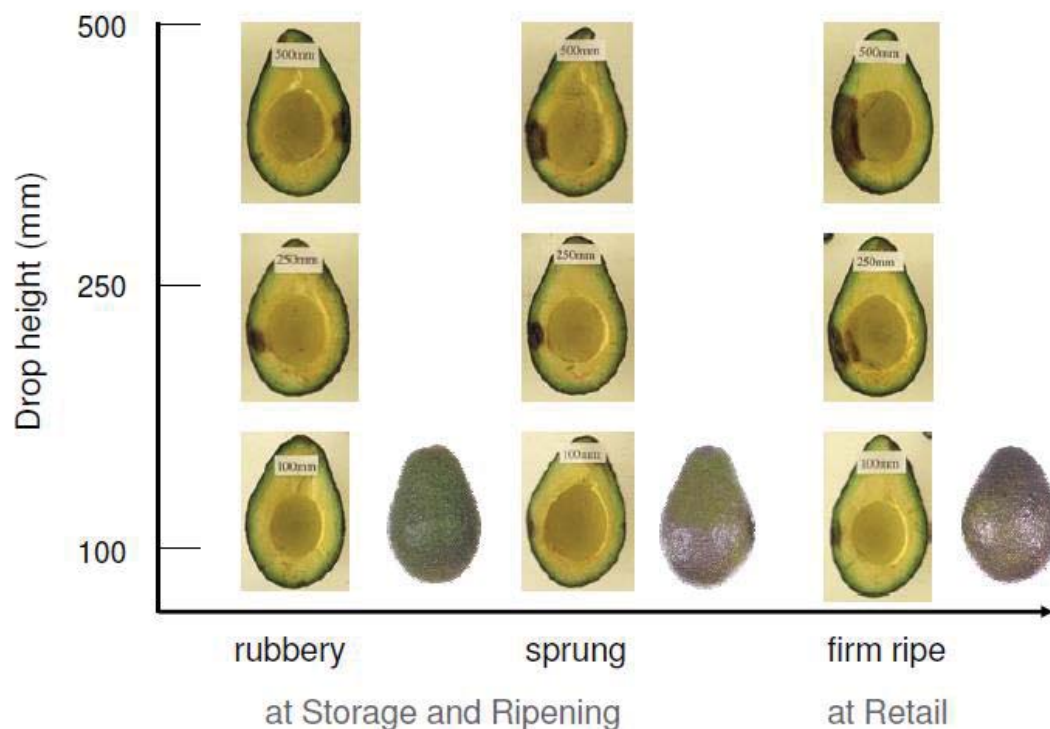


FIGURE 7: DIAGRAM SHOWING THE RESULTS OF THE ROBUSTNESS TEST (Campbell & Campbell, 2009)

The results of the robustness test emphasises the importance of proper handling of the fruit, especially the handling of ripe fruit. This information will be helpful in improving the handling practises of ZZ2.

In their report 'Improving the avocado supply chain' Campbell & Campbell (2009) also focused on growing practises and how this influences the crop. Several factors were identified that can affect quality including the effect that different levels of pruning have on the next year's harvest. This however is not within the scope of this project and will not be investigated further.

To conclude, the case study shows that problems arise in all sections of the supply chain and since these problems are connected, co-operation of all the different supply chain

partners is required to find the best solution. It is also determined that continuous learning, information sharing and training is required to ensure continuous improvement of supply chain performance.

INPhO Avocado Post-Harvest Compendium – Food and Agriculture Organization for the United Nations

This compendium compiled by Dorantes, Parada, and Ortiz (2004), considers the complete impact that avocados have, including economic and social considerations, the post production operations, as well as pest and decay control. Since the scope of this project focusses mainly on post-harvest activities, only that section of the compendium will be discussed further.

The Post-Harvest Compendium (Dorantes, et al., 2004), states that one of the objectives of post-production operations is to reduce the quality and quantity losses that occur as the fresh produce makes its way through the supply chain. Since avocados have high respiration rates, they release carbon dioxide and ethylene at a fast rate; which in turn causes a high decay rate of the fruit after harvesting. The high water content of avocados also makes them more prone to dehydration, fungal and bacterial attacks, as well as the mechanical injuries that are caused by improper handling. All of these factors emphasise the importance of correct post-harvesting operations and shows why it is important to analyse and improve supply chain operations.

According to research conducted by Ogunleye & Adefemi (2007) post-harvest losses are approximately 10-20% worldwide. This is similar to the findings of Aiello et al, (2012) who estimate that approximately 12% of fresh produce in developed countries are lost. Even if post-harvest losses are as low as 10%, the result is still a R1.2 billion loss in terms of 2012 fruit exports.

Dorantes, et al., (2004) also focusses on the importance of harvesting at the correct time. As discussed in the background of this project, if avocados are picked pre-maturely, the fruit will not ripen. However an important point that is discussed in the post-harvest compendium is that if the fruit are left too long before picking, their shelf life decreases significantly. Dorantes et al, continue to further discuss the importance of correctly executing the moisture test and the level of dry matter content required: a dry matter level of 22.8% (77.2.5 moisture) for Hass and 21% (79% Moisture) for green skins. These levels are confirmed by

Fuchs et al. (1995), who states that avocados are considered mature when the fruit has a moisture content of 77% for Hass varieties and 79% for green skin varieties.

Under the harvesting section of the compendium Dorantes et al. (2004) describes the Mexican practice of cutting avocados with extended scissors and leaving the fruit to fall to the ground. The fruit are then picked up at a later stage, even sometimes leaving the fruit on the ground overnight. This method is not ideal since the fruit are damaged by the fall and the prolonged exposure to the elements. They further state that it is important to reduce mechanical damage as far as possible, since mechanical damage affects pulp firmness and causes bruising. Bruising and skin injuries accelerate respiration rates, ethylene release rates as well as water loss and causes entry points for pathogen attacks. In order to prevent mechanical damage, during the supply chain analyses, focus will be placed on the handling of the avocados throughout the supply chain in order to identify and improve improper handling practices.

The section of the compendium regarding the sorting and packaging of avocados, describes research done to determine the optimal type of packaging for avocados. The aim of packaging should always be to improve the appearance and preservation of the fruit (Dorantes, et al., 2004). One of the aspects that they took into consideration was that packaging could restrict gas diffusion and even lead to an increase in post-harvest losses. Another aspect is the price increase caused by handling as well as packaging expenses. This is important to consider in the ripening process at ZZFresh since the ripe and ready avocados are re-handled and need to be handled more sensitively. The packaging that will be used for the ripe and ready avocados are also more expensive and careful consideration will need to be taken to choose the optimal packaging for the ripe and ready avocados.

2.2 Industrial Engineering Techniques

The following Industrial Engineering Techniques that are researched and discussed are tools that could aid in the completion of this project.

Time studies and Method Engineering

According to the Industrial Time Study Institute (2014), a time study is conducted by analysing a specific job, executed by a qualified and experienced worker. The goal is to identify the tasks that cause the longest delays or negatively impact the system. By identifying and eliminating these tasks, the most efficient method can be found, focussing on reducing both time and effort. A time study therefore calculates the time that will be

necessary to complete a certain task when implementing the best method. Time studies can also aid in establishing time standards for each process.

Another approach very similar to a time study is called Method Engineering or Method Study. Method engineering systematically analyses and records each task, focusing on the manner in which the tasks are executed, rather than on the time they take to complete. The focus remains to identify tasks that can be improved as well as reduce the work content of a job (Industrial Time Study Institute, 2014).

Combining a time and method study is called a work study (Sinha & Garg, 2011). A work study will be very useful in analysing the avocado supply chain. Conducting a time study will aid in identifying the tasks along the supply chain that waste the most time and has the potential to be improved. A method study can aid in identifying tasks that can be changed in order to reduce the workload on the workers and improve the overall process. Once these tasks have been identified and the collected data has been analysed, the focus can shift to improving or completely eliminating these problem areas.

Business Process Modelling Notation

Business Process Modelling Notation (BPMN) is a graphical modelling language that uses symbols to define relations and attributes in a business (Bizagi Suite, 2014). The main goal is to model flow within the processes, almost in the same way as a flow chart, except that BPMN is based on fixed terms of usage. It is these fixed terms of usage that makes BPMN such a useful mapping tool since it enables the conversion of diagrams into machine-readable files using Extensible Mark-up Language (XML). Furthermore BPMN provides a universal language which enables all involved parties to communicate the processes clearly and completely. BPMN defines the notation and semantics that is required for a Business Process Diagram (BPD). A BPD shows the sequence of activities that occur in a process graphically.

BPMN can be used to map the Avocado supply chain. This will be a helpful tool, since in order to map the supply chain in BPMN, it is important to study and understand the entire supply chain. This will in turn help to identify problems and find solutions to these problems. Once the complete process is mapped, the focus can then shift to the problem areas, zooming in in more detail.

Information Systems Design

According to Kaye Morris (2012), Information Systems Development is a set of logical development phases that can be followed to ensure that all the steps to analyse, design, implement and maintain information systems are taken. These phases are: scope and objective, feasibility, analysis, logical and physical design, implementation, maintain and finally review.

The analysis and logical design steps can be useful tools to analyse dataflow throughout the system of a company. Analysis focuses on gathering and documenting information regarding the current system, as well as information that would be required by a new system. Logical design aids in supplying a detailed logical definition of the required system.

There are two diagrams that can aid in the analysis and logical design processes. The first is a Data Flow Diagram (DFD). A DFD is a graphical representation of the flow of data through an information system. According to Bruza & Van der Weide (1993) a DFD is often used to create a preliminary overview of the system. The second diagram is an Entity-Relationship Diagram (ERD). An ERD is a graphical representation of an information system that defines the relationship between people, objects and places that form a system. An ERD is a data modelling tool that can be used to define the different processes in a business (Rouse, 2014). An ERD is usually used to form the basis for a database.

Following the information systems design process to analyse the data flow throughout the avocado supply chain will help to identify areas where required information is not being captured, or not being passed along the supply chain. This will help to determine if traceability is present throughout the supply chain and address the problems that exist.

Supply Chain Operations Reference

Supply Chain Operations Reference or SCOR is an analytical model used in Supply Chain Management. SCOR focusses on the different phases that contribute to satisfying customer demand. One of the main benefits of SCOR is that it is standardized and describes the supply chain in a universal language (Duvenage, 2008). Firstly supply chain performances is identified, and then measured against standard SCOR metrics. The SCOR Model also helps to identify opportunities for improvement and set different performance goals.

SCOR consists of 3 main parts: process modelling, performance measurements and supply chain best practices. Broken down further, process modelling consists of five management processes: planning supply chain operations; sourcing goods or services; making or

manufacturing products; delivering finished goods; and handling product returns. In the Performance measurement section, the SCOR model makes use of over 150 Supply Chain Counsel approved Key Performance Indicators (KPI's) which are used to measure the success of a supply chain operation. Under supply chain best practices the SCOR model requires practices to meet certain requirements. SCOR has been used by manufactures around the world to identify and adhere to critical supply chain metrics (Cole, 2008).

SCOR can be used as a diagnostic tool to identify gaps in the avocado supply chain's traceability and communication flow. However this can also be achieved by making use of the Information Systems Design process as previously discussed. SCOR is a powerful tool that can help to establish a standard practise for an efficient and effective supply chain, but since this project does not aim to develop Key Performance Indicators (KPI's) for the supply chain, the standard SCOR metrics would not be used. For mapping the supply chain, BPMN would be a sufficient tool to use.

Business Model Canvas

The function of a business model is to help describe and understand, or even predict the performance of processes in the real world. A business model is a model that takes aspects of a system such as input and output activities and organizes them to create value over the short, medium or long term (International Integrated Reporting Council, 2013). This is accomplished by simplifying the system. A business model takes external factors as well as the future outlook of the company into consideration.

Business Model Canvas (BMC) is a tool that helps management to strategize, create, explain, design and challenge the company's business model. It is a representation of the workings of a company and addresses the following business aspects: customer segments, value propositions, channels, customer relationships, revenue streams, key resources, key activities, key partnerships and cost structure (Osterwalder, 2004).

A business model defines the manner in which a company incurs profit. It can provide the company with a document that portrays their activities and trade-offs that can potentially have an impact on the company as well as a proposed business model to encourage future growth. Although a Business Model Canvas is a strong tool that can be used to help management create and change the company's business model, it will not be the optimal tool to use in this project, since this project does not aim to change the business model of the company.

3. Problem Investigation and Data Analysis

3.1 Avocado Supply chain analysis

To fully understand the Avocado Post Harvest Supply chain, an AS-IS analysis of current processes was conducted. The analysis is divided into Pre-harvest, Harvesting and Post-harvest activities.

3.1.1 Pre Harvest Activities



Growing of different cultivars

Due to limited availability of avocado tree seedlings in nurseries, ZZ2 built a nursery to grow avocado trees themselves. Growing avocado trees is a complex process, but a worthwhile exercise since it provides ZZ2 access to a wide range of cultivars. The different types of cultivars ripen at different times of the year and this allows ZZ2 to produce year round avocados. The Hass varieties are especially popular since they produce avocados almost year round. The Export market peaks between March and October and focusses mainly on Hass, Maluma Hass, Lamb Hass, Fuerte, Pinkerton and Ryan.

Preparation of orchards for planting

The preparation of avocado orchards is very important and therefore significant planning, time and money is invested into this process. Avocado trees are planted on ridges (small hills) since avocado trees are sensitive to water stress. Too little or too much water for long periods of time will damage the roots of the trees, and the ridges prevent the latter. To avoid damages to the trees due to drought, drip system irrigation is used to supply the trees with a constant flow of water. All the irrigation used at ZZ2 is automated and can be controlled from the offices. Fertilizer is distributed through the same irrigation systems.

Orchard layout and pruning

To yield the most fruit per tree, regular pruning of the avocado trees is very important. Trees that are not pruned form large branches that no longer bear fruit. The aim in pruning is to

keep the avocado tree in more of a shrub shape than a tree shape, resulting in smaller branches that bear more fruit. This way the trees are also kept a manageable size and additional ladders or cranes are not needed when the avocados are harvested. Large 'tree' shaped trees carry equal or even less fruit than the smaller shrub like shaped trees, but require more space per tree, therefore reducing the overall tons per hectare produced. The larger trees also require more labour, time and special equipment to be picked.

Moisture test

As mentioned in the literature review, avocados do not ripen on the tree. To ensure that the fruit will ripen after it has been picked, the fruit must have a certain maturity level (mature = potential to ripen) before the fruit is picked. The maturity level is determined by a moisture test. To conduct the moisture test, 5 random sample avocados are picked on a weekly basis from each orchard block. The process for the maturity test is as follows:

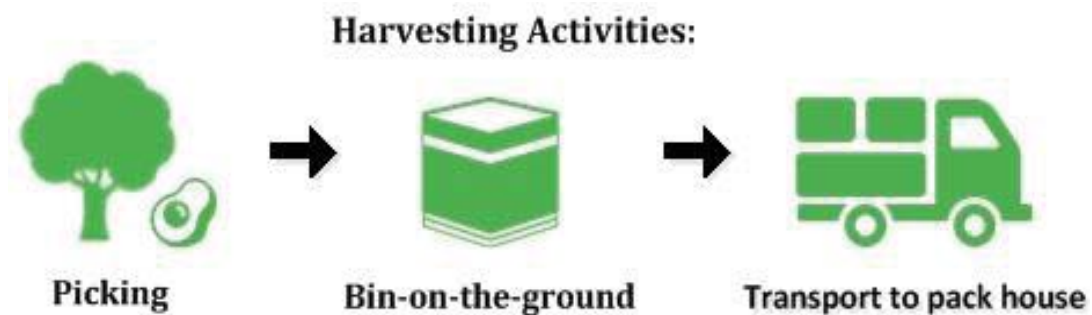
- The five avocados from each orchard block picked
- The avocados are brought to the pack house and each one is cut in half
- Half of each avocado is discarded and the pit is removed from the remaining half
- A section of the skin around the cut section is peeled and the flesh of all five the avocados are grated into plastic containers with a very fine grater.
- A sensitive scale that can pick up 0.01 grams is used (see FIGURE 8).
- First a petri dish is placed on the scale and the weight jotted down.
- Then the fine grated avocado is added to the petri dish until it is exactly 10g heavier than the weight of the empty petri dish.
- Three of these petri dishes are filled up with the gratings from the five sample avocados that came from the same orchard block.
- The three filled petri dishes are then placed four times into a microwave for 60 seconds each time.
- After each minute the petri dishes are taken out, weighed and the weight written down. The petri dishes are then placed back into the microwave for increments of 30 seconds at a time, until there is no longer a change in the weight. The avocado is then considered dry.

An avocado is considered mature when it has a moisture content of 77% for Hass varieties and 79% for green skin varieties. The results of each moisture test is captured and communicated to the management team on a weekly basis.



FIGURE 8: SCALE USED TO CONDUCT DRY MATTER TEST

3.1.2 Harvesting Activities



Picking

Pickers are divided into three teams of more or less 40 people per team, depending on the season. Each Picker receives an over the-shoulder 20kg bag, pruning shears and a picking pole to pick with. The team works through an orchard from one side to the other, lane by lane. Pickers use the pruning shears to pick low hanging fruit. To pick fruit that are out of reach the pickers either climb the avocado trees or make use of picking poles. The design of the picking pole is a pole with a pruning shear like blade that cuts the stem of a hanging avocado. This blade is attached to a wire and a rope that can be pulled from a distance. The pole is also equipped with a bag that catches the avocado when the stem is cut. Examples of the picking poles are shown in FIGURE 9.



FIGURE 9: PICKERS USING PICKING STICKS TO REACH THE HIGHER BRANCHES

Before adding an avocado to the carry bag the stems of the avocados are cut short with pruning shears. If this is not done the long extruding stem of the avocado damages the fruit surrounding it when placed in the containers. It is however important to note that if the stem is removed completely, the fruit dries out more quickly and the avocado is no longer suitable for the export market. Once the bag is full the picker takes the bag to the person in charge of stamping their ticket. If the filled level of the bag is approved the pickers' ticket is stamped and the bag of avocados is carefully tipped into the bin. In this way there is kept track of how many bags each picker picks, which is important since the pickers are paid per bag.

Bin-on-the-ground

ZZ2 has recently introduced a new way of collecting the bins (large pallet size square containers in which the avocados are transported to the pack house, see FIGURE 10) called bin-on-the-ground. Previously, bins were stacked on top of each other at the end of the lanes. This meant that once a picker's bag was full, the picker would travel to the end of the row to empty their bag and then back to where they were picking. With this new method, bins are placed along the row that is being picked, before picking starts. The number of bins that will be required is calculated beforehand, based on the estimated harvest of the orchard.

The pickers can therefore unload their bags into the bin next to them and do not have to walk to the end of the line and back each time. A tractor with a trolley then drives through the row (shown in FIGURE 10) to pick up the bins. The tractor can pick up 8 bins each time. These full bins are then taken to a waiting area, and loaded onto a truck. Open, non-refrigerated trucks that are sealed with tarps at the side are used. Once the truck is loaded it takes the fruit to the pack house. The bin-on-the-ground system is less labour intensive than the previously used method and reduces the traveling times of the pickers. The system does

however have some limitations. The tractor and trolley system for example will not be able to operate on the steep slopes where the avocado varieties that bear fruit later in the season are grown.



FIGURE 10: BIN-ON-THE-GROUND TRACTOR TO THE LEFT, TRANSPORT TRUCK TO THE RIGHT

3.1.3 Post-harvest Activities



Sorting and Packaging

Every morning the results of the previous day's maturity tests are communicated to the pack house manager to ensure that the pack house is prepared for the avocados picked that day. The pack house starts to pack as early as 4:30 and sometimes only finish at night, especially during peak season. A land-to-pack-house letter is sent with each load that arrives at the pack house. The letter contains information regarding the number of avocados, cultivars, number of bins and orchards from where the avocados were picked.

At the pack house several sections of sorting takes place. The criteria by which avocados are sorted are size, colour and overall appearance. On arrival at the pack house, the bins containing the fruit are placed in the shade. The bins are then tipped one by one into a water bath where after the fruit float in a constant stream through the sorting system. At the first sorting station the avocados are divided into three classes as shown in FIGURE 11. The avocados are divided into class 1 (export), class 2 and class 3 avocados. The class 3

avocados are transported by conveyor belt to a different section and will be used in the production of avocado oil. The class one and class two avocados are cleaned dried and passed through a second sorting station where the class 1 avocados are separated and packed into boxes. The remaining avocados are then sent by a conveyor belt and packed in different boxes for the local market.



FIGURE 11: AVOCADO SORTING STATION TO THE LEFT, POLISHING BRUSHES TO THE RIGHT

Transportation

Different transportation methods are used for the export and local markets. For the export markets, ZZ2 outsources the transportation of the avocados to a transporting company. The fruit is transported in refrigerated trucks from Mooketsi to the Cape Fruit Terminal. The outsourced company is based in Tzaneen and the trucks are sent from Tzaneen when the pack house is ready. A temperature monitor is sent with each truck that monitors the temperature from the pack house, to the Cape Fruit Terminal and then on a ship to the final destination. This information is then sent via email to the pack house manager who checks to see that the cold chain was not broken.

For the local markets the avocados are transported in ZZ2's own trucks. These trucks are not cooled but the truck's sides are sealed with tarp (see FIGURE 10) and operate mainly at night. The number of avocados going to different locations, as well as the truck that will transport the fruit, is determined by the head of marketing. This information is then communicated to the logistics department. Avocado shipments that do not fill an entire truck are added to tomato shipments that are already on route to the specific markets, filling up the trucks as far as possible. ZZ2 sends out avocados to markets all across South Africa. Some of the shipments are sent to their distribution centre, ZZFresh in Lanseria, to be repacked into smaller packaging, or to undergo the ripening process.

Ripe and Ready (Distribution centre ZZFresh)

When trucks arrive at the distribution centre the avocados are unloaded and immediately placed in refrigerated rooms. Depending on the schedule and the number of avocados currently in the distribution centre, the pallets are sent through a rapid cooler to reduce the pulp temperature and are then stored in a cold room. The avocados' ripeness level is tested, and depending on the needs of the clients, either repackaged and sent out, or sent through the ripening process.

In the ripening chambers the temperature is strictly controlled. Fruit are 'tricked' into ripening by introducing ethylene gas, which is the natural gas that fruit give off during the ripening process, into the chambers (FIGURE 12). The level of ethylene gas is monitored and can be controlled remotely. Ventilation systems ensure the build-up of ethylene gas is never too high. Manual tests are done every day to inspect the level of ripeness of the fruit. ZZ2 classifies Avocados into 5 different stages of ripeness: hard, pre-conditioned, breaking, firm and ripe. The level of ripeness at which the avocados are removed is dependent on the final destination of the avocados. After the ripening process is complete, the avocados are repackaged into the required packaging form, which depends on the client's request. The final product is then transported by either ZZ2's own truck to its final destination or picked up by the client.



FIGURE 12: ZZFRESH AVOCADO RIPENING CHAMBERS

3.2 Data Analysis

The following graphs show temperature and humidity logger results of avocado samples followed through the supply chain. The data was obtained by sticking a probe into a sample avocado and placing the avocado back with a batch of avocados as they travelled through the supply chain.

Set 1: Avocado sample from harvesting at Rooiland to the pack house:

FIGURE 13 shows the increase in outside temperature (red) as well as pulp temperature (blue) of an avocado, from the time it's picked at Rooiland (orchard) at 08:15 in the morning, until it undergoes the sorting process at the pack house at 15:00. The graph clearly shows the increase in temperature starting out at 20°C and increasing to 26°C as the day progresses.

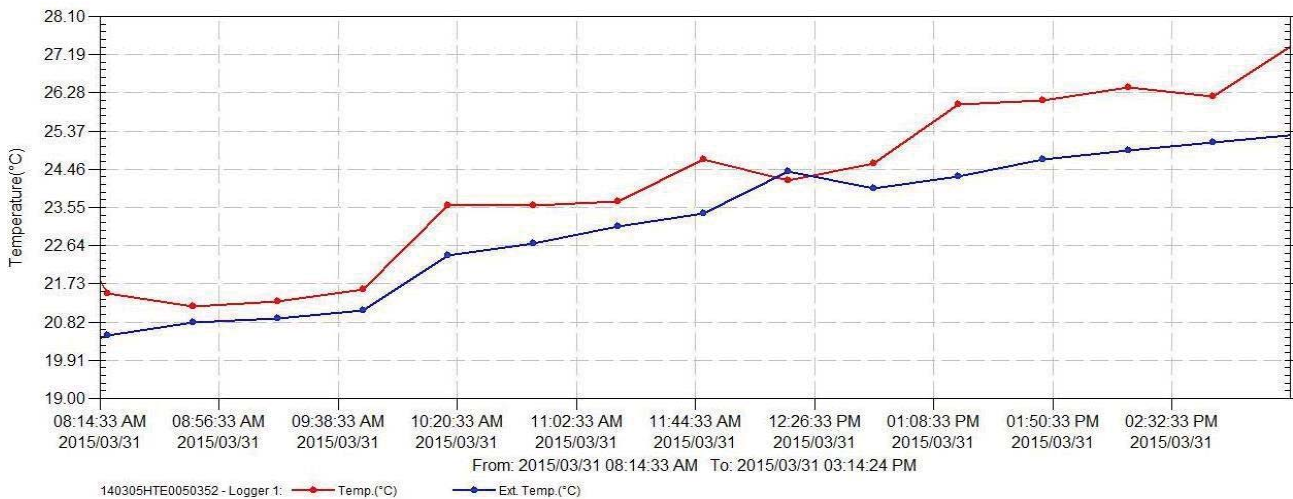


FIGURE 13: GRAPH SHOWING TEMPERATURES OF AN AVOCADO FROM ROOILAND TO THE PACK HOUSE

FIGURE 14 shows how the decline in relative humidity levels (green) from around 80% to 50% through the day.

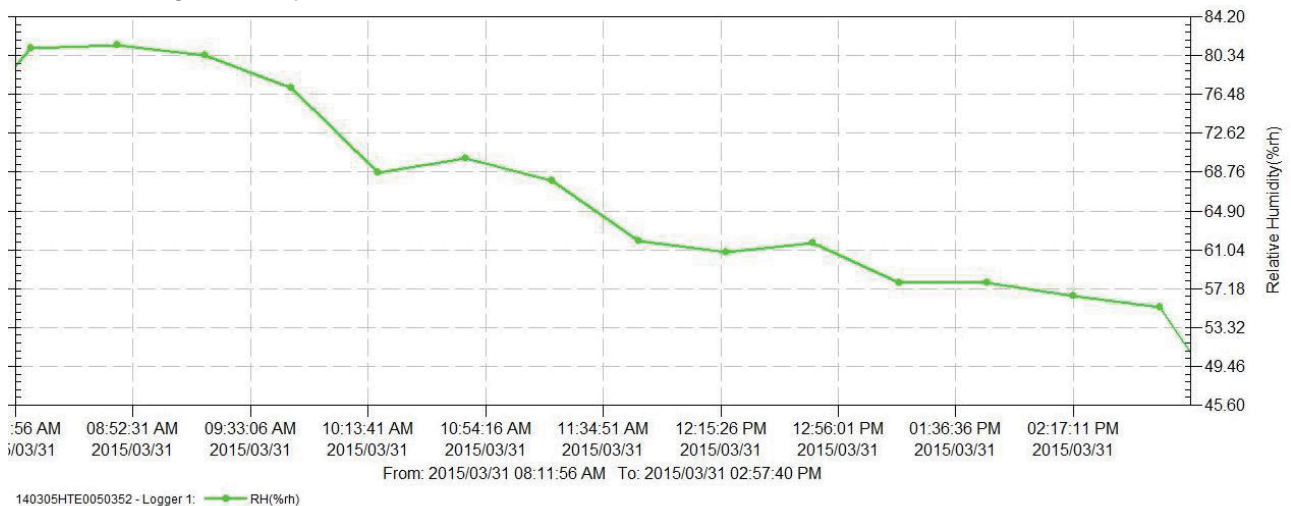


FIGURE 14: GRAPH SHOWING RELATIVE HUMIDITY OF AN AVOCADO FROM ROOILAND TO THE PACK HOUSE

Set 2: Avocado sample from harvesting at Wagendrift to the pack house:

As with the previous set of graphs, FIGURE 15 shows the increase in outside temperature (red) as well as pulp temperature (blue) of an avocado; from the time it's picked at Wagendrift (orchard) at 09:30 in the morning, until it starts the sorting process at the pack house at 14:00. The graph clearly shows the increase in temperature from around 22°C to 24°C as the day progresses.

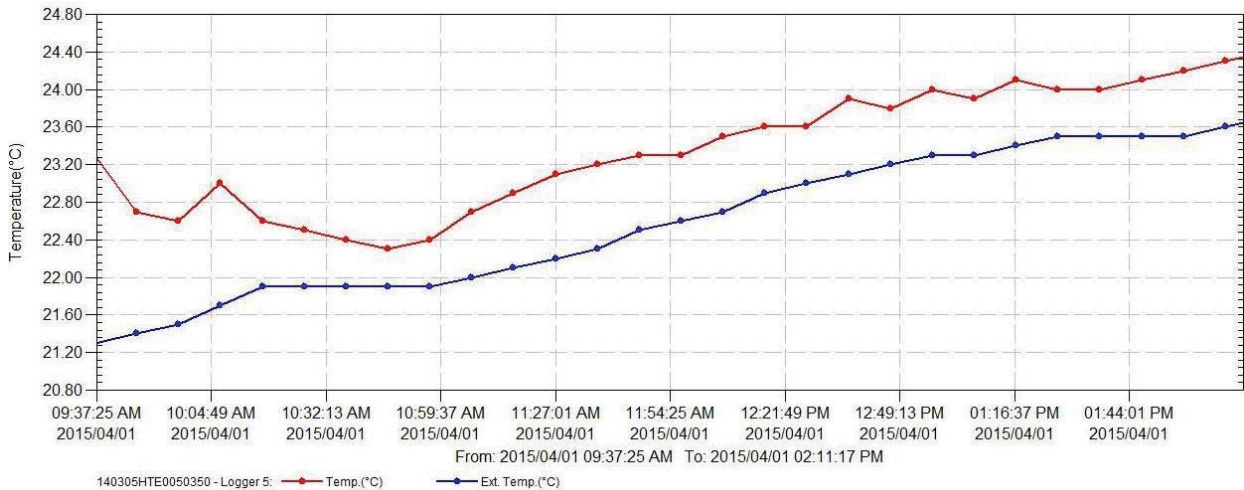


FIGURE 15: GRAPH SHOWING TEMPERATURES OF AN AVOCADO FROM WAGENDRIFT TO THE PACK HOUSE

FIGURE 16 shows how the relative humidity levels (green) change throughout the day.

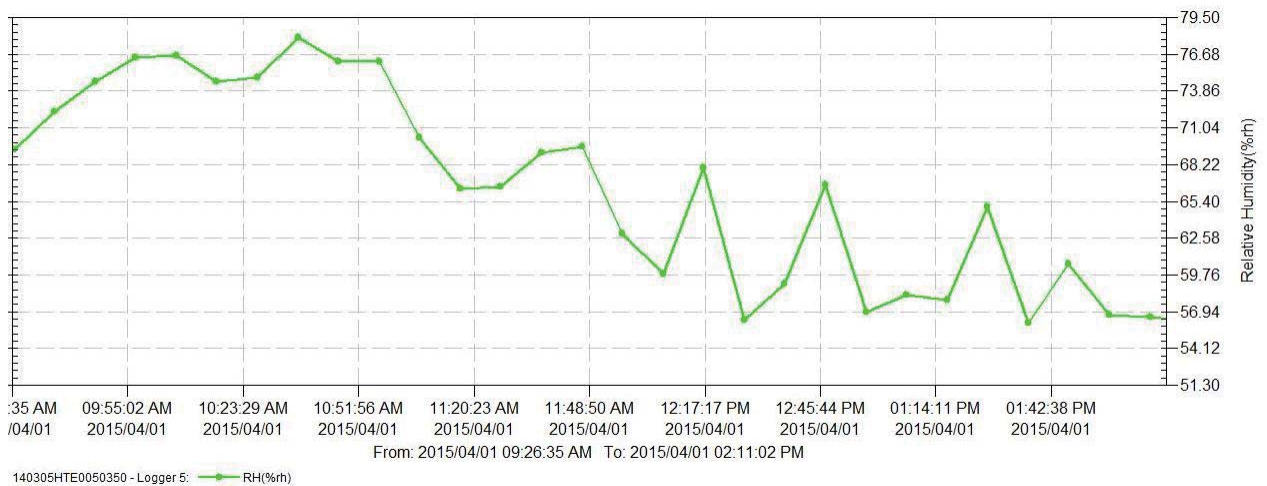


FIGURE 16: GRAPH SHOWING HUMIDITY OF AN AVOCADO FROM WAGENDRIFT TO THE PACK HOUSE

Both sets of graphs emphasises the importance of starting to pick early and getting the fruit removed from the field and into the pack house as soon as possible. Aspects such as good communication between management, and faster picking practises could all help to reduce the time the fruit are in the field.

Set 3: Pack house to ZZFresh over night

FIGURE 17 shows the decrease in outside temperature (red) as well as pulp temperature (blue) of an avocado; from the time it finishes the sorting and packing process at 13:30 at the pack house in Mooketsi, during its waiting period in the pack house, as well as overnight transportation to ZZFresh at Lanseria. The shipment arrived at Lanseria at 03:00 the following morning and was placed in the cool chambers until 06:00. The graph clearly shows the advantage of traveling during the night as the fruit cools down during the early morning hours from an initial temperature of around 25°C and arrived at ZZFresh at a temperature of around 18°C.

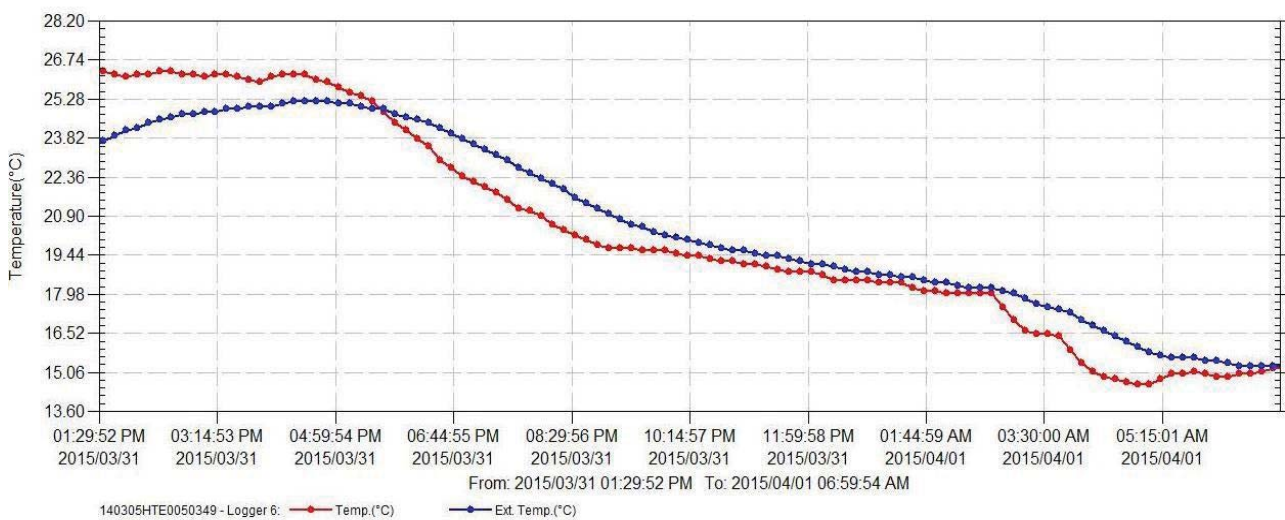


FIGURE 17: GRAPH SHOWING TEMPERATURES FROM THE PACK HOUSE TO ZZFRESH

FIGURE 18 shows the change in relative humidity levels during the same time frame.

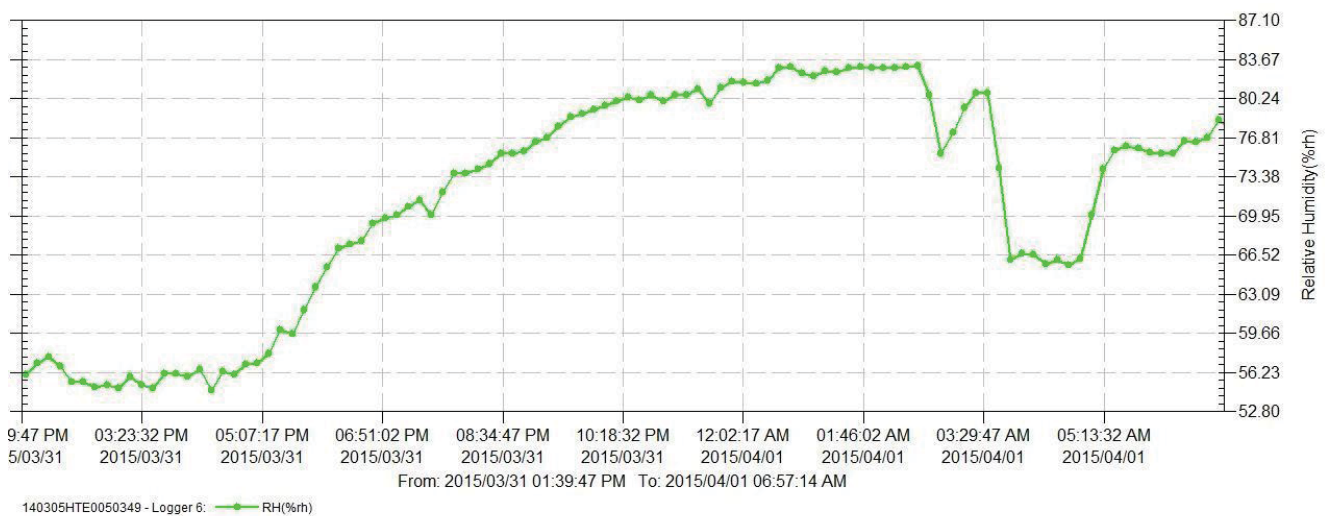


FIGURE 18: GRAPH SHOWING HUMIDITY LEVELS FROM THE PACK HOUSE TO ZZFRESH

3.3 BPMN Map of Avocado Supply chain

The next page shows a Business Process Modelling Notation (BPMN) map of the entire avocado supply chain. The map shows five different swim lanes, the processes followed in each pool as well as the flow of information between the different departments. The five pools are:

- The maturity testing team
- Management
- The picking team
- The pack house
- The ripening facility

Creation of the BPMN diagram, helped to understand the entire supply chain. By constructing the map, focus had to be placed on how the flow of information works throughout the supply chain. This aided in identifying problem areas, which are discussed in detail in section 4.

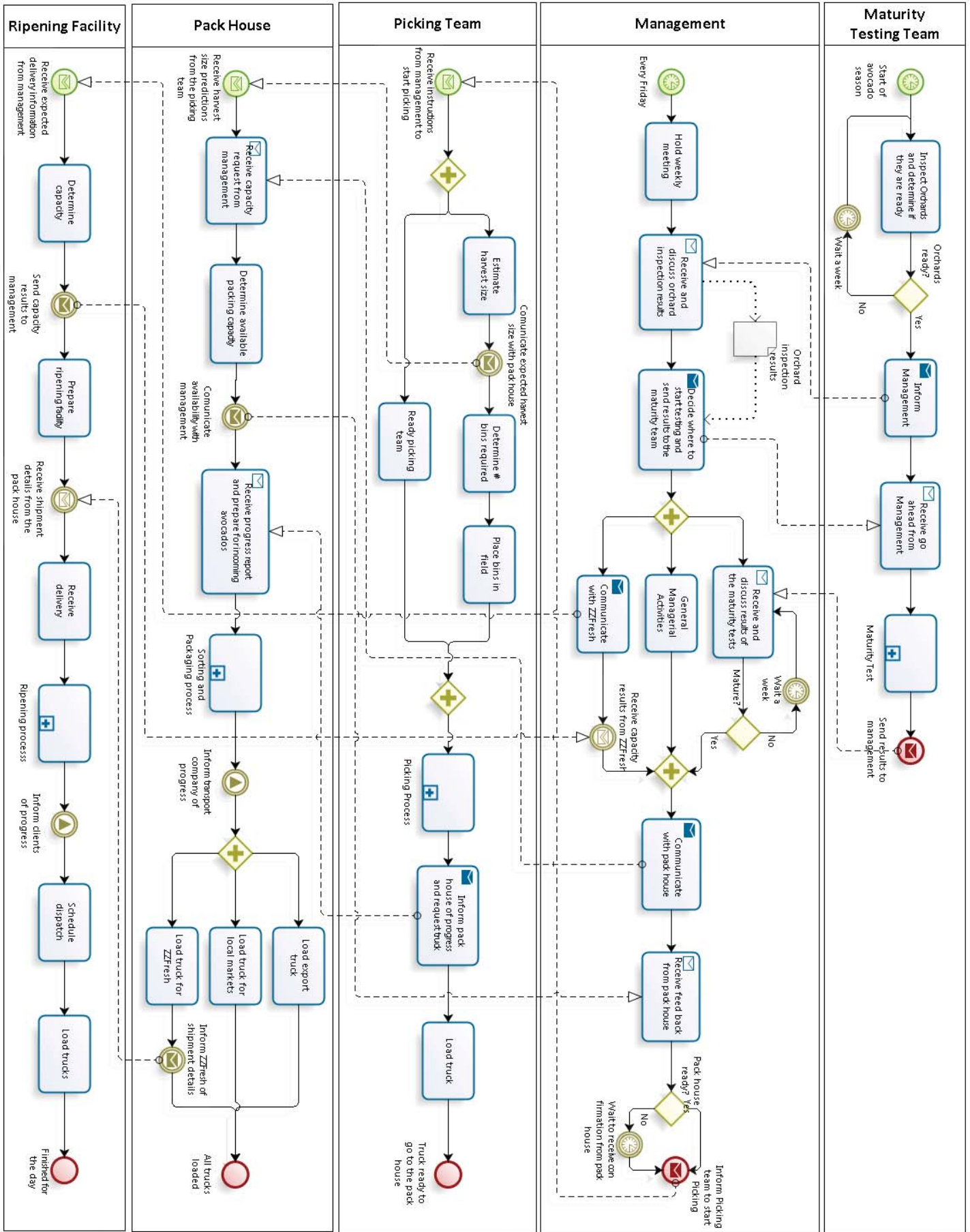


FIGURE 19: BPMN MAP OF THE SUPPLY CHAIN

Problem Areas Identified

The following section discusses two different problems that were identified through the supply chain analysis. These problems will be further analysed and this project aims to reduce or eliminate these problems.

4. Problem 1: Addressing damaged caused to the trees during the picking process

This section starts by carefully analysing the picking process and the damages caused during this process. Solutions that can reduce the damage are considered and evaluated against certain criteria. Based on the criteria a proposed solution is chosen. The proposed solution is then further developed and tested until a final solution is reached. The final solution is implemented, tested and verified. This section concludes with recommendations on how to further improve the final design.

4.1 Problem Discussion

As mentioned in the supply chain analysis, to reach the avocados growing at the top of the trees, pickers either make use of picking poles, or simply climb the trees. Some pickers prefer climbing since the picking pole is time consuming to operate. Although climbing is effective, there are however, a few negative factors that need to be considered.

Firstly, it is important to consider the safety of the pickers. The pickers are rushed when they pick since they are paid per bag of avocados that they pick. This means that they do not always tread carefully when climbing the trees. There have been incidents of workers who had to be taken to the clinic after falling out of the trees. Secondly the trees are damaged when they are climbed. For the same reason as mentioned above, pickers aren't extremely careful of where they step and frequently break off branches, especially the younger branches. After a picking team has been through an orchard the devastation can be seen (FIGURE 20).



FIGURE 20: NEW GROWTH BROKEN OFF DURING PICKING PROCESS

This is a problem that needs to be addressed. As mentioned in the discussion of the growing practises; the ideal shape of an avocado tree is less that of a tree and more the shape of a shrub. It is the younger branches with new growth and not the older branches that carry the fruit. ZZ2 deliberately prune the new trees to have a more shrub like appearance (FIGURE 21). In the younger orchards trees are also planted closer to each other, since they have found that a larger yield can be harvested from smaller trees, planted closer together than large trees planted further apart. This way, more trees fit in per hectare. If the trees are pruned properly from a young age these smaller shrub like trees yield the same and sometimes even more fruit than the large trees with open branches.



FIGURE 21: OLDER TREE WITH LARGE NON FRUIT BEARING BRANCHES TO THE LEFT, MORE SHRUB LIKE TREE TO THE RIGHT

Taking these factors into consideration, it is clear that climbing the trees is not the ideal way of harvesting, since it is specifically this new growth that is damaged by the climbing process. In the long run this is going to become an even a bigger problem. Avocado trees produce more avocados each year, until they reach a certain age. After this age the older trees are replaced with younger trees. Currently the older trees are the larger trees that have large thick branches that can be climbed.

ZZ2 is rapidly expanding their avocado production, and planting more new orchards each year. These younger orchards' trees are planted closer together and pruned correctly from the beginning. Ideally these trees will not grow to be large trees with bare branches, but rather grow into large bushes. This means that in a few years' time, pickers will not be able to climb the trees, or if they manage to, they are going to do even more damage. This emphasise the importance of addressing this problem and finding a sustainable solution.

4.2 Alternative Solutions

A solution to the problem would be if the pickers stopped climbing the trees entirely. To accomplish that, however, a more user friendly method of picking the fruit from the higher branches would be required. By designing an effective picking tool that is easy to operate, the amount of climbing that the pickers would need to do could be reduced.

Current Picking Pole

The current picking pole's design was analysed and the pole was found to be difficult to operate. One of the main reasons is that the tool requires good aim since it uses a blade almost similar to the blades of pruning shears to cut the stem of the avocado. This blade is attached to a rope that is pulled to cut the stem (see FIGURE 22). One of the problems of this design is that it requires good aim and stability to ensure the stem of the avocado falls within the cutting area before the rope is pulled to cut the stem.



FIGURE 22: PHOTO OF THE CURRENT PICKING POLE

The pickers also complain that after excessive use, the friction caused by the rope hurts their hands. Another problem is that the custom made cutting blade is not sharpened regularly. A similar problem with maintenance is that the bag is stitched around the bent wire and cannot be removed and replaced easily. This results in the bag not being cleaned or replaced. The advantages and disadvantages of the current picking pole are stated in TABLE 1.

<i>Current Picking pole</i>	
<i>Advantages</i>	<i>Disadvantages</i>
small cutting blade	requires aiming
small ring diameter	multiple moving parts
can be used on all avocado varieties	custom shaped blade
can be used for mangoes	difficult to manufacture
	rope not ergonomical
	fixed blade
	fixed bag
	need to reel in to empty bag

TABLE 1: ADVANTAGES AND DISADVANTAGES OF THE CURRENT PICKING POLE

Design 1: Cross cutting blade

Burden et al. (1989) suggested a design where a cutting blade is used instead of a shear design. Eliminating the shear cutting motion would reduce amount of aiming as well as the number of moving parts that is required. Less moving parts make the design easier to manufacture and also requires less maintenance. If a blade was attached across the ring, a pulling motion could be used to cut the stem of the avocado, rather than having to aim to get the stem of the avocado within the cutting mechanism. The blade would be attached to the

pole as shown in FIGURE 23, allowing the picker to pick fruit with either sides of the blade. These blades can then be removed, sharpened and replaced at regular intervals.

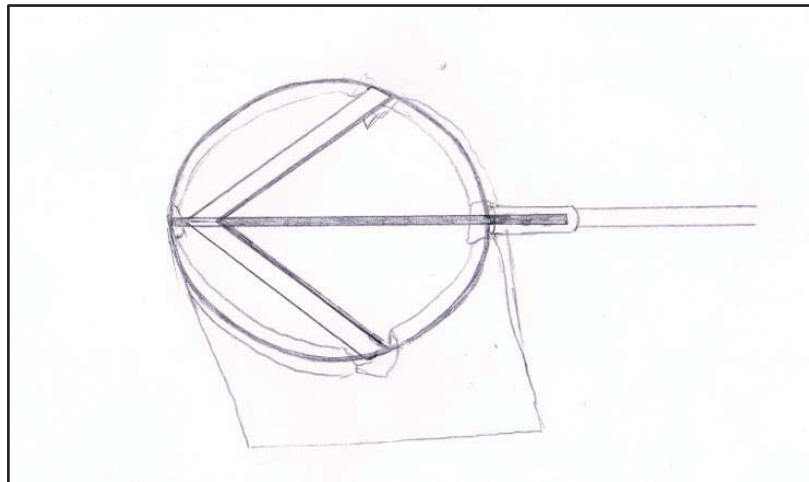


FIGURE 23: DESIGN 1 WITH TWO BLADES ACROSS THE RING

The design however does not take into account the removal of the bag itself. Another downside of the design is that the size of the ring would have to be increased significantly, in order to allow the larger varieties of avocados such as Queen Avocados to pass through the ring. Ideally the picking pole also needs to be used for picking mangoes, which can be much larger than avocados. The advantages and disadvantages of the first design are stated in TABLE 2.

<i>Design 1: Cross cutting blade</i>	
<i>Advantages</i>	<i>Disadvantages</i>
requires less aiming	large cutting blade
no moving parts	can only be used on smaller varieties
good ergonomics	large ring diameter
easy to manufacture	fixed bag
standard shaped blades	cannot be used for mangoes
removable blades	need to reel in to empty bag

TABLE 2: ADVANTAGES AND DISADVANTAGES OF DESIGN 1

Design 2: Blade moved to outer edge

Based on the same principle as the first design, namely that a blade can be used to slice through the avocado's stem instead of using a shear cutting motion, the most significant change in this design would be to reposition the blade to the outer edge of the pole (FIGURE 24). This would allow the size of the ring to remain relatively small and still be used to pick larger varieties of avocado, and even mangoes. The hanging fruit would be guided to the

outer edge, and the stem cut with a swift pulling motion. The blades on this design can also be removed, sharpened and replaced. In this design the bag can also be removed since there are no cross bars in the way. The advantages and disadvantages of the second design are stated in TABLE 3.

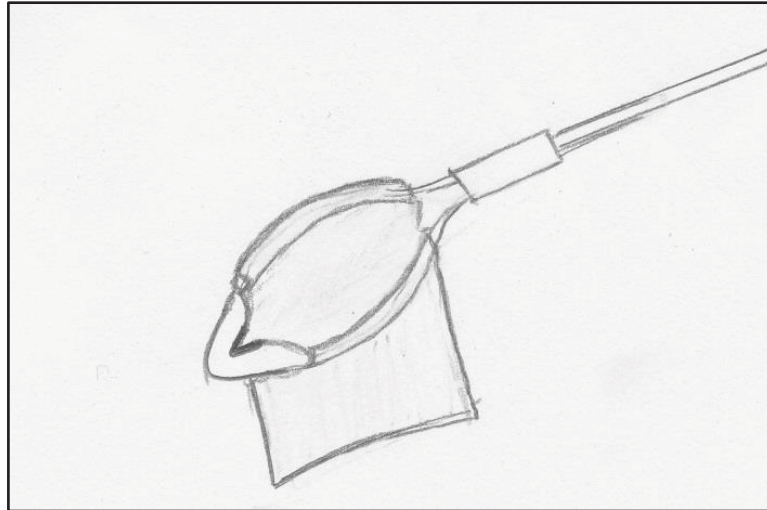


FIGURE 24: DESIGN 2 MOVING THE BLADE TO THE OUTER EDGE

<i>Design 2: Blade moved to outer edge</i>	
<i>Advantages</i>	<i>Disadvantages</i>
requires less aiming	need to reel in to empty bag
no moving parts	
good ergonomics	
easy to manufacture	
small blade size	
standard shaped blades	
removable blades	
removable bag	
smaller ring diameter	
can be used on all avocado varieties	
can be used for mangoes	

TABLE 3: ADVANTAGES AND DISADVANTAGES OF DESIGN 2

Design 3: Chute attached to pole

One of the problems discussed throughout the analysis of the current design, was the amount of time lost during the picking process as a result of emptying the bags. The poles need to be reeled in towards the body in order for the picker to be able to reach the picked fruit, and transfer the fruit into the shoulder bag. Therefore a design with a chute attached to the pole was considered. The function of the chute would be to guide the avocado towards

the body of the picker, breaking the speed of falling, and emptying via the chute into the 20kg shoulder bag of the picker (See FIGURE 25).

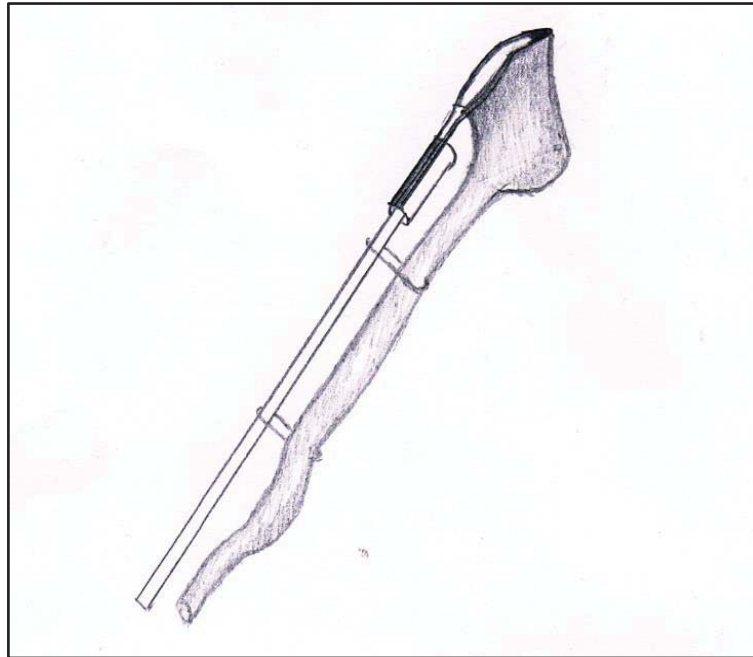


FIGURE 25: DESIGN 3 WITH A CHUTE ATTACHED TO THE POLE

However, there are a few problems with this design. In order to break the speed of the falling avocado the material would have to be somewhat elastic. To survive in the environment where the picking poles are used, the material would also need to be durable and strong. Another aspect to take into consideration is how much the chute would impact overall operability of the picker. The pickers often use these poles stretched out in difficult to manoeuvre places between the branches of the avocado trees. The chute would increase the overall size of the picking pole, and could negatively impact the mobility of the pickers.

The chute could potentially hook onto branches and other obstacles. When making use of the picking poles, the pickers extend the poles from their bodies to reach the hanging fruit. This would make designing a chute that could deposit the fruit into the bags around their shoulders difficult. The advantages and disadvantages of the third design are stated in TABLE 4.

<i>Design 3: Chute attached to pole</i>	
<i>Advantages</i>	<i>Disadvantages</i>
requires less aiming	large and difficult to operate
good ergonomics	difficult to manufacture
no need to reel in to empty bag	multiple parts
small cutting blade	fixed blade
small ring diameter	fixed bag
can be used on all avocado varieties	cannot be used for mangoes

TABLE 4: ADVANTAGES AND DISADVANTAGES OF DESIGN 3

4.3 Evaluation of Alternative Solutions

In order to decide on the best design to develop further, criteria was developed and the different designs evaluated against the criteria. The advantages and disadvantages of each design were taken into consideration, as well as additional criteria that were developed. Each design was reviewed and discussed with ZZ2's engineering team. Each of the designs is given a mark out of 5 per criteria, where 0 is low and 5 is high, adding up to a total mark out of 50. TABLE 5 shows the evaluation matrix.

<i>Criteria:</i>	<i>Different Designs</i>			
	<i>Current picking pole</i>	<i>Cross blade</i>	<i>Blade on outer edge</i>	<i>Shoot attached to pole</i>
Ease of use	2	4	4	3
Speed of use	2	3	4	4
Learning curve	2	4	5	3
Damage caused to fruit	5	2	3	3
Accuracy	3	4	4	3
Ease of Manufacture	3	5	5	2
Cost of Manufacture	4	5	5	3
Ergonomics	2	4	4	5
Safety	4	3	4	4
Cleanliness	2	3	4	3
Total (/50)	29	37	42	33

TABLE 5: EVALUATION MATRIX FOR THE DIFFERENT PICKING POLE DESIGNS

Ease of use refers to the ease of handling the design, taking factors such as size and weight into consideration. *Speed of use* estimates how fast the pole will be able to pick fruit. *Learning curve* refers to how difficult it is to learn to operate and master use of the design. *Damage caused to fruit* determines the potential of the design to damage fruit, based on factors such as the blade's design and size, as well as other exposed sharp objects. *Accuracy* refers to how many times out of each try, an avocado is successfully picked. This is based on aspects such as the blade design as well as the amount of aiming that is required.

Ease and cost of manufacture is based on aspects such as total amount of parts, material of parts, custom designs required and design of the blade used. *Ergonomics* takes the strain on the worker's body, caused by use of the picking pole into consideration. This includes injuries that could be caused by operating the pole as well as overall weight and size of the design. *Safety* considers aspects that pose danger to the picker as well as persons surrounding the picker, including characteristics such as protruding sharp edges and exposed blades. *Cleanliness* takes into consideration how easy it is to frequently clean and replace both the blade and the bag of the pole as well as other aspects that could contaminate the fruit.

4.4 Selected Design

Based on the results of the evaluation matrix, as well as further discussion with ZZ2's engineering team, the second design where the blade is moved to the outer edge of the ring is chosen as the best option to be further developed and tested.

Design Process

As mentioned above, the most significant change to the picking pole's design would be to reposition the blade to the outer edge of the ring. To test if such a cutting mechanism is feasible; a blade was fastened to the end of an existing picking pole (FIGURE 26, Photo 1).



FIGURE 26: PICKING POLE FIRST IMPROVEMENT WITH ALMOST CLEAN CUT

Picking with this blade showed a lot of promise. The avocado stems were sufficiently cut by the blade to be picked without damaging the avocados. However the result was not a clean cut (see FIGURE 26, Photo 2). Possible reasons for this include the thickness and sharpness of the blade, as well as the cutting angle. Further tests determined that a 20° angle should result in a clean cut. A second blade was manufactured to be sharper and have a cutting edge of 20° (see FIGURE 27, Photo 1). The new prototype was then tested and the results were clean cuts of the avocado stems (See FIGURE 27, Photo 2).



FIGURE 27: PICKING POLE SECOND IMPROVEMENT WITH CLEAN CUT

The proto type showed a lot of promise, specifically in user friendliness and the clean cut of the avocado stems that were obtained. However there were still some aspects that needed to be taken into consideration for the final design.

Aspects to take into consideration for the final design:

Moving the blade to the outer edge is definitely an improvement over the design of the current picking pole. The movement of guiding the avocado towards the blade at the back of the ring and swiftly pulling the pole towards you is a much more natural movement than aiming and cutting.

However there are a few aspects that can be improved further. It is extremely important that the avocado is not scraped or physically damaged in any way. The blade on the prototype is large and protruding. Only a small section in the corner needs to be sharpened since this is where the stem is guided by the pulling motion, gets caught on the blade and is cut through. The rest of the parts on the picking pole need to be blunt to ensure that avocados are not damaged during the picking process (see FIGURE 28).

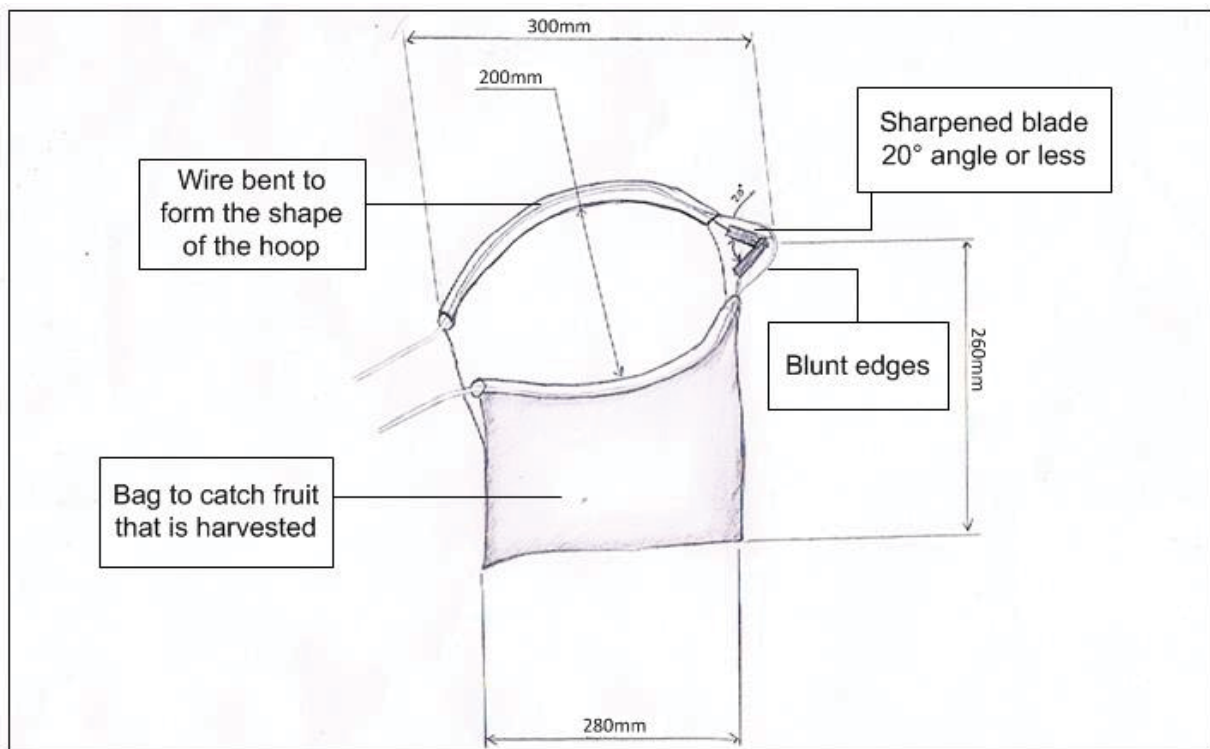


FIGURE 28: PRELIMINARY DESIGN SKETCH 1 OF IMPROVED PICKING POLE

To improve the cutting ability even further, the angle of the tool (as seen from the side) needs to change. The picking pole is used while extended at an upwards angle, and not horizontally. A better cut can be achieved by adjusting the angle of the section of the ring where the blade is attached, so that when the pole is extended at an upwards angle, the section with the blade is still perpendicular to the stem of the hanging avocado's (see

FIGURE 29). A quick pulling action now ensures an even better cut since the blade is perpendicular to the avocado stem.

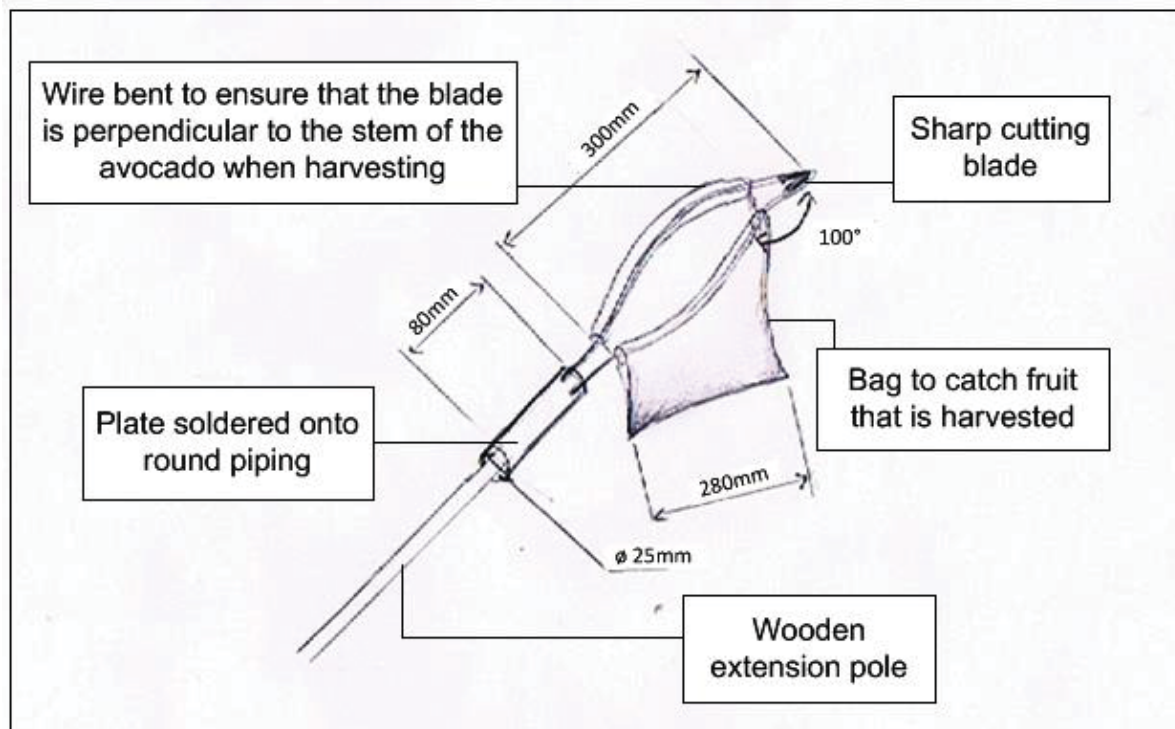


FIGURE 29: PRELIMINARY DESIGN SKETCH 2 OF IMPROVED PICKING POLE

Another aspect to take into consideration is long service life and maintenance of the design. Since the tool is exposed to rough handling and constantly exposed to the elements, the blade cannot be too thin or soft. The tool will not be durable in the long run. The complicated design of the blade used in the current picking pole, is difficult to sharpen and as a result it is not sharpened frequently enough. The blade on the final design should therefore be a trade-off between a standardized, easily replaceable and/or easy to sharpen thin blade, and a custom thicker blade that can endure the surroundings it is subjected to. Along with the introduction of a new picking tool, a rotation system can also be implemented where picking poles that are not currently being used, are being sharpened.

Final design

The final design incorporates all the aspects mentioned above. The cutting blades are positioned on the outer edge with a 20° angle between the two blades. The blades are identical and removable which implies that additional blades can be manufactured in advance and used to replace old blades when required. In addition, instead of the wire ring that supports the bag being soldered onto the piping, a 'click-in' design as seen in FIGURE

30, Photo 2 is used. This design allows the bag to be removed, in order to be easily be washed or replaced. Extra bags can also be manufactured in advance since they do not have to be stitched around the rim of the ring. The design overall has significantly less ‘moving parts’ than the original design. There are no springs that could wear over time and most importantly no rope that hurt the hands of the pickers.



FIGURE 30: PHOTO OF THE NEW PICKING POLE

4.5 Results and Validation

A time study was conducted to compare the current picking pole with the new design. The same worker was used to reduce the amount of variables as far as possible. A worker with no experience in using either the old or new stick was chosen. The results are as follows:

<i>Results:</i>	<i>Picking Pole:</i>	
	<i>Current</i>	<i>New</i>
Average picking time per fruit (sec)	13.98	7.04
Minimum picking time per fruit (sec)	3.50	3.67
Maximum picking time per fruit (sec)	35.00	18.00
Percentage of damaged fruit	4.24	13.99
Percentage of misses	34.04	12.96

TABLE 6: COMPARED RESULTS OF THE TIME STUDY

Hypothesis Test

The following hypothesis test was carried out to determine if there is a statistically significant difference between the picking time per avocado of the new pole and the picking time per avocado of the current picking pole. The large sample sizes (>30) and the central limit theorem validates the use of normal approximation.

μ_c = The actual average picking time per avocado (population mean) of the current picking pole

μ_n = The actual average picking time per avocado (population mean) of the new picking pole

\bar{x}_c = The sample average picking time per avocado (sample mean) of the current picking pole

\bar{x}_n = The sample average picking time per avocado (sample mean) of the new picking pole

s_c^2 = The sample variation of the picking time per avocado of the current picking pole

s_n^2 = The sample variation of the picking time per avocado of the new picking pole

n_c = The sample size for the current picking pole

n_n = The sample size for the new picking pole

Null Hypothesis: $H_0 : \mu_c - \mu_n = \delta = 0$

Alternative Hypothesis: $H_A : \mu_c - \mu_n > 0$

Test Statistic:

$$Z = \frac{\bar{X}_c - \bar{X}_n - \delta}{\sqrt{\frac{s_c^2}{n_c} + \frac{s_n^2}{n_n}}}$$

$$Z = -4.6597$$

$Z = -4.65$ is less than -1.6449 (the lower 5% of the normal distribution curve) therefore the null hypothesis can be rejected. This proves with a 95% confidence level that the picking time achieved by the new pole is shorter than the picking time of the current picking pole.

Discussion of results

As confirmed by the hypothesis test, the time study results show that the new picking pole picks avocados faster than the current picking pole, reducing the average picking time per fruit from 13.98 seconds to 7.04 seconds. That is a reduction of 49.65 %, almost cutting the picking time per fruit in half. The new pole is also more accurate, missing 12.96% of the time. On average one in three (34.4%) tries with the current picking pole does not cut the fruit. This can be attributed to the fact that the new pole requires much less aiming than the new pole.

However there is a down side to the new pole. As shown in TABLE 6, the new pole causes more damage (13.99%) than the old stick (4.24%). One example of damage is when an avocado is picked without its stem still attached. When the stem is removed, the avocado is

more prone to dehydration and is no longer suitable for the export market due to the long traveling time. Damage could also refer to any cuts or mechanical bruises on the avocado skin. The cutting mechanisms on the older stick, although more tedious to operate, ensures a clean cut of the stem more frequently than with the new design. Since the current picking pole is more difficult to use, and requires more aim, it is used more carefully. This also accounts for the slow picking time. Although the new pole is easier to operate, this also causes the picker to work faster and as a result less carefully. As a result more fruit with damage were observed when the new pole was used.

Hybrid Picking Pole

The data clearly shows that the new picking pole is the faster tool. However the increase in damage caused is significant. A trade off will therefore need to be made between speed and accuracy. An alternative solution that was suggested by one of the pickers (See Appendix 1: Interview with picker: for the full interview) is to combine the design of the current pole with the new one. This would imply to add a blade at the end of the ring, while also including the shear at the base of the ring.

The reasoning behind this is that by including both cutting mechanisms it will allow the picker to choose which method he wants to use at what time. Some of the fruit hang from the tree in such a way that it is easier to cut with the pulling motion of the new design. Other times the action of the shear is more preferable due to the placement of the fruit. A combination of the two would therefore allow the picker to choose his preferred method. This hybrid picking pole would be more expensive, and more difficult to manufacture, but the reduction in both time and damage could well be worth it. This design would also reduce the resistance from the workers against a new unknown picking pole design. The current pickers could still use the old design, until they get used to the new design. The advantages and disadvantages of the hybrid picking pole is discussed in TABLE 7.

<i>Hybrid Picking Pole</i>	
<i>Advantages</i>	<i>Disadvantages</i>
requires less aiming	need to reel in to empty bag
good ergonomics	multiple moving parts
small blade size	difficult to manufacture
removable bag	custom and standard shaped blades
smaller ring diameter	removable and fixed blades
can be used on all avocado varieties	
can be used for mangoes	

TABLE 7: ADVANTAGES AND DISADVANTAGES OF A HYBRID PICKING POLE

4.6 Recommendations

Possible Areas for further improvements on the new design

While conducting the time study with the new picking pole, additional areas for improvement were identified. The new pole was also sent around to be tested out by multiple workers, and they were interviewed for further suggestions for improvement. The suggested improvements are as follows:

Larger bag: The pickers would prefer to be able to pick more avocados before it is necessary to reel in the pole to empty the bag. Although it was initially thought that a larger bag would be too heavy to operate when full of fruit, the strength of the pickers was underestimated. The pickers use picking poles every day, and would prefer to be able to choose when the bag is too heavy. It is however important to note that there is still a limit on the size of the bag. The bag size impacts the operability of the picking pole. If the bag becomes too large it makes it more difficult for the picker to manoeuvre the pole in between the branches of the avocado trees.

Larger ring diameter: When the picking pole is extended vertically, the actual size of the gap where the hanging avocado needs to fit into is reduced significantly (if viewed from directly above). This sometimes leads to the cut fruit bouncing off the pole, and falling to the ground. This can be addressed by further bending the edge of the ring, as well as by increasing the size and overall diameter of the ring. This is necessary since some of the varieties such as Queen Avocados can be quite large. Since the pole would also be used for mangoes that are on average larger than avocados, this is a worthwhile change to make.

Material of the bag: For the prototype as seen in FIGURE 30, normal cotton like material was used. For the final design a durable and strong material will need to be used. The bags quickly wear through, so a material such as denim or canvas will be required.

Longer guide area: The blade itself is large enough. It should not be bigger since a longer blade would increase the area of the picking pole that could cause damage to the fruit. However, the shape of the ring could be adjusted, so that the area around the blade forms more of a guide for the stem to move towards the blade.

Possible Areas for further improvements on the hybrid picking pole

The same improvements that have been mentioned above for the new design would still be valid, along with an added improvement on the rope. The pickers complain that the rope that is attached to the cutting mechanism hurt their hands due to friction caused by repetitive pulling actions. A possible solution to this problem is to make use of a thicker rope. Another solution is to add a handle that can be adjusted along the length of the rope. Alternatively gloves can be supplied for each worker.

To avoid the rope tangling, a hook can be added to the pole for the rope to be looped through when the pole is not being used. This intervention will prevent the rope from hooking onto objects in the field as well as prevent tangling when the picking poles are being transported or stored.

4.7 Conclusion

The results of the time study clearly show that the new picking pole picks avocados faster than the current picking pole, reducing the average picking time per fruit from 13.98 seconds to 7.04 seconds. That is a reduction of 49.65 %, almost cutting the picking time per fruit in half. The new pole is also more accurate, missing only 12.96% of the time compared to the 34.4% for the current picking pole. The increase in damages caused (from 4.24% for the current pole to 13.99% on the new design) is a significant factor to consider.

The percentage of damages caused can be reduced if pickers are given time to practise and master the new pole. As the picker states in the interview (Appendix 1: Interview with picker:) the more the pole is used, the better the picker will pick with the new pole. Workers also need to be briefed about the importance of food safety, with emphasis placed on avoiding damages. Workers with track records of no or few damages can be rewarded and pickers must be encouraged to speak up when the blade of their pole becomes blunt, or when the bag is dirty. The engineering team at ZZ2 is confident that the new picking pole can improve the picking process. The substantial amount of time that the new design can save during picking, especially considering the scale at which ZZ2 operates, makes testing the new pole for a longer period of time a worthwhile exercise.

5. Problem 2: Addressing the lack of information captured throughout the avocado supply chain.

This section starts by carefully analysing the lack of information captured throughout the supply chain and empathises that capturing the necessary data can add value for ZZ2, specifically at the ripening process. Methods that can analyse and pin point data fields that needs to be captured is considered and the best method chosen. The chosen technique is then implemented and a diagram is developed that focuses on the required data fields. Emphasis is placed on the sections of the supply chain where the data is not being captured in the current system, and solutions to improve this are discussed. Finally an Entity Relationship Diagram (ERD) is constructed to form the blue print of a potential database.

5.1 Problem Discussion

As mentioned in the supply chain analysis in section 3.1.3 Post-harvest Activities, some of the avocados that are sent to the local markets, undergo a ripening process at ZZFresh in Lanseria. For the ripening process to be successful, certain information is required to make the right decisions. The avocados are subjected to a controlled atmosphere within which three factors are adjustable: the time a batch of avocados is subjected to the conditions in the ripening chambers, the temperature to which it must be subjected and the levels of ethylene gas that it should be exposed to. According to Mission (2012), the following information needs to be known in order to determine the ripening conditions more accurately:

- Avocado cultivar
- Maturity levels of the avocados at time of picking
- Picking date and time
- How long the avocados were in the field after picking and at what temperatures
- Transporting times

At the moment all of the required information does not reach the ripening facility. Some of this information is not captured at all; other data is recorded, but is not passed along the supply chain, or it is not captured on a central database, and ends up being lost along the way.

When the fruit reach the ripening facility at ZZFresh, the workers estimate the time that the avocados will need to be kept in the ripening chamber. A rough guess of between 5 to 7 days is made. The avocados are then checked by hand each day to monitor their progress and determine their ripeness level. Since the ripening chambers are still new and not yet

operating at optimal capacity, this is sufficient for now, however this is not a sustainable method. As the ripening process is used more and more, it will become increasingly important to accurately schedule the avocados that enter the ripening process. To attempt to satisfy a growing demand, it will be necessary to utilise the ripening chambers at their full capacity. This goal can be achieved by determining beforehand, to a certain degree of accuracy, how long a specific batch will take to ripen.

Accurate and reliable information is therefore required throughout the supply chain. In order for the required information to reach the ripening facility, traceability of the produce is required. In agriculture however, this is easier said than done. Some information is difficult or too time consuming to capture, such as capturing data directly in the field. A method is required to analyse the dataflow throughout the supply chain and identify the necessary data fields that needs to be captured.

5.2 Alternative Solutions

Alternative methods for identifying and mapping out the dataflow throughout the supply chain are considered.

Solution A: SCOR Map

Mapping the supply chain in Supply Chain Operations Reference (SCOR) could help identify the specific areas where data flow is insufficient. A proposed solution for this problem would therefore be to design and implement a framework for information flow throughout the process. By carefully following the steps set out to complete SCOR, focus can be placed on the information that is required throughout the system to allow traceability.

Solution B: Information Systems Design

As mentioned in the literature review, an information systems design process usually commences with a requirements analysis phase followed by a logical design phase, physical design phase and ends with implementation. By only following the first two steps of this process, requirements analysis and logical design, the areas where information capturing is not up to standard can be identified. By compiling the necessary diagrams that would lead to constructing a database, emphasis will be placed on where, what type of data needs to be captured, to ensure traceability throughout the supply chain.

If the correct information can be captured at the right time into a central database, the information can then be extracted from the database and used to calculate more accurately the ripening time and conditions required for each batch of avocados. This information would

also create a path of traceability, meaning that a final product, such as a box or punnet of avocados, could be traced back through the supply chain. In addition to determining a more accurate ripening time, this would allow ZZ2 to answer questions such as who handled the fruit and from which field the fruit was harvested.

5.3 Selected Solution

Although SCOR is a powerful tool that can aid in establishing standard practise for an efficient and effective supply chain, this project does not aim to develop Key Performance Indicators (KPI's) for the supply chain, therefore the standard SCOR metrics would not be used. Following the information systems design process would aid more in collecting the required data, as this process focuses specifically on the flow of information and data throughout the system.

Solution development

In order to map out the required data, in the required places, the logical design process is followed. The aim is to create an Entity Relationship diagram (ERD) that will form the blueprint for a database. This database would contain all the information that is required to estimate a more accurate ripening time, as well as allow traceability throughout the supply chain.

To ensure all the information that is required is captured, a flow chart was developed that maps out each section of the supply chain. The flow chart shown in FIGURE 31, lists at each section of the supply chain the data fields which needs to be captured to ensure traceability throughout. Data that is not being captured at the moment is highlighted in the chart. The green data fields are relatively straight forward to measure and capture. The sections highlighted in blue are not as straight forward, due to some challenges in data capturing within the agricultural environment.

The blue highlighted data fields are discussed in the section following the diagram. Emphasis is placed on the importance of capturing the missing data. Suggestions on how to capture the required data in a way that is practical in agriculture is also discussed.

AVOCADO SUPPLY CHAIN REPRESENTATION

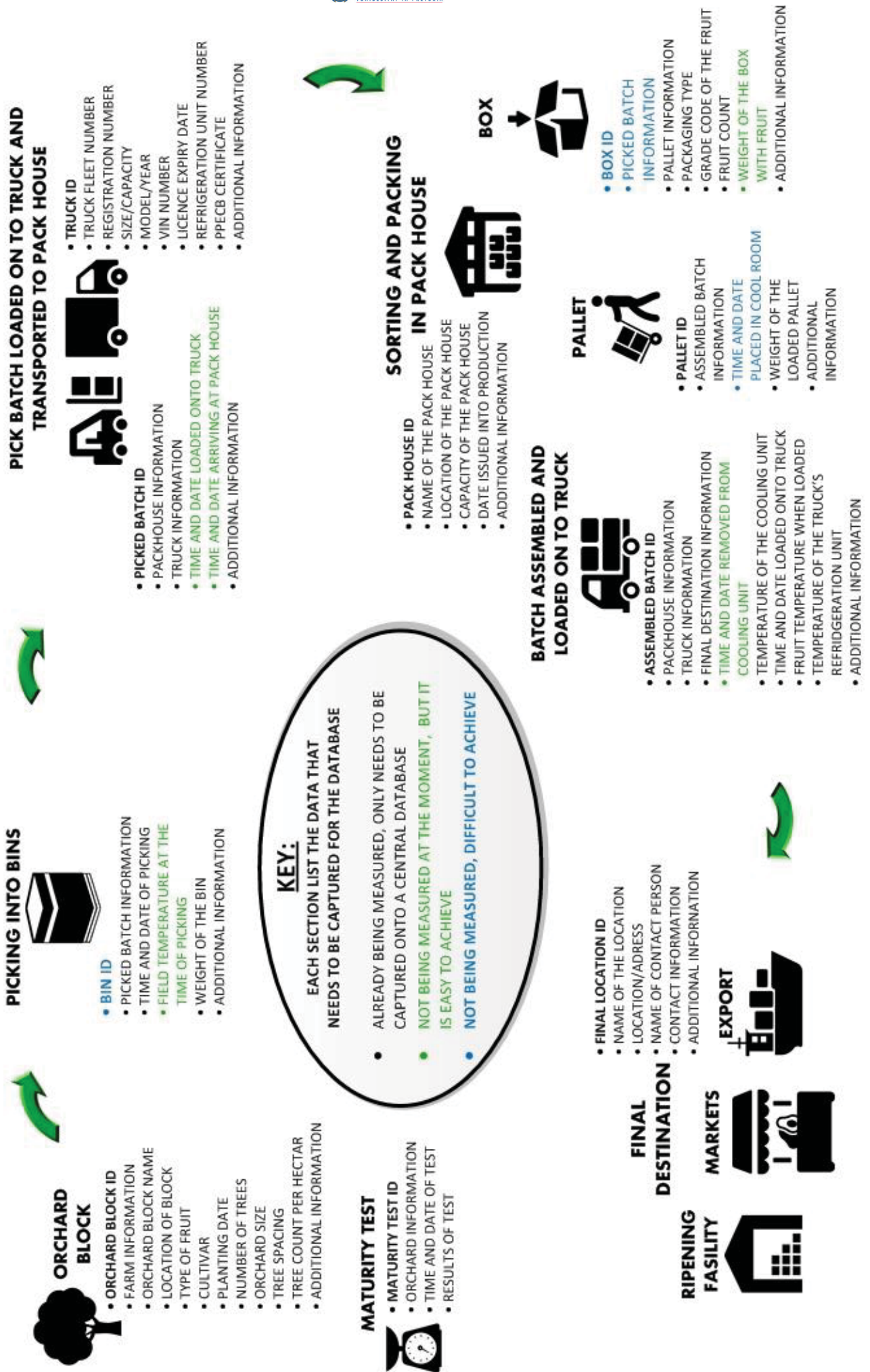


FIGURE 31: FLOW CHART REPRESENTATION OF THE AVOCADO SUPPLY CHAIN

Discussion of the Flow Chart

In the agricultural sector it is not always possible to capture and trace data. The following is a discussion on all of the areas highlighted in the chart, as well as solutions on how to capture the data in a way that is practical in the agriculture supply chain.

As mentioned above, some of the data that is not currently being captured (highlighted in green on the flow chart) is easy to measure and capture. This needs to be done in order to ensure the necessary information that will be used for the calculator is captured in the database. These data fields include:

- Field temperature when picking starts
- Time at which a picked batch is loaded on to the truck (removed from the field)
- Time at which a picked batch arrives at the pack house
- Time at which a completed pallet stacked with sorted and packaged fruit is placed into the cold room
- Time at which the pallet is removed from the cold room and loaded onto the truck

Other sections highlighted in blue are not so straight forward to capture and are discussed separately throughout the rest of this section.

Unique identification number per bin

At the moment each bin is not marked with a unique identification number. The main reason for this is the difficulty of capturing data in the field. Currently, each bin is marked in the field with the field name from which it is harvested, as seen in FIGURE 32. A unique code needs to be added to this. The code could be constructed in such a way that it is easy to remember. This will enable a worker to mark the bins in the field without requiring a computer to generate a unique code. An example of such a code could be: *[date_picked_field_code_bin number]* e.g. *[20150930_WDA3_66]*. This unique code, along with the weight of the bin can then be captured into the database on arrival at the pack house.



FIGURE 32: MARKED BIN IN THE FIELD

Unique Box ID and weight of each box:

After sorting and packing has taken place, each box of packed avocados needs to be captured with information such as variety, size, weight, colour and quantity. For this to be possible a unique identification number will need to be assigned to each packed box. Due to the vast amount of boxes that is packed, as well as the speed at which this is done, in practice this will be difficult, but not impossible to achieve. Different methods and alternatives to labelling will need to be investigated.

Boxes are consolidated onto pallets. A certain grouping of pallets together completes a specific order. Currently information such as weight and variety is only captured per pallet. The information would be much more accurate if it was captured per box. For example, additional calculations such as loss due to over packing could be calculated more accurately if information such as packed weight was available per individual box and not only per compiled pallet.

Linking the Box ID to the information of the picked batch:



FIGURE 33: REPRESENTATION OF LINK BETWEEN A BIN AND A PACKED BOX OF AVOCADOS

From the moment that the bins are tipped into the water bath, it is extremely difficult to trace the specific batch through the sorting process. The main reason for this is the fact that the fruit is tipped into a water bath as shown in FIGURE 34, eliminating most methods of marking or tracing the fruit that belong to a specific batch that came from the field.



FIGURE 34: AVOCADO BATCH BEING TIPPED INTO THE WATER BATH

If a packed box of avocados could be linked to the batch that arrived at the pack house, information regarding the fruit could be traced through the entire supply chain. By creating this link, it will be possible to access information such as from which field the avocados of a specific box were harvested, the temperature at picking, as well as the maturity level of the avocados. This data could also be used to estimate a more accurate ripening time. Furthermore, if any problems were to arrive from a specific box of avocados, the problem could be traced back as far as the field from which the fruit were harvested. This would help to determine if the problem was caused in the field, occurred in the pack house, was caused due to harsh handling or possibly occurred during transportation. This would enable ZZ2 to address the problem swiftly and accurately.

As noted in the post-harvest activities section of the supply chain analysis, a pallet consists of a compilation of multiple boxes that, together, form a specific order. It would therefore be impossible to link an entire pallet back to a specific orchard, since the fruit on the pallet could be from any number of different orchards. It would, however, be possible to link an individual box to the original bin, emphasising the need to capture unique data per box, rather than only per pallet, as discussed in the preceding chapter.

One way to link a box to the original bin would be to let a specific batch run through the whole sorting process, marking the boxes as the fruit is packed, before the bins of a second batch is tipped. However, this method would not be practical, since the bins are tipped at a continuous rate and by doing this, the throughput rate in the pack house would be reduced significantly. Alternative methods of marking a certain batch that have been considered include adding a coloured dye to the water when a new batch is tipped, as well as adding some kind of floating device in between batches. Neither of these options is practical since the fruit are divided into different lanes throughout the sorting machine. Adding a coloured dye to the water would only work for a certain section of the sorting process, as the fruit is removed from the water half way through the process and there is no guarantee that the floating device would follow the correct route.

A possible method to trace the fruit, suggested by a ZZ2 employee, is to calculate the time it takes an avocado to travel through the washing and sorting process, until it reaches the person who packs the fruit in the box. This would be possible since the water flows at a constant rate through the system. After a new batch is tipped, and that amount of time has passed, a signal would indicate to the packers to change the information on their label guns. The new label would then indicate that a new batch is being packed. This method would not be 100% accurate, but it is a method that could be executed in a practical way, without delaying the sorting and packing process.

5.4 Entity Relationship Diagram

If all the information is captured as shown in the flow diagram in FIGURE 31, an ERD (Entity Relationship Diagram) can be constructed to form the blueprint for the database. An ERD that is a representation of data captured for the ideal system is shown in FIGURE 35. The relationships created between the entities in the ERD emphasises the need to capture the required information throughout the system. A central database containing accurate and relevant information can be a very valuable tool for ZZ2.

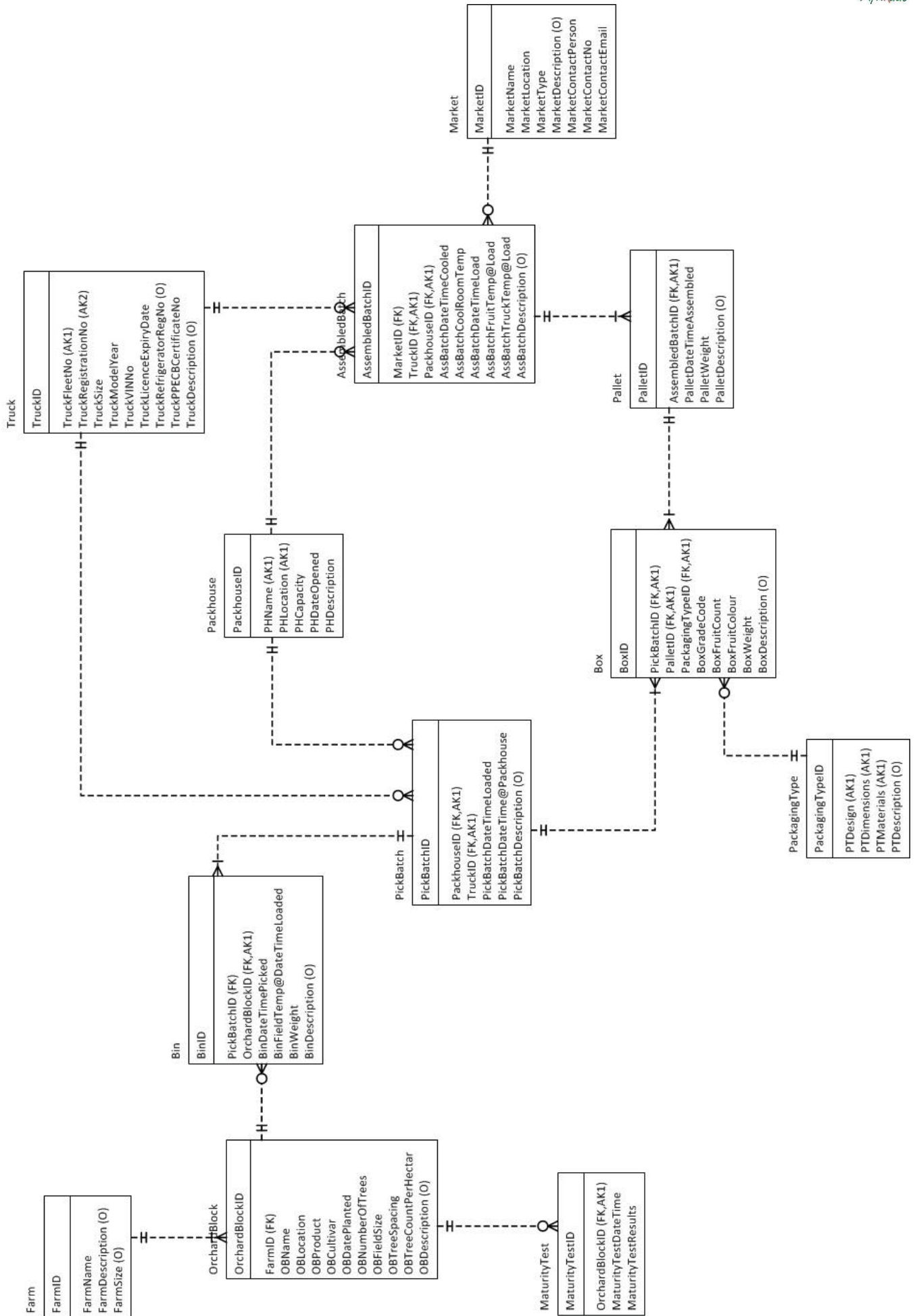


FIGURE 35: ENTITY RELATIONSHIP DIAGRAM OF THE IDEAL SYSTEM

6. Conclusion

The initial aim of the project was to analyse and improve the avocado supply chain and eliminate all controllable variables in order to be able to successfully implement the ripening process at ZZFresh. This is achieved by conducting a thorough literature review on fresh produce supply chains, avocado ripening facilities as well as different industrial engineering techniques that can aid in achieving the aim of the project. The industrial engineering techniques discussed in chapter 2 include: Work study, Business Process Modelling Notation (BPMN), Supply Chain Operations Reference (SCOR), Information systems design and Business Process Diagram (BPD). A supply chain analysis of the entire supply chain is given in section 3.1. Results of carefully monitoring the temperatures and humidity levels of a batch of avocados as the batch made its way through the supply chain is shown in the form of graphs in section 3.2 and a BPMN map of the current supply chain is shown in section 3.3 FIGURE 19.

Through the supply chain analysis two main areas with potential for improvement were identified. The first problem is that pickers cause significant damage to the avocado trees when they climb the trees to reach the avocados growing on the taller branches. This problem is addressed in chapter 4, where an improved picking pole was identified as a possible solution to this problem. Three possible designs were developed and evaluated. Based on certain evaluation criteria the best design was chosen and developed further. The final design was built and a time study done to compare the design of the new picking pole with the picking pole that is currently being used.

The time study results indicate that the new picking pole shows significant promise for improving the throughput time of the picking process. Based on the results the new pole picks avocados faster than the current picking pole, reducing the average picking time per avocado from 13.98 seconds to 7.04 seconds. That is a reduction of 49.65 %, almost cutting the picking time per fruit in half. This data is statistically validated by a hypothesis test.

Chapter 5 addresses the second problem, which is caused by a lack of data capturing throughout the supply chain. A solution is achieved by following the information system design steps to map out the data flow throughout the process. A flow diagram (FIGURE 31) is constructed to map out where current data is being captured, as well as highlight what data fields are not being captured that will be necessary to ensure traceability throughout the system. An Entity Relationship diagram (ERD) is then constructed based on the data fields, forming the blueprint for a potential database. If the correct information can be captured at

the right time into a central database, the information can then be extracted from the database and used to calculate more accurately the ripening time and conditions required for each batch of avocados. This information would also create a path of traceability, meaning that a final product, such as a box or punnet of avocados, could be traced back through the supply chain. In addition to determining a more accurate ripening time and scheduling optimal utilization of the ripening facility, this would also allow ZZ2 to answer questions such as who handled the fruit and from which field the fruit was harvested.

Steps to come

The promise showed by the improved picking pole design, warrants further testing. A few picking poles, with the suggested improvements added needs to be built, and tested over a longer period of time. This will give the pickers an opportunity to master the pole, and tests can be done to determine if the damages caused can be reduced.

For addressing the lack of information captured throughout the supply chain, the final Entity Relationship Diagram (FIGURE 35) forms a blueprint for the ideal database. ZZ2 can start by implementing the suggestion methods for capturing the data fields as highlighted in the flow diagram (FIGURE 31). Having a central database in place that allows traceability throughout the system could give ZZ2 access to extremely valuable information. Ultimately, a calculator could be built from the database to more accurately estimate the ripening factors required for a certain batch of avocados. This would allow ZZ2 to schedule optimal utilization of their ripening facility.

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8. Appendices

Appendix 1: Interview with picker:

- ~ Name Surname: *Steve Kganyamane*
- ~ Current position at Zz2: *Work in the Wagendrift pack house as a quality controller.*
- ~ Any experience as picker: *No this is the first time picking.*
- ~ Looking only at the way of picking, which stick would you say worked easier? *The one without the string*
- ~ Which stick allowed you to pick the fastest? *The stick without the rope is a bit faster*
- ~ Which stick allowed you to work the most accurate? *The stick with the string, the one without the rope caused more damage*
- ~ Which stick would you prefer to work with if you had to choose? *I would normally go for the stick without the rope*
- ~ Comparing the two sticks over all, which stick do you think is better and why? *I choose the stick with the rope. As a quality controller I understand the importance of picking in such a way that the stem is still attached as the fruit without stems cannot be used for export. So even though the stick without the rope works easier, it causes more damage so I think the one with the rope will be better.*
- ~ Are there any improvements that you would suggest on the new stick? *A bit bigger bag, but not too big. A longer extension pole.*
- ~ Are there any improvements that you would suggest on the old stick? *Thick rope, over time I think that the rope will hurt your hands*
- ~ Do you have any overall suggestions for improving the sticks? Describe the perfect stick? *Combine both sticks. Include scissors with rope, as well as blade to cut. In some instances it is easier with the scissors, and other times the blade cuts easier, depending on how the avocado is hanging. Since pickers differ from person to person and they do not have equal physical capabilities, it would be good for them to be able to choose the method of cutting that they prefer. For instance I feel that the damaged cause by using the stick without the rope could be because of the way I picked and that could be different for different pickers.*
- ~ Do you think you would improve in picking with the new stick, if you had more time to practise? *Yes, I will definitely improve over time*
- ~ Do you think you would improve over time in picking with the old stick? *Yes I will definitely improve over time*