A framework for capacity planning and capacity relocation in the wine supply network

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Declaration

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Abstract

South Africa is classified as a key player in the global wine industry. The wine industry however is under threat as it is experiencing different challenges which it must overcome. These challenges are placing the wine industry under great financial pressure. This leads to the following key research question for this study:
How can an approach be developed for supporting better long-term capacity planning decision making in the wine supply chain?

A Pragmatism research philosophy was used for this project which led to an inductive research approach being followed since the project was not based on a pre-existing theory, but a new theory was developed by analysing data. The research method that was mainly used for the project is mixed method seeing that the required data was obtained by means of structured interviews and physical observations. A combination of case study and design science research strategy was used. Orange River Cellars (Oranje Rivier Wyn kelders-OWK) was used as a case study which contributed to the development and testing of the framework.

The focus of the literature study was on capacity planning decisions of wine cellars within a supply chain network. The aim was to get a clear understanding of the supply chain networks and current research regarding capacity planning and supply network design in the wine industry. The main databases that were used consisted of Scopus and Google Scholar. It was found that limited research has been done on capacity planning, facility relocation and supply chain network design regarding the wine industry. Thus, the gap was identified as the lack of capacity planning of supply chain networks and facility relocation in the wine industry.

Next the conceptual framework was developed to capture the considerations and the approach for facility relocation planning and capacity planning in the wine industry. The framework aids in obtaining a good understanding of supply chain network seeing that with each stage a better understanding of the supply chain network is formed. For this framework the profitability of the cellars is first determined. With that information the most economical allocation of capacity in the supply chain is then determined as well as the relocation cost and capacity of the cellars that are no longer profitable.

The framework was then applied to the OWK case study. This case study consisted of a wine corporation that is situated in the Northern Cape. OWK has 6 cellars that receive grapes to produce either juice or wine. The amount of grapes received by the cellars are decreasing each year which caused OWK to ask the question of whether all the cellars are still profitable.

The framework concluded, that for the OWK case study, Cellar5 is not profitable anymore. The framework further recommends that Cellar5 be closed and the supply of grapes moved to Cellar4. The yeast tanks should also be moved to Cellar4 seeing that all the cellars experience a peak in the supply of grapes at approximately the same time during the harvest.

Opsomming

Suid-Afrika word as 'n sleutelspeler in die globale wynbedryf geklassifiseer. Die wynbedryf word egter bedreig aangesien dit verskeie uitdagings ervaar wat oorkom moet word. Hierdie uitdagings plaas die wynbedryf onder groot finansiële druk wat aanleiding gee tot die volgende navorsingsvraag:

Hoe kan 'n benadering ontwikkel word om beter langtermyn kapasiteitsbeplanning in die wynvoorsieningsketting te ondersteun?

Die kern navorsingsfilosofie van die projek was hoofsaaklik pragmaties en daar is besluit om ‘n induktiewe navorsingsbenadering te volg. Hierdie navorsingsbenadering is gevolg aangesien die projek nie op 'n bestaande teorie gebaseer was nie en 'n nuwe teorie ontwikkel moes word deur verskeie data te analiseer.

Die navorsingsmetode wat hoofsaaklik vir die projek gebruik is, is gemengde metode aangesien die vereiste data verkry is deur middel van gestruktureerde onderhoude en fisiese waarnemings. 'n Kombinasie van gevallestudies en ontwerpwetenskap navorsingstrategie is gebruik. OWK is as gevallestudie gebruik wat bygedra het tot die ontwikkeling en toetsing van die raamwerk.

Die fokus van die literatuurstudie was op kapasiteitsbeplanningsbesluite van wynkelders binne 'n voorsieningsketting netwerk. Die doel was om 'n duidelike begrip van die voorsieningsketting netwerke te kry en bestaande navorsing rakende die wynbedryf te bestudeer. Die hoofdatabasisse wat gebruik is, bestaan uit Scopus en Google Scholar. Daar is gevind dat beperkte navorsing gedoen is oor kapasiteitsbeplanning, fasiliteitsverplasing en voorsieningsketting-netwerkontwerp ten opsigte van die wynbedryf. Die gaping is dus geïdentifiseer as die gebrek aan kapasiteitsbeplanning van voorsieningsketting netwerke en fasiliteitsverplasing in die wynbedryf.

Volgende is die konseptuele raamwerk ontwikkel om die oorwegings en die benadering tot fasiliteitsverbeteringsbeplanning en kapasiteitsbeplanning in die wynbedryf vas te lê. Die raamwerk help om 'n goeie begrip van die voorsieningsketting netwerk te verkry, aangesien daar met elke fase 'n beter begrip van die voorsieningsketting netwerk gevorm word.

Vir hierdie raamwerk word die finansiële lewensvatbaarheid van die kelders eers bepaal. Met die inligting word die mees ekonomiese toewysing van kapasiteit in die voorsieningsketting bepaal, sowel as die verhuiskoste en kapasiteit van die kelders wat nie meer finansieel lewensvatbaar is nie.

Die raamwerk is dan toegepas op die OWK gevallestudie. Hierdie gevallestudie bestaan uit 'n wynkorporasie wat in die Noord-Kaap geleë is. OWK het 6 kelders wat druiwe ontvang om sap of wyn te produseer. Die hoeveelheid druiwe wat die kelders ontvang, verminder elke jaar, wat veroorsaak het dat OWK die vraag vra of al die kelders steeds finansieel lewensvatbaar is.

Die raamwerk het tot die gevolgtrekking gekom dat kelder5 vir die OWK gevallestudie nie meer finansieel lewensvatbaar is nie. Die raamwerk beveel verder aan dat kelder5 gesluit word en die verskaffing van druiwe na kelder4 verskuif. Die gistenks moet ook na kelder4 verskuif word, aangesien al die kelders ongeveer dieselfde tyd gedurende die oes 'n hoogtepunt in die verskaffing van druiwe ervaar.

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List of Acronyms

AHP	Analytical Hierarchy Process
ALA	Alternative Location-Allocation
CPLM	Capacitated Plant Location Model
CPLP	Capacitated plant location problem
CPFR	Collaborative Planning Forecasting and Replenishment
GSCF	Global Supply Chain Forum
JIT	Just in Time
LSCP	Location set covering problems
MCDM	Multi-Criteria Decision Making
MCLP	Maximal covering location problems
NP-hard	Non-deterministic Polynomial
OWK	Oranje Rivier wyn Kelders(AFR)/Orange River Cellars(*ENG*)
PDSD	Production-Distribution System Design
PET	Polyethylene terephthalate
RTD	Ready To Drink
SC	Supply Chain
SCC	Supply Chain Council
SCM	Supply Chain Management
SCND	Supply Chain Network Design
SCOR	Supply Chain Operations Reference
SME	Subject Matter Expert
TOPSIS	Technique for Ordering Preference by Similarity to the Ideal Solution
UFLP	Uncapacitated facility location problem
UFLP-SS	Uncapacitated facility location problem self-serving demand
VSM	Vertex Substitution Method
WDM	Weighted Decision Matrix
WSC	Wine industry Supply Chain

Glossary

Distilling wine	Wine that is prepared to be distilled to spirits.
Equity	Rights bought by a farmer/supplier to deliver grapes to a certain cellar.
Lees	Deposits of dead yeast or residual yeast.
Must	The juice obtained after the crushing stage that contains the seeds, stems and skins of the grapes.
Pomace	The solids remaining after the juice is removed during the pressing stage.
Rebate wine	Wine prepared for Brandy for double distillation.

Chapter 1 Introduction

The purpose of this chapter is to provide insight into the research study that was undertaken. First, a brief background of South Africa's wine industry is given. Next, the research problem is explained followed by the research question and objectives. The research design and methodology are then described along with the delimitations and limitations that were encountered. The chapter concludes with the ethical implications of the research study and the way in which this document is outlined.

1.1 Background

South Africa is a key player in the global wine industry. According to a recent study, South Africa is the seventh biggest wine producer in the world. The annual wine production is 898.4 million litres and the annual sales of wine on the domestic market is 436.9 million litres. The annual amount of wine exported is 451.8 million litres (Froud, 2017).

The wine industry is currently experiencing different challenges. These include increasing labour costs, water restrictions, and lack of skills and experience in supply chain management. All of these challenges cause financial pressure on the wine industry (Donati, 2013).

According to the VinPro Production Plan survey (Part2) (van Zyl, 2017), it is clear that the profit per hectare for the average farmer is very low, which causes the farmers to consider other crops that might yield a better profit. A study conducted by VinPro revealed that around 44% of the farmers in South Africa are operating at a financial breakeven point and 40% are making a financial loss (Greeve, 2017). According to a recent study only a third of the wine farmers are making a sustainable income(Cape Business News, 2017). This in turn causes the wine production of South Africa to decrease since the total hectares of wine grapes decrease.

Table 1 provides a financial overview of the income and expenditures of the top third, the average and the bottom third of wine farmers in South Africa. From this overview, it is clear that the profit per hectare of the average farmer is very low.

Table 1: A statement of the income and expenditure of the top third, the average and the bottom third wine farmers (van Zyl, 2017).

INDUSTRY 2016 HARVEST	Top Third	Average	Bottom Third
Production per ha	23,69	17,56	14,36
Income per ton	R 2 841	R 2 909	R 2 679
Income per ha	R 67 324	R 51 092	R 38 482
Production cost per ha	R 44 459	R 44 390	R 49 665
NFI per ha	**R 22 865**	**R 6 702**	**-R 11 183**
ROC	**6,86%**	**0,68%**	**-6,32%**
Cash expenditures	R 33 931	R 34 047	R 38 967
Provision for renewal	R 10 528	R 10 344	R 10 698
Total Production cost	R 44 459	R 44 390	R 49 665

One of the biggest obstacles faced by the farmers is the labour issue (Bloomberg, 2013). The increase in labour costs causes the profit per hectare to decrease dramatically and this leads farmers to replace the vineyard with other crops that are less labour intensive. Another issue which has an impact mainly on the Western Cape wine farms is the current drought and water shortage (James, 2014) (Peens, 2016). Farmers are forced to cut back on the amount of water they give the vineyards, which will influence the quality of the grapes of the next harvest.

The supply chain network of the wine industry typically consists of the farmers who supply the grapes to the cellars. The cellars then use the grapes to produce either wine or juice. Then, depending on the market, the wine or juice will either be transported in bulk to the market or first be bottled before it is sent to the different markets. The key players in the wine supply chain therefore are the farmers, the cellars, and the different markets.

The supply chain network for the wine industry is driven by the amount of grapes supplied by the farmers to the cellars (therefore supply push). This is because the amount of wine that can be made by the cellars is dependent on the amount of grapes received from the farmers. The management of the supply chain network is important because by efficiently managing the supply chain the costs of producing the different products can be reduced and more value can be added to the products that are sold to the different markets.

A survey was conducted by Stellenbosch University and the CSIR as well as PWC on the South African wine industry (Donati, 2013). This survey showed that cellars in South Africa do not have the skills or experience to manage a competitive supply chain network. Wine cellars in South Africa are experiencing financial pressure. For cellars to survive in these tough financial times, they must focus on their supply chains with regards to reducing costs and improving efficiency.

Wine is sold in two forms: bulk wine sales and packaged wine sales (Loots, 2017). Bulk wine is sold at a lower price than packaged wine due to the value that is added to the packaged wine. Bulk wine is still the largest volume of wine that is sold if compared to other types of wine such as packaged wine. However, bulk wine is sold at a very low cost. This means that the income gained from bulk wine sales is very low. The bulk wine to packaged wine ratio is currently 61:39. The Wine Industry Strategic Exercise target for the ratio for 2025 is 40:60 (Cape Business News, 2017). According to Heyns (2012), most of SA's largest wine exports to other countries are done in bulk. The bulk wine is then bottled and distributed in that country. Packaged wine, however, is more profitable than bulk wine sales. This is because of the value that is added to the wine during the packaging phase (Cape Business News, 2017). Value can therefore be added to the products by re-examining the product mix of the amount of products sold in bulk compared to the amount of bottled products sold.

By reducing the production cost of the products and adding more value to the products that are sold, the farmers can be better compensated for the grapes they deliver to the cellars. This will motivate the farmers to plant more grapes.

Van Schalkwyk (2017) stated that, over the past 40 years, the wine industry has also experienced significant changes which were mainly caused by the market. In the late 1900's, the market was not that particular on the quality of the wine. This meant that more low-quality wine and distilling wine was made and only a few litres were high-quality wine. As time passed, the market demand changed as the request for higher quality wine increased. Since the process according to which low-quality wine is made is similar to the process of making high-quality wine, the transition was possible.

Another major change which affects the wine industry was the raisin market (van Schalkwyk, 2017). From the late 1900's, the raisin market grew stronger causing the raisin price to increase, so the price the farmers received for the raisins also increased. This caused the farmers to replace their wine grapes with raisin grapes because raisins were/are more profitable. This meant that the amount of grapes received by the cellars decreased by almost 40% and is still decreasing today (van Schalkwyk, 2017). Another key replacement crop type being planted currently by wine farmers are pecan nuts. This is because farmers have realised that pecan nuts are more lucrative than wine grapes (Kriel, 2017).

This study originated from a need expressed by one of the largest wine cooperatives in the world called Orange River Cellars (Oranje Rivier Wyn Kelders - OWK) which is situated in the Northern Cape province of South Africa. OWK is the second largest wine cooperative in the world and is the largest wine cooperative in the Southern Hemisphere as well as the largest in South Africa. OWK has 6 different cellars (5 wine cellars and 1 juice cellar) situated along the Orange River in the Northern Cape that are being used as an intake for the wine grapes in the area. The farmers take their grapes to the facility closest to the farm and then the grapes are used to make wine. The wine is either sold in bulk to Distell (a leading producer and marketer of wines, spirits, ciders and other ready-to-drink (RTD) beverages in South Africa and Africa, also operating internationally), or shipped to a bottling plant in the town of Upington in the Northern Cape (where the wine is bottled and sent to various local and international markets).

The OWK cellar and bottling facilities were built in the early seventies, and since then have not changed much. The environment around the facilities has changed dramatically since the early seventies. The environment changed in the sense that the farmers are replacing wine grapes with raisin grapes or pecan nut trees. The winemaking procedure has not changed significantly over the years.

Over the past several years, the farmers started to plant other crops that yield better profits and are not replacing old vineyard with new vineyard because it is not financially feasible. This caused OWK to start asking the question of how to best structure the capacity in their current network of cellar facilities.

An initial review of the supply network design and wine industry literature revealed that, although a lot of work has been published on supply network design, facility location and relocation, as well as supply chain capacity planning, very limited studies have focused specifically on the wine industry (Nagurney & Nagurney, 2010) (Lambiase et al., 2013) (Sridharan, 1995) (Dupont, 2008).
Different databases were accessed to identify the key journals describing research that is being done in supply chain network design in the wine industry. This included the Scopus database, which is one of the largest abstract and citation databases of peer-reviewed scientific literature.
Scopus only had 46 results for supply chain in the wine industry. Those papers ranged from 2008 to 2016. When the search focus was changed to the capacity planning in the wine industry no documents were found. Then the search focus was changed to search for documents relating to the supply chain network design regarding the wine industry and only one document was found. This document was about sustainable supply chain network design with regards to the wine industry in Australia.

Thus, it is clear that the wine industry and, more specifically, the wine industry in South Africa has not yet been researched with regards to the supply chain network design and capacity planning which means that very little literature is available on these topics.

In the paper of Varsei & Polyakovskiy (2016) which focuses on a sustainable supply chain network design, it is pointed out that strategic decisions regarding the number, the location, and the capacity of the facilities have been the point of interest in supply chain design networks for the past few decades. This paper mainly focuses on proposing a generic model for sustainable wine supply chain network designs.

According to the paper written by Jooste, van Eeden and van Dyk (2015), cellars are struggling to maintain and manage their supply chains because of a shortage of the required information. However, the aim of their paper was to produce a framework to improve the performance of the supply chains used in the wine industry, provide strategic directions, and enable decision making.

The supply chain network of the wine industry has some unique characteristics that influence the planning and design of the network (Farmer's weekly, 2014). Traditionally, the wine supply chain is more supply driven. In the OWK case study, each cellar had a certain amount of equity available for the farmers to buy. The amount of equity is directly linked to the capacity of the cellar. The equity gives the farmers permission to deliver grapes to the cellar. The equity is also used by the cellar to get an indication of the amount of different cultivar grapes it will receive. The equity is rights bought by a farmer/supplier to deliver grapes to a certain cellar. If a farmer, for some reason, cannot deliver the amount of grapes prescribed by the equity they own, then a penalty must be paid by the farmer. All the equity of the OWK cellars is sold to the farmers so if a farmer wants to increase their equity they must buy equity from other farmers.

The quality of the product delivered to the market is also dependent on the quality of grapes received, since good wine cannot be made from lower quality grapes. The needs of the different markets must also be fully understood because if a product is made it cannot be changed if the market's need was misread.

It can be concluded from the above background description that the wine industry is under significant financial pressure. Improved planning and structuring of the supply chain (specifically with regards to capacity) can help to relieve some of the financial pressure the wine industry is experiencing. Various drivers and factors affect the supply chain of the wine industry, and some of these are unique to the wine industry so must be focused on and improved.

A gap and need were therefore identified to research the specific considerations and methods for cellar network capacity planning in the wine industry and develop a model that can aid practitioners in the wine industry to make better-informed decisions regarding cellar network capacity planning. The following sub-sections describe the research problem statement and questions, as well as the research aim, objectives, and approach in more detail.

1.2 Research problem statement and questions

From the literature that was obtained, a gap was identified in the supply chain network design in the wine industry. No papers could be found that focused on the capacity planning of cellars in a wine supply network. Capacity planning is a very important part of supply chain management and should be revised on a regular basis. This is becoming a more important aspect of supply chain network design in the wine industry of South Africa due to the replacement of wine grapes with other crops and the resulting change in the supply mix and volume of wine grapes.

This leads to the following key research question for this study:
How can an approach be developed for supporting better long-term capacity planning decision making in the wine supply chain?

To answer this question a few sub-questions must first be answered.

1. What is the current structure and challenges of the SA wine industry with a focus on the supply chain?
2. What are the specific challenges, needs, constraints, and considerations for facility relocation planning and capacity planning in the South African wine supply chain?
3. What models are available to assist with facility relocation and capacity planning, specifically in the wine industry?
4. What are the challenges associated with facility relocation and capacity planning?
5. How can a model be developed that will consider the needs, constraints, and considerations for the wine industry, and provide support with regards to capacity planning of wine cellars in a wine supply chain network?

1.3 Research objectives

The aim of this study is to contribute towards a better understanding and execution of network capacity planning decision making in the wine supply chain, specifically with regard to capacity planning decisions of wine cellars within a supply chain network.

In order to achieve this aim, the following objectives have been defined:

1. Create an in-depth understanding of the wine supply chain focusing on the planning, sourcing, making, and delivery activities. A specific focus will be on the South African wine supply chain.
2. Identify current approaches for supply chain network design, capacity planning, and facility relocation planning – specifically investigating approaches and models applied to the wine industry.
3. Identify particular challenges, needs, constraints, and considerations for facility relocation planning and capacity planning in the South African wine supply chain.
4. Develop a model and framework that will support improved capacity planning of wine cellars in a wine supply chain network.
5. Evaluate the accuracy and usefulness of such a model and framework for the wine industry.

1.4 Research contribution

This research contributes towards the currently limited body of theoretical knowledge on supply network design and capacity planning in the wine industry. This is provided through a better understanding of the challenges, needs, constraints, considerations, and approaches for facility relocation planning and capacity planning in the wine industry.

Furthermore, a model was developed that, together with the conceptual framework, provides practitioners in the wine industry the necessary support towards improved capacity planning when redesigning their supply network.

1.5 Research design

"A research design provides a framework for the collection and analysis of data" (Bryman, et al., 2017). One approach for describing the different elements in research design is the Research Onion from Saunders et al. (2012). The Research Onion consists of different layers. Each layer acts as a guide to direct a researcher when a research strategy must be developed. Each layer depicts a more detailed step of the research process. Figure 1 is a representation of the Research Onion used for research design.

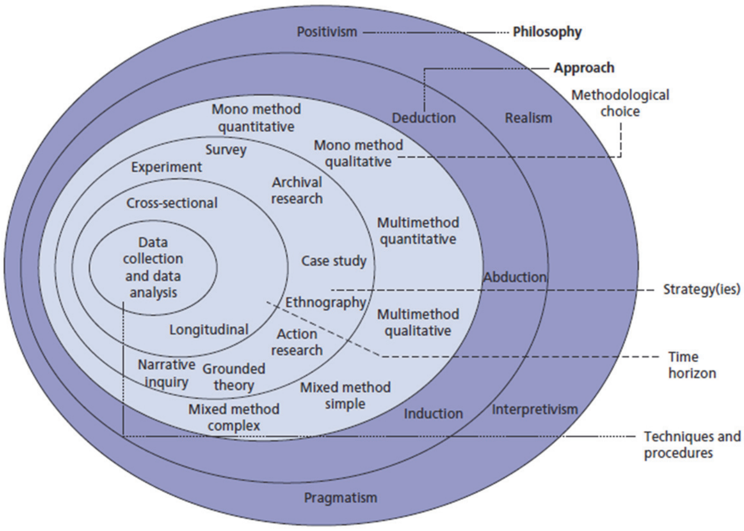

Figure 1: Research Onion ((Saunders, et al., 2012).

The Research Onion consists of six layers and each layer is a more detailed step of the research process used to conduct a research strategy. The first layer is the research philosophy layer which is the starting point of any research strategy. This is the way the researcher views the world which directs the researcher's actions and causes the researcher to do tasks in a certain way (Al Kindy, et al., 2016).

The second layer is the research approach. This determines the approach that the researcher will use to complete the project. There are three main approaches: deduction, induction, and abduction.
A deductive approach uses literature to identify theories. It starts with a hypothesis that must be tested and ends with a conclusion of the hypothesis (Al Kindy, et al., 2016). An inductive approach, on the other hand, consists of collecting data and developing a theory. Thus, it starts with a certain objective and will end with a certain theory (Al Kindy, et al., 2016). An abduction approach is a combination of deductive and inductive and moves back and forth between the approaches.

The third layer is the research method, which can use qualitative, quantitative, or mixed methods. The difference between quantitative and qualitative is that qualitative is a non-numerical approach and quantitative is a numerical approach. As the name suggests, mixed method is a mix of quantitative and qualitative approaches (Al Kindy, et al., 2016).

The fourth layer is the research strategy. This is the type of research that the researcher will follow to answer the research question (Al Kindy, et al., 2016).

The fifth layer is the research time horizon. There are two-time frames that can be followed by the researcher. These two-time frames are cross-sectional and longitudinal (Al Kindy, et al., 2016).

The cross-sectional time frame consists of taking a snapshot at a certain period in time. The longitudinal time frame consists of taking more than one snapshot over a longer period of time (Al Kindy, et al., 2016).

Using the Research Onion model as a reference, the following paragraphs describe the research design chosen for this study.

The research philosophy for this project was Pragmatism. Pragmatism consists of using the method that best suits the specific research problem instead of searching for the best approach (Alzheimer Europe, 2009). Furthermore, Saunders et al. (2012) stated that pragmatics noticed that the world could be interpreted in many different ways. Pragmatics also realised that research can be undertaken in different ways which leads to the statement that the entire picture cannot be provided by a single viewpoint but that there may exist multiple realities.

Pragmatic researchers can use any method, procedure or technique that can be associated with quantitative and/or qualitative research. In the case of the Pragmatism philosophy, the most important determinant is the research question. The Positivism and Interpretivism research philosophies only consist of one research approach but the pragmatic research approach can consist of more than one approach in the same study.

In the OWK case study, after the research question was provided, multiple SME's were consulted to obtain different viewpoints so that an accurate picture of the research question was formed. After the entire picture was formed, different approaches and strategies were used to solve the research question. Table 2 is an illustration of the different research philosophies and the differences between them.

Table 2: Illustration of the difference between the positivism, Interpretivism and Pragmatism research philosophies.

	Research approach	**Ontology**	**Axiology**	**Research strategy**
Positivism	Deductive	Objective	Value-free	Quantitative
Interpretivism	Inductive	Subjective	Biased	Qualitative
Pragmatism	Deductive/Inductive	Objective/subjective	Value-free/Biased	Qualitative/ Quantitative

The approach that was followed for this project was inductive. Since this project is not based on a pre-existing theory it cannot be described as a deductive approach but rather an inductive approach. Furthermore, this project was not aimed at testing a theory but to propose a new theory that will be developed by analysing data. The purpose of this project was to build a new framework and model that can be used for the capacity planning of the supply chain network for the wine cellars.

The research method for this study was a mixed method, therefore considering both qualitative and quantitative data. The data required for this study was obtained by having structured interviews with the personnel at the cellar, as well as observing the procedure by which the wine is produced at the different cellars during harvest time. This project was primarily quantitative since data was used to build the required model. Although the inductive approach is usually qualitative based, there is no rule stating that inductive approaches must be qualitative.

The research strategy for this study was a combination of case study and design science research. The case study was used to identify the specific challenges, needs, constraints, and considerations for facility relocation planning and capacity planning in the South African wine supply chain. Design science was used to develop a model (artefact) and evaluate the usefulness and applicability of the model. OWK was used as the case study for this project. The winemaking process of OWK was studied, and relevant data collected by means of structured interviews as well as observations. The other design strategy that was applicable to the project is design science research, since a model was developed that can be used by wine corporations to determine if all their wine cellars are still profitable, as well as to assist in the capacity planning of the cellars.

The model was evaluated by validating and verifying the models to ensure the correct model was built and that it was built correctly. The model also consisted of a financial side where different financial options were compared. Since this model consisted of both qualitative and quantitative models that work together as one model, the choices for this project can be classified as a mixed method.

The time horizon for this project can be categorized as cross-sectional. This is because the data were collected at a certain point in time seeing that the project has a specific predetermined time frame. The data collection techniques that were used for this project were primarily structured interviews. Structured interviews were held with the different cellar masters to obtain the required data regarding each cellar.

1.6 Research methodology

First, problem awareness was created by OWK. This was done by OWK contacting the researcher with the problem. The problem they faced was whether or not their cellars are still profitable due to the fact that the supply of wine grapes has decreased. This is because the suppliers (farmers) are replacing the grapes with other crops.

A literature study then commenced to get a clear understanding of the supply chain networks and what was already researched regarding the wine industry. The gap was then identified, which was the lack of capacity planning of supply chain networks in the wine industry.

After the gap was identified, suggestions were made in the light of different models that could address this gap as well as provide a contribution to the literature. It is important to define the gap thoroughly before different models are suggested.

After the different models were suggested, a decision was made regarding a modelling approach and a decision support model was developed. The software used to develop the models depended on the complexity of the models since a lot of software is available that can be used to develop the models.

The models were then verified and validated. Validation was done by obtaining feedback from relevant stakeholders within OWK (the case study company), as well as the insights and comments of other subject matter experts in the wine industry.

A conceptual framework was then developed to capture the considerations and an approach for facility relocation planning and capacity planning in the wine industry.

Figure 2 indicates the flow diagram illustrating the research methodology followed for this project.

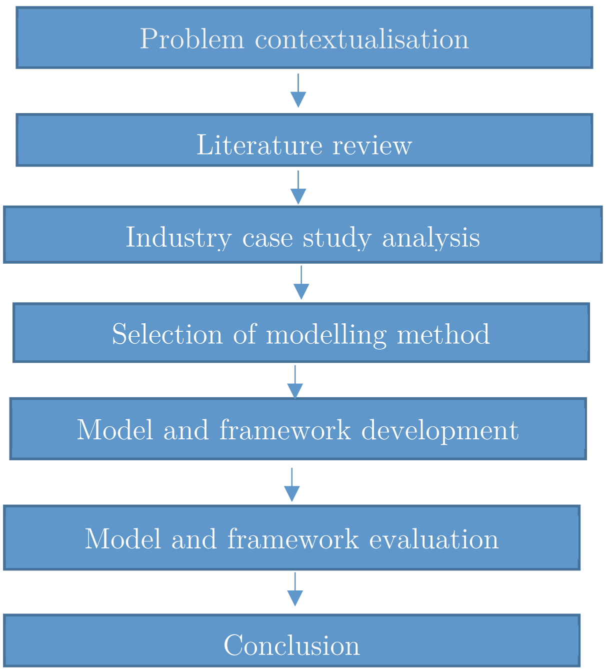

Figure 2: Flow diagram of the research methodology.

1.7 Delimitations and limitations

The limitation of this model was that it is mainly applicable to large wine corporations that consist of various cellars at various locations supplying to various markets.

For this project, the scope was to build a model that would be able to provide insight into whether a cellar should be kept open or closed down. For this model, the main input was the amount of grapes received by the cellar which was determined by the hectares of vineyard in the region of the cellar. This project does not consider the product mix and how the profit of the cellars can be increased by changing the product mixture. This project does not distinguish between red and white wine; the main focus is also on the wine and not the juice. For this project, the only case study used was OWK, which is situated in the Northern Cape.

1.8 Ethical considerations

For this research study, the information and data were obtained by means of structured interviews. The data and information obtained during the structured interview were handled as classified and only the data and information regarding OWK that are publicly available were displayed in the report. Any other data information obtained that is not publicly available were not used in the report. The data information was stored on a laptop which is fingerprint protected as well as password protected and stored in a safe office at the Stellenbosch University. After the project was completed, any hard copies of the information and data were destroyed and the data and information stored on the laptop permanently deleted.

Any data of OWK used were multiplied by a random factor that was generated using an Excel function. The names of the different cellars were also replaced by other names.

1.9 Document outline

This thesis is structured as follows:

- Chapter 1 is the introduction to the project. It provides a background of the wine industry in SA. It also provides the research problem statement, research objectives, research contribution, the research design and methodology, as well as the limitations of the project.
- Chapter 2 provides the literature that was found regarding supply chain networks in the wine industry. The literature was limited due to the fact that not a lot of research has been done regarding the supply chain of the wine industry. This chapter provides different supply chain designs, insight into facility location planning models that have been developed, different modelling types that can be used to model a problem as well as different qualitative models that can be used to determine the qualitative effect of certain actions.
- Chapter 3 provides the reader with a brief background of OWK that was used for the case study as well as a detailed description of the different processes according to which the OWK cellars produce the wine. It also provides the reader with a description of the network layout of the cellars of the OWK case study.
- Chapter 4 discusses the generic framework that was developed. A detailed description of the different stages of the framework is also provided. The different models consist of a Profitability Model, capacitated plant location model, Scenario decision model, and a weighted decision model.

- Chapter 5 discusses the development of the different models used in the framework
- Chapter 6 discusses the procedure according to which the framework was applied to the OWK case study. The output of each stage of the framework was also explained as well as final recommendations for the supply chain network.
- Chapter 7 provides a summary of the project that was done as well as the conclusion that was reached.

1.10 Summary

The objective of this chapter was to introduce the research that was undertaken. It described the formulation of the research question, as well as the objectives and contributions. The research design and methodology were then described followed by the delimitations and limitations of the research. The chapter was concluded by stating the ethical implications of the study and a detailed document outline. The following chapter contains a detailed review of the literature that is available regarding capacity planning and facility relocation with the focus on the wine industry.

Chapter 2 Literature Review

This chapter reviews the relevant literature that provides the theoretical foundation for this study. The following relevant knowledge areas were explored: the wine value chain, capacity planning, supply chain network designs, facility location planning, and different modelling types.

In the wine value chain section, the South African wine industry was studied. The focus was then placed on the Northern Cape wine region since the case study is about a wine corporation that is situated in the Northern Cape. This section ended by looking at the winemaking process as well as the value chain of the winemaking process.

The next section covered the topic of capacity planning. The two subsections of capacity planning that was researched was capacity expansion as well as capacity relocation. This section was concluded by providing some insight into the capacity planning in the wine industry.

In supply chain network design, the focus was on supply chain management, supply chain management frameworks, and designing a supply chain network.

Different definitions for supply chain management were provided in this section. For the supply chain management framework, the SCOR model as well as other models were examined. This section concluded by providing some information regarding designing a supply chain network.

A key component in supply chain network design is the location of the facilities in the supply chain network. Thus, extensive focus was placed on facility location planning models. The facility location planning section consists of the following subsections: different optimisation models, qualitative models and facility location, and capacity planning models in the wine industry.

The following optimisation models were researched in the first part of this section: Uncapacitated facility location models, Capacitated facility location models, and Static vs Dynamic planning models.

In facility location planning, two approaches were described. These two approaches are: Weber's location problem and the P-median. The Uncapacitated facility location model and Capacitated facility location model is also described in this section of the chapter.

In the qualitative methods section, the qualitative effects of relocating a facility were researched as well as different qualitative models, such as the weighted decision matrix, Pugh matrix, the Analytical Hierarchy Process as well as TOPSIS.

The last section of this chapter is the literature summary and conclusion section. This section provides a brief overview of the literature that was researched as a conclusion to the section.

2.1 Overview of the Wine Value Chain

2.1.1 The South African wine industry

Froud (2015) stated that there are currently 3 314 farmers in South Africa who farm with wine grapes. The total number of wineries in South Africa is 559 with wholesalers numbering 109. The total number of hectares under vine in South Africa is currently about 99 463 ha. Froud (2015) stated that the hectares are spread out across the regions as indicated in Table 3.

Table 3: Indication of the different wine regions with the associated hectares (Froud, 2015).

Region	Hectares
Stellenbosch	16 037
Paarl	15 835
Robertson	14 652
Swartland	13 591
Breedekloof	13 022
Olifants River	10 149
Worcester	8 858
Northern Cape	4 659
Klein Karoo	2 660

Table 4 indicates the percentage of white and red grape vineyards found in South Africa. It also shows the amount of each cultivar that is found in SA.

Table 4: Indication of the percentage of white and red grape vineyards in SA (Froud, 2015).

Total white grape vineyards: 54.6%	**Total red grape vineyards: 45.4%**
Chenin Blanc: 18%	Cabernet Sauvignon: 11.5%
Colombar(d): 12%	Shiraz: 10.5%
Sauvignon Blanc: 9.3%	Pinotage: 7.4%
Chardonnay: 7.4%	Merlot: 6.1%
Muscat d'Alexandrie: 2%	Ruby Cabernet: 2.4%
Semillon: 1.2%	Cinsaut: 1.9%
Viognier: 0.9%	Pinot Noir: 1.1%
Muscat de Frontignan: 0.8%	Cabernet Franc: 0.9%

Table 5 is an indication of the amount of wine that is exported and to which country it is exported. It also indicates the amount of wine that is imported and the type of wine that is being imported.

Table 5: Indicates the amount of wine imported and exported for the year 2015 (Froud, 2015).

Exported	**Imported**
United Kingdom: 109 million litres	Natural wine: 517 953 litres
Germany: 79 million litres	Fortified wine: 6 953 litres
Russia: 28 million litres	Sparkling wine: 408 385 litres
Sweden: 25 million litres	
France: 25 million litres	
Netherlands: 22 million litres	
Denmark: 20 million litres	
Canada: 18 million litres	
USA: 11 million litres	
Belgium: 9 million litres	
China: 9 million litres	
Japan: 6 million litres	
Switzerland: 6 million litres	

2.1.2 The Northern Cape wine region

The focus of this study is on the Northern Cape's wine industry since the case study wine corporation is situated in the Northern Cape. The Northern Cape province of South Africa extends over 360 000 square kilometres. It is the largest province as it covers 30% of the country. The Northern Cape is known for its wine, wildlife, cattle and sheep farming, table grape and raisin production, vegetables, deciduous and citrus fruit, lucerne, olives, pecan nuts, wheat and cotton, and diamonds. The Orange River, South Africa's largest river, meanders for 2 320km through the countryside. It twists through the Northern Cape landscape roughly from east to west. The capital of the Northern Cape is Kimberley. The total vineyard area comprises a staggering 17 200 ha and extends over 350km in close proximity to the Orange River, also known as the "Great Gariep" (Northern Cape Wines, 2017).

Apart from a narrow strip of winter rainfall area along the coast, the province is a semi-arid region with little rainfall in summer. The weather conditions are extreme with cold and frosty winters and extremely high temperatures in summer. These extreme weather conditions are ideal for the vineyards. The frosty winter ensures that the vineyard can rest properly and recover from the previous harvest. The vineyard growth stops during this time. This resting period of the vineyard is usually from the beginning of June to the end of July, but it depends on the weather. The high temperatures during summer help to produce high-quality grapes which are used to produce wine, juice, or raisins.

The Northern Cape also produces some of the highest quality products in South Africa, such as grapes, lucerne, cotton, wheat, corn, carrots, potatoes, ground nuts, and soya beans. The province is fast becoming a significant exporter of table grapes, raisins and meat (Brand South Africa, 2015). The Northern Cape wine industry is mainly associated with the production of bulk wine and white varieties such as Chenin Blanc, Colombard, and Hanepoot. Grapes were first planted in the Northern Cape in the early 20th century for the production of raisins. It wasn't until the 1960s, when irrigation technologies improved, that the area began to yield grapes suitable for wine production. Nowadays, the largest wine co-operative in the Southern hemisphere (Orange River Cellars) operates along the river, harvesting around 140 000 tons of grapes per year. The majority of grapes grown in the area are made into white wine, although there is a growing contingent of red wines made from Cabernet Sauvignon, Pinotage, and Shiraz (Wine searcher, 2013). Wines are exported to countries in the European Union, including Holland and the UK, the USA, Africa, and to various Eastern countries such as Malaysia, mainland China, Singapore and also into Hong Kong (Northern Cape Wines, 2017).

The Northern Cape produces about 25.6% of the Colombard vines and about 10% of the Chenin Blanc vines of the total amount of Colombard and Chenin Blanc vines produced by South Africa (abdas., 2013). There are plans to add 40 000 tons of grapes for wine, juice and raisins to the Northern Cape's capacity. A SA Wine Industry Information & Systems (Sawis 2012) report stated that planting of wine grapes decreased dramatically in 2012, with raisin cultivars such as Merbein being preferred. The most popular wine cultivars are currently Villard Blanc and Chenin Blanc, with 'mainly old unproductive cultivars' being uprooted: Chenel, Raisin Blanc, Clairette Blanche, and older Colombard.

Orange River Wine Cellars supplies about 2.8 million litres of wine to the retail group, Spar. Grapes are collected from 749 farmers along the Orange River for a distance of more than 350km. Orange River Wine Cellars has been selling wine to China for five years and is experiencing a sharp growth in sales to that huge market. The company won six gold medals at the 2012 China Wine Awards.

Douglas Wine Cellar produces about 6 000 cases per year together with the Landzicht cellar (just over the border in the Free State), Douglas Wine Cellar however, is a GWK company. The Douglas Cellar crushes 7 000 tons of grapes every year and produces 5.6 million litres of wine. Hartswater Wine Cellar is a part of the region's other big agricultural company, Senwes. Two wine brands (Overvaal and Elements) are produced in the Hartswater irrigation area north of Kimberley (Young, 2013). Table 6 indicates the wine grape varietals found in the Northern Cape.

Table 6: Indication of the different white and red wine cultivars found in the Northern Cape (Northern Cape Wines, 2017)

White wine grapes	Red wine grapes
Chenin Blanc	Pinotage
Colombard	Ruby Cabernet
Chardonnay	Merlot
Muscat d'Alexandrie	Shiraz
White Muscadel	Cabernet Sauvignon
	Petit Verdot
	Tannat
	Red Muscadel

Current blends include:

- Chenin Blanc/Colombard/ Chardonnay
- Ruby Cabernet/ Merlot
- Shiraz/ Cabernet Sauvignon
- Ruby Cabernet/ Shiraz Bordeaux style blends

2.1.3 The winemaking process and value chain

There are five main stages in the winemaking process. These are: Harvesting, Crushing and Pressing, Fermentation, Clarification, Ageing and Bottling (Myers, 2014). Each of the stages will be briefly described in the rest of this section. Cellars can have different processes that are performed at each stage but the five stages of making the wine is similar for all winemaking cellars.

Figure 3 shows the general winemaking process according to which all cellars make wine. The process within the steps may vary from cellar to cellar, but the general five steps are the same for all cellars.

Figure 3: Flow diagram showing the general winemaking process.

The first stage is called the harvesting process. This stage consists of harvesting the grape in the vineyard and transporting it to the cellar. In the Northern Cape, the grapes are still harvested in the vineyard by hand labour. In the Western Cape and other parts of the country, most of the grapes are harvested using machines.

The second stage of the process is called the crushing and pressing stage. Once the grapes arrive at the cellar, the crushing and pressing process begins. During the crushing and pressing stage, the grapes are de-stemmed and crushed into what is known as "must". "Must" is grape juice that consists of the skins, seeds, and solids of the grapes.

Following the crushing and pressing stage is the fermentation stage. This is also the third stage of the process. Fermentation is the process of converting the sugar into alcohol. Winemakers intervene in the fermentation of the wine by adding commercial yeast. The yeast period can be from 10 days to one month.

The clarification process is the fourth process. This process can start once the fermentation process is completed. This is when all the sugar is converted into alcohol. The clarification process consists of removing all the solids from the wine. Solids include things such as tannins, proteins, and dead yeast cells (Myers, 2014). Clarification can be done by fining or filtration.

Fining is done by adding substances to clarify the wine. Filtration is done by using a filter to remove large particles from the wine.

Ageing and bottling is the last stage of the winemaking process. Wine can either be bottled right away or it can be left to age for a certain time. Wine that is meant for bulk sales will not go through this stage as it will not be bottled by the cellar.

2.2 Capacity planning

For the purpose of this thesis, capacity is referred to as the upper limit/ceiling on the load that an organisation's operating unit can handle.

Aarabi & Hasanian (2014) defined capacity planning as the balance between the demand that is placed on the system and the system's ability to satisfy the demand. In organisational terms, capacity can be described as the ability of the organisation's systems within a certain time period to produce a certain amount of outputs. As soon as there is a difference between desired and current capacity, it results in what is called capacity being out of balance. However, there exists an optimum point between over- and under capacity for each business.

Aarabi & Hasanian (2014) stressed the importance for each organisation to find the optimum point between overcapacity and under capacity as it ensure that the organisation operates optimally. The result of overcapacity in an organisation is high operating costs while a case of under-capacity in an organisation causes strain on resources. Sule (2012) pointed out that strain placed on the resources due to under capacity can further lead to the possible loss of customers.

According to Sule (2012), capacity planning on the other hand is a key strategic component that forms part of the designing of a system used to control the capacity of an organisation. Capacity planning encompasses varies basic decisions which have long-term consequences for the organisation.

Different inputs are required in the decision process of capacity planning (Sule, 2012). Forecasts are one of the basic inputs due to the fact that it provides information on future demand. The primary goal of capacity planning is to match supply to the demand.

There are mainly four reasons why organisations usually start to adapt their capacity (Sule, 2012):

- Changes in demand.
- Changes in technology.
- Changes in the environment.
- Perceived threat or opportunities.

Capacity planning has 3 categories based on the planning horizon, namely (Sule, 2012):

- Long-term capacity.
- Medium-term capacity.
- Short-term capacity.

Long-term capacity is known as strategic capacity planning which is usually undertaken for a period longer than three years. It is also stated that there are various other types of capacities upon which long-term capacity is dependent. Those are capacities such as: design capacity, production capacity, sustainable capacity, and effective capacity (Management study Guide., 2016).

Design capacity is known as the maximum amount of output equipment can produce under ideal conditions. (Management study Guide, 2016). This specification is provided by the manufacturer. Production capacity, on the other hand, is stated by Management Study Guide (2016) as the maximum amount of output that can be produced by the equipment under normal conditions. While sustainable capacity is known as the max production level that can be achieved under realistic work conditions, effective capacity is, according to Management Study Guide (2016), the optimum production level that can be achieved under the following conditions: pre-defined job, pre-defined work-schedules, and normal working conditions.

Medium-term capacity, on the other hand, is stated by Management Study Guide (2016) as when an organisation undertakes strategic capacity planning for a period of two to three years.

Short-term capacity is capacity planning which is usually undertaken for daily, weekly or quarterly periods by the organisation (Management Study Guide, 2016).

In the paper of Orr (1999), it is stated that there are three factors that are very important competitive priorities in the wine production. These factors are: the supply dependability, product cost/price, and the use of advanced processing technology.

2.2.1 **Capacity expansion**

According to Luss (1982), capacity expansion can be defined as a method of determining the amount with which a facility or facilities should be expanded, as well as the timing of when it should be expanded so as to minimise the expansion cost. In the early 1960s, Manne (1961), published the first and simplest modelling of capacity expansion in the paper, "Capacity expansion and probabilistic growth". The model assumed that the demand was deterministic, the organisations only consisted of single facilities, and the economic life of the facilities was infinite.

Since the publication of Manne (1961), the literature on capacity expansion started to evolve. In the 1980s, the literature of capacity expansion started to incorporate capacity expansion for multiple facilities (Luss, 1982). The literature on capacity expansion is still growing today.

In 2007, Julka et al. (2007) published a journal paper covering capacity expansion of manufacturing plants. In this paper, capacity expansion is deemed as one of the critical decisions that a manufacturing company has to make. Julka et al. (2007) further explained in the journal that there exists two factors of capacity expansion. The one factor is policy-based where capacity expansion is done on an infinite time horizon. The other factor is where capacity expansion is a once-off step which is based on a single time period. According to Julka et al. (2007), a capacity expansion decision consists of four aspects. These aspects are: the timing of the expansion, the size of the expansion, the products that are impacted by the expansion, and the production location which is expanded.

Correia & Melo (2017) stated that, for certain cases, it is better to make capacity adjustments to existing facilities than to install a new facility or close down an existing facility. The capacity adjustments consist of either expanding capacity or contracting capacity at existing facilities. Sometimes trade-offs have to be made between adjusting the capacity and opening/closing facilities.

In the paper of Correia & Melo (2017), a new type of problem was studied which consisted of sizing decisions being reversible. This is the case if space and equipment can be rented. According to Lieberman (1987), there are four strategies that are associated with capacity expansion. These strategies are: the pre-emption strategy, the timing strategy, the coordination strategy, and the insulation strategy.

The pre-emption strategy consists of making a large investment earlier than the rivals so as to gain a larger share of the market. The timing strategy consists of time expansions of capacities in order to benefit from a market upturn. The coordinating strategy entails that capacity expansion plans should be coordinated with competitors in order to avoid redundant expansions. The last strategy is the insulation strategy, which aims to insulate the organisation from fluctuations that occur in the market by integrating vertically or forming a niche.

2.2.2 Capacity relocation

Daskin (2008) describes three groups according to which location models can be classified. These three groups are: continuous location models, network location models, and discrete location models.

According to Klose & Drexl (2005), these three groups can be defined as follows:

- In the continuous location model, it is assumed that the feasible solution is located on every point in the studied area.
- In the network location model, the solutions are expected to be located on the network which is simulated using an actual site.
- In the case of the discrete location model, the solutions are restricted to a predetermined set of potential locations.

According to Arabani & Farahani (2012), three aspects have to be considered when a facility must be relocated. These three aspects are: timing of the relocations, number of relocations, and cost of relocating the facility. Ballou (2001) states that by relocating a facility, logistical costs can be reduced by 5%-15%.

In the paper of Samir et al. (2016), facility relocation is observed according to two broad approaches. These approaches are: the optimization of an initial facility location that is based on current demand, and the possibility of adding facilities are used to find the best locations for initial facilities.

2.2.3 Capacity planning in the wine industry

Orr (1999) argues that capacity management is a critical success factor when considering the wine industry, but there is limited research on capacity management in this industry.

The Scopus database was accessed to obtain journals relating to capacity relocation. First, the keywords “Capacity relocation” yielded 6 documents. For the second search the keywords “ Capacity relocation and wine industry” which yielded no results.

The key words “capacity” and "wine" limited to a document type article yielded 10 documents. None of these results were applicable since all the documents focused on the capacity of different parts of the winemaking process.

The focus of the next search was aimed at finding journals or articles that covered capacity relocation in South Africa. However, this search yielded no results. The focus of the search was then moved to “capacity planning” and "South Africa". This search yielded a total of 3 documents. When the search was limited to engineering only one document remained. This document is, however, not applicable to this study since the document focuses on capacity planning of a rapid bus transport model.

The next database that was used to find journals on capacity planning, capacity relocation, and capacity expansion in the wine industry of South Africa was Google Scholar.

"Capacity planning wine industry" were used as search words in the Google Scholar database in a time range from 2012-2017. This search yielded various articles but none of the articles covered capacity planning in the wine industry.

The next search focused on capacity management in the wine industry. The time range for this search was also set as 2012-2017. This search also yielded various articles but none of the articles focused on capacity management in the wine industry. The articles focused on other aspects of the wine industry.

It can be concluded that there are no capacity planning, capacity relocation, capacity management, or other capacity-related articles that focus on the wine industry available in the literature.

2.3 Supply chain network design

2.3.1 Supply chain management

"A supply chain is a network between a company and its suppliers to produce and distribute a specific product, and the supply chain represents the steps it takes to get the product or service to the customer. Supply chain management is a crucial process, because an optimized supply chain results in lower costs and a faster production cycle." (Investopedia, 2003).

The following two paragraphs provide two further definitions found in the literature describing the term Supply Chain Management.

"Supply Chain Management (SCM) is the oversight of materials, information, and finances as they move in a process from supplier to manufacturer to wholesaler to retailer to consumer. Supply Chain Management involves coordinating and integrating these flows both within and among companies. It is said that the ultimate goal of any effective Supply Chain Management system is to reduce inventory (with the assumption that products are available when needed)" (Rouse, 2010).

"SCM is a set of approaches utilised to efficiently integrate suppliers, manufacturers, warehouses, and stores so that merchandise is produced and distributed at the right quantities to the right locations at the right time in order to minimise system-wide costs while satisfying service level requirements" (Investopedia, 2003).

Supply Chain Management is defined by the supply chain management council as the set of organizations which are linked by up and downstream linkage, various techniques as well as actions that manufactures value through products and services by the end user (Camargo, et al., 2013). SCM can be seen as the transformation of the way in which operations meets the customer's needs. If looking at an operational level, SCM is used to integrate the traditional functions in an organisation such as sourcing, buying, storing, making, and distributing. SCM is used in conjunction with Supply Chain.

The Supply Chain of an organisation is a framework including all activities that is associated with the flow of products and services with regards to the organisation, from raw materials to finished goods. Supply Chain also notes the interaction between the different role-players that influence a product during its life-cycle (Du Toit & Vlok, 2014). Du Toit & Vlok (2014) stated that supply chains are furthermore used to link the suppliers and customers with each other according to who is involved in the process of transforming raw materials into finished usable goods.

There is a direct link between the number of products and suppliers a company has and the number of supply chains it has. This means that, as the products and suppliers of the company increase, the number of supply chains of the company also increases.

According to Beamon (1998), a supply chain is an integrated process consisting of different business entities working together for the purpose of acquiring raw materials and then converting the raw materials into final products to be delivered to the retailers/end users.

2.3.2 Supply chain management frameworks/ models.

Supply Chain and Supply Chain Management are two concepts that regularly create confusion since these two concepts are inter-related. Supply Chain Management is, in effect, the management of the Supply Chains. With that in mind, it is clear that it is important to first understand the Supply Chain concepts before it can be attempted to understand Supply Chain Management concepts. Supply Chain has a lot of different definitions and each definition has its own scope/idea with its own level of detail but, in essence, all the definitions relate to the same core principles (du Toit & Vlok, 2014).

Naslund & Williamson (2010) focused on four different SCM frameworks in their journal. These four frameworks are: Supply Chain Operations Reference (SCOR), Global Supply Chain Forum Framework, Collaborative Planning Forecasting, and Replenishment and The Mentzer Framework. Each of these four frameworks will briefly be explained in this section.

2.3.2.1 Supply Chain Operations Reference (SCOR)

The SCOR model was developed in 1966 by the Supply Chain Council and AMR Research (Naslund & Williamson, 2010). The Supply Chain Operations Reference model is also seen as one of the most popular and well-known reference models for SCM (SCC, 2012).

"The supply chain operations reference model (SCOR) is a management tool used to address, improve, and communicate supply chain management decisions within a company and with suppliers and customers of a company" (Hudson, 2004).

According to Camargo et al. (2013) the SCOR framework was initially developed to aid organisations in increasing their supply chain effectiveness in order to support management with making certain decisions.

The SCOR framework focuses mainly on five areas of the supply chain, namely: plan, source, make, deliver, return. These five areas are repeated over and over in the supply chain (Camargo, et al., 2013). Camargo et al. (2013) stated that the SCOR framework can also be used as a tool to measure the total supply chain performance of an organisation by evaluating the five focus areas described earlier.

2.3.2.2 Global Supply Chain Forum (GSCF)

According to Naslund & Williamson (2010), the Global Supply Chain Forum Framework is seen as the second most popular supply chain framework. In this framework, eight key processes which form the foundation for supply chain management are identified.

Cooper et al. (1997) termed the eight business processes as follows:

- Customer Relationship Management
- Customer Service Management
- Demand Management
- Order Fulfilment, Manufacturing Flow Management
- Supplier Relationship Management
- Product Development
- Commercialization and Return Management

According to Croxton et al. (2001), each process is performed cross-functionally through all the functional silos of the organization. Croxton et al. (2001) stated that customer relationship management and supplier relationship management are important to external companies seeing that it links the company and the external companies in the chain.

2.3.2.3 Collaborative Planning Forecasting and Replenishment (CPFR)

This framework is stated by Naslund & Williamson (2010) as being a conceptual tool rather than a framework. It is also seen as the third most popular framework for improved supply chain collaboration. Naslund & Williamson (2010) describes CPFR as being a web-based format created with the intention of coordinating activities between the supply chain trading partners. According to Fliedner (2003), the aim of CPFR is to create a platform (shared web server) where internal information can be exchanged. This will create a reliable and long-term view of demand in a supply chain (Fliedner, 2003).

CPFR is sometimes seen as focusing more on information technologies than SCOR and GSCF (Naslund & Williamson, 2010).

CPFR has four main steps which are (Naslund & Williamson, 2010):

1. Planning
2. Forecasting of demand and supply
3. Execution
4. Analysis

2.3.2.4 The Mentzer Framework

This framework was developed by Mentzer et al. (2001) for the purpose of consistently conceptualizing supply chain management (Naslund & Williamson, 2010). "The supply chain is in this framework presented as a pipeline which illustrates supply chain flows, inter-functional coordination of traditional business functions, and the inter-corporate coordination between supply chain partners from the supplier's suppliers through the customer's customer to ultimately provide value and satisfaction for the consumer" (Naslund & Williamson, 2010).

According to Naslund & Williamson (2010) the main focus of this framework is on the cross-functional side of an organisation. This framework also focuses on the development of relationships with some of the other supply chain elements.

2.3.3 Designing the supply chain network

According to Melo et al. (2008)., designing a supply chain network requires the following inputs: customer zones that must be served, products that should be manufactured and distributed, demand forecasts for the customer zones, and information regarding future conditions, costs, and resources. Using these inputs, the decision must be made regarding the location of the new facility, allocation of procurement and production activities to the different manufacturing facilities, and how the products will be transported to the customers.

Melo et al. (2008) states that network design and supply chain network design (SCND) are usually used as synonyms of strategic supply chain planning. Melo et al. (2008) further states that it is important to have reliable location models to aid the SCND phase. According to Melo et al. (2008), design of distribution systems was the focus of research from an early date but they did not take the supply chain as a whole into consideration. During the SCND phase, it is very important to have good location models since the location of the new facility is a vital part of the supply chain (Melo, et al., 2008).

Different mathematical models can be used to design a supply chain network. These include models such as Facility location models, Capacitated plant location models, and Uncapacitated plant location models (Melo, et al., 2008).

Supply chain network design is used to find the supply chain configuration that will best comply with the competitive strategy and long-term goals of the specific organisation (Varsei & Polyakovskiy, 2016). The supply chain network design is concerned with long-term strategic decisions regarding the following three concepts:

1. the number of production plants, the location of production plants, and the capacity of production plants as well as distribution centres;
2. the flow of raw material, intermediate and/or finished products throughout supply chain; and
3. the set of suppliers to select.

Trade-offs do exist between certain aspects, such as the service level and the annualized supply chain cost in the supply chain network design problem (Varsei & Polyakovskiy, 2016).

2.4 Facility location planning

According to Melo et al.(2009), general facility location problems consist of a set of randomly distributed customers as well as a set of facilities that aim to serve the customer's demand. Facility location planning is stated by Rezaei & Zarandi, (2011) as the location choice of one or more facilities in a given area that is subjected to certain constraints and that should fulfil certain objectives.

"Facility planning is important to all organisations because it gives an organisation another perspective of how it does business and how it might change, as well as how the physical setting affects the way the organisation does business. Facility planning can also form part of the general management strategy." (Maxwell, 2003).

According to Farahani et al. (2009), facility location can be seen as a strategic management decision. Facility location models must consider some degree of future uncertainty. This is because facility location/relocation is a big financial investment and thus it must be operational for a certain period of time (Farahani, et al., 2009) (Owen & Daskin, 1998).

Rezaei & Zarandi (2011) stated that facility location planning can also sometimes be part of a bigger problem called Production-Distribution System Design (PDSD). The objective of PDSD is to determine the best configuration of the location and the size of facilities, the technological content of the facilities, commodity offerings, and transport decisions for achieving the long-term goals of the organisation. Rezaei & Zarandi (2011) further claims that efficient PDSD can reduce transportation cost, increase operational efficiency, as well as logistic performance, and improve the quality of the service.

According to Rezaei & Zarandi (2011), facility location problems can be categorized by the following characteristics:

- Number of facilities
- Objective function
- Solution space
- Number of commodities
- Capacity limitations
- Shape of facility

- Demand

According to Rezaei & Zarandi (2011), the main objective of PDSD is to minimize the sum of the fixed cost, the operational cost, and the transportation cost. Some of the main objectives of facility location planning are stated by (Rajaraman, 2000) as the following:

- Locate the facilities so as to minimize the travelling distance/time to the customers.
- Locating the facilities so as to minimize the total construction cost and the average travelling distance to the customers.

Other objectives stated by Melo et al.(2009) for which facility location planning can be used is the following:

- To determine which facilities should be open and which should be closed.
- To determine which facility should serve which customers in order to minimize costs.

An important factor of facility location planning explained by Plastria (2001) is the break-even distance. The break-even distance is the distance which a customer will travel for a product or a service at a new facility.

Facility location also consists of important decisions classified by Owen & Daskin (1998) as one of the critical elements associated with strategic planning for both private and public firms. The other benefit of facility planning is that it helps an organisation to make important decisions regarding the need for new space, renovated space, and obsolete spaces. According to Lovering (n.d) there are seven factors affecting facility location planning. These seven factors are: layout, cost, logistics, labour, political stability, regulations, and the community.

The physical layout of a facility determines if future expansions can consist of enlarging the facility space. While the acceptability of a location is greatly determined by the cost of relocating facilities to the specific site and the logistic factor determines if the transportation routes to the chosen site are acceptable. The labour factor determines if the labour that is available in the area of the chosen site is adequate. Political stability entails that facilities located at international locations might benefit from a cost point of view. Political stability also determines the stability of the environment from a political point of view. The regulations factor focuses on government regulations and taxes that may prove costly. Facilities are not located on a temporary basis, so it is important that they fit with the community with which it is associated (Lovering, n.d.).

The following criteria as defined by Melo et al.(2009) must be considered when developing a facility location model. The first is to determine the properties that the facility location model should fulfil to be acceptable in the supply chain context. Secondly, it should be determined if facility location models already exist, and also if they fit in the supply chain context. Lastly and most importantly, it should be determined whether SCM needs facility location models.

Two commonly used facility location models that are well known in the literature are Weber's location planning model and the p-median model. These two models will be described in more detail in the following paragraphs.

Weber's Location planning model

Weber's problem is a single facility location model that is used to determine where single facility should be located (Nakamura, 2010). Weber's location problem consists of finding a certain point which minimizes the sum of the transportation cost from the specific point to n destination points. The "n" destination points are each assigned with different cost per unit costs. Weber also considers a plain with different points where it is possible to move directly from one point to any of the other points at any given rate (Hansen, et al., 1998). According to Hansen, et al (1998), with the Weber problem the market site, the location of the resources, as well as the distribution of labour, are regarded as a given.

The following conditions are assumed to hold in Weber's problem: production factors are homogeneous, no restriction on the supply of labour at the current wage level, there are fixed technical coefficients in the production function, and demand for goods is inelastic with respect to price (Hansen, et al., 1998).

Hansen, et al (1998) further stated that, concerning the conditions previously mentioned, the profit maximization objective of the firm can only be attained by minimizing transportation costs.

P-Median

According to Rahman & Smith (2000), the focus of the p-median problem is to determine how to locate p facilities as to minimize the demand weighted average distance between facilities and certain demand nodes. This problem is another classical location problem. However, the p-median problem focuses on minimising only the total travel distance which may inequitably causing some users to travel very far. The paper written by Daskin & Maas (2015), stated that the p-median problem consists of mainly three key properties which will be explained in the following paragraphs.

The first property of a p-median problem is that it can be classified as Non-deterministic Polynomial (NP)-hard on a general graph but it can also be solved in polynomial time on a tree. The good news is that there are many effective algorithms as well as approaches to solve p-median problems (Daskin & Maas, 2015).

The second property is that at least one of the p-median's optimal solutions consists of locating the facilities on the nodes (Daskin & Maas, 2015).

The final property is that the demand weighted total cost or distance decreases with each addition of a subsequent facility (Daskin & Maas, 2015).

Rahman & Smith (2000) observed that the usage of a facility declines rapidly when the travel distance/time exceeds some critical value. Thus, it is important that the critical value is defined in such a way that a customer is willing to travel to the nearest facility. With the previous statement in mind, Rahman & Smith (2000) concluded that the objective of p-median problems is to locate a given number of facilities so that the total travel distance (or time) between facilities and demand points are minimised.

Facility location problems can be solved using mathematical models or simulation models. The next sub-section will describe the mathematical models that can be used to solve facility location models. There are various models of facility location planning, such as: Uncapacitated facility location model, Capacitated facility location model, Capacity expansion, Capacity relocation, Multi-period model, and Single period model. These six models will be described in detail in the following six subsections.

2.4.1 Optimisation models

In this subsection, different optimisation models will be examined and the Capacitated plant location model and Uncapacitated plant location model will be closely examined. The Capacitated plant location model is concerned with locating facilities when the facilities has a capacity constraint while the Uncapacitated plant location model is concerned with locating facilities that have no capacity constraint.

The ultimate goal when locating facilities and allocating capacities is that the overall profitability of the supply chain should be maximized while providing the responsiveness desired by the customers. The profit of a firm is the difference between the revenue and costs of the firm. The revenue is the sales of the product where the costs are comprised of facilities, labour, transportation, material, and inventories. Locating facilities requires weighing certain trade-offs against each other. Trade-offs such as building many facilities to serve the market reduces transportation cost but increases facility and inventory costs.

When the facility location model is being built certain input data is required. The input data is the following (Chopra & Meindl, 2013):

- Location of the supply sources and markets.
- Location of potential facility sites.
- Demand forecasts of the market.
- Facility, labour and material costs of each site.
- Inventory cost as a function of quantity for each site.
- Different sale prices for different regions.
- Taxes and tariffs.
- The desired response time and other service factors.

It should be noted that not all the input data are required to build the model. The geography of the model determines what input data are required (Chopra & Meindl, 2013).

2.4.1.1 **Uncapacitated facility location models**

A facility location problem is known as an Uncapacitated facility location problem if an arbitrary number of customers can be assigned to the specific facility (Zhang, et al., 2006).

Posta, et al (2014) pointed out that the Uncapacitated facility location problem is, in fact, a renowned combinatorial optimisation problem, which is also sometimes referred to as the warehouse location problem or simple plant location problem. The aim, according to Posta, et al (2014), of the Uncapacitated facility location model is to establish (n) locations where the plants can be built so that (m) customers can be served. In Uncapacitated facility location models, the assumption is made that the facilities do not have a capacity constraint, so it can produce and ship an unlimited number of products (Galvao, 2003).

According to Rajesh, et al (2013), the customers of an Uncapacitated plant location problem will be supplied by the facility closest to them. Galvao (2003) stated that the objective of the basic Uncapacitated facility location model is to determine the least number of facilities needed so that all demand points are satisfied and that they are satisfied by at least one facility. Galvao (2003) pointed out that in the case of certain models, the number of facilities that can be located are fixed which means that, in those cases, it is not guaranteed that all the demand areas will be covered.

The minimum cost operating problem is a sub-division of Uncapacitated facility location models. In this sub-division, each facility can serve only clients within a given radius from that facility, but it is not necessary to serve all the clients. If a client is not served, there is a penalty cost involved. The aim of the minimum cost operating problem is to minimise the sum of the cost of establishing facilities and of the penalty cost for not serving clients (Kolen, 1983). The drawback of the minimum cost operating problem is that the clients that can be served are limited to those that are within a certain range from each facility. It is, however, not required to serve all the clients. The problem is rather how to serve all clients at minimum cost (Kolen, 1983).

In the Uncapacitated plant location problem, it is possible for each facility to serve all the clients. However, besides the cost of establishing facilities, there is a cost for transporting goods from the facility to a client. This cost is assumed to be directly related to the distance travelled. This means that the objective of Uncapacitated plant location problems is not only to minimise the sum of the cost of establishing facilities but also to minimise the transportation cost (Kolen, 1983).

The Erlenkotter algorithm is one of the methods that can be used for Uncapacitated facility location problems. It should be noted that the Erlenkotter algorithm is viewed as a heuristic, weak-dual based method used for Uncapacitated facility location problems. The Erlenkotter method can be modified so that it can be directly applied to Uncapacitated facility location problem self-serving demand (UFLP-SS).

The main objective of UFLP is to find a set of facilities that will meet all of the demands at the least cost (Harkness & ReVelle, 2003). There are three types of costs involved in locating facilities to meet the demand of the customers. These costs are: fixed costs for opening the facility, unit production/ manufacturing cost, and unit shipping cost (Harkness & ReVelle, 2003).

The cost for opening a facility is comprised of two types of costs. These costs are: site setup cost and facility set up cost. Site setup cost is a fixed cost that is associated with opening a certain site and it does not depend on the number of facilities located on it.

Facility setup cost is the cost associated with locating a facility on a site. This cost is a function of the size of the facility (Zhang, et al., 2006).

The UFLP with a general cost function can be formulated as follow:

(1) is a representation of the general cost function for the UFLP.

$$\boldsymbol{Min \sum_{i \in I} g_i(Z_i) + \sum_{i \in I} \sum_{j \in J} c_{ij} x_{ij}} \qquad (1)$$

Subject to

$$\sum_{i \in I} x_{ij} = 1,$$

$$\sum_{j \in J} x_{ij} \leq z_i,$$

$$x_{ij} \in \{0, 1\},$$

$$z_i \geq 0,$$

I represent the set of facilities while J represents the set of customers.

g_i(z) represent a non-decreasing function for each of the "i" facilities.

$g_i(z_i)$ is the facility setup cost that is occurred when facility "i" is opened that has a size of "z_i".

c_{ij} represents the cost of assigning customer 'j' to facility "i".

z_i represents the number of customers assigned to facility "i".

$z_i > 0$ if facility "i" is open or $z_i = 0$ of facility "i" is closed.

The following formulation is, in some ways, similar to the general cost function mentioned above except that it also takes into account production/ manufacturing cost and transportation cost.

(2) is an extension of the general cost function of the UFLP as it takes into account production cost and transportation cost

$$Min \sum_{i \in I} f_i y_i + \sum_{i \in I} \sum_{j \in J} (t_{ij} + e_i) d_j x_{ij} \qquad (2)$$

s.t

$$\sum_{i \in I} x_{ij} \geq 1$$

$$x_{ij} \leq y_i$$

$$x_{ij} \geq 0$$

$$y_i \in \{0, 1\}$$

I and i represents the set an index of candidate facility locations.
J and j represents the set and index of demand locations.
y_i represents the decision variable which is equal to 1 if site i is selected to install a facility and 0 otherwise.
x_{ij} is the decision variable ranging from 0 to 1 depending on the fraction of demand of j that is being supplied from location i.
f_i is the fixed cost of setting up a facility at location i.
t_{ij} is the cost of shipping one unit from location i to demand point j.
e_i is the cost of manufacturing one unit of product at location i.
d_j is the number of units required at demand point j.

Posta, Ferland and Michelon used a similar mathematical formulation in their paper "An exact cooperative method for the Uncapacitated facility location problem" and proved that the formulation is able to solve Uncapacitated facility location problems.

The primal process is also sometimes used to find a good solution for the objective function (1) by improving the upper bound through searching for other solutions by metaheuristics. The primal process finds good solutions by exploring the neighbourhood of a certain solution. The neighbourhood is explored by flipping one component of the solution and evaluating the new solution to see if it is feasible. By flipping the component, the facility's status is changed either from open to closed or from closed to open. After exploring all the neighbours, the next step is to evaluate all of them to see if there is a solution yielding a more optimal solution.

The dual process can also be used as a way to find other good solutions for the objective function (1) by improving its lower bound through the method of enumerating a lagrangian branch and bound search tree. This is done by recursively partitioning the objective function (1) into subproblems. By using a Lagrangian dual, the lower bound for each of the sub-problems are computed.

2.4.1.2 Capacitated facility location models

According to Sridharan (1995), a problem can be defined as a Capacitated Plant Location Problem (CPLP) when every plant has a certain capacity that cannot be exceeded. Capacity in the context of CPLP is referred to as the upper limit of the amount of demand which the plant can handle (Sridharan, 1995).

The paper of Zhang, et al., (2006) stated that the objective of CPLP models is to minimize total fixed cost and transportation cost so that the demand of the clients is satisfied without violating the capacity constraints of the facility servicing that demand area. The CPLP model is a two-stage model. The first stage is the decision stage where the decision has to be made regarding which facility to open and where it should be opened. The second stage is where customers are to be assigned to the facilities that has been opened (Klose, 2000).

A certain restriction, namely a customer can only be served from one plant, can be added to the CPLP. This constriction then transforms the CPLP to a Capacitated Plant Location Problem with Single Source constraint (Sridharan, 1995). With CPLP, there exists a set of potential plant locations with fixed costs as well as fixed capacities, and a set of customers with a demand for certain goods supplied from the plants. There are also transportation costs associated with the supply of the goods. The challenge is to find the subset of plants which will minimize the total fixed and transportation costs, so that all the demand of the customers will be satisfied without violating any capacity constraints of the plants (Sridharan, 1995).

In certain versions of CFLP, the output of a facility only contains upper limits, but it is also possible for the output of the facility to have both upper and lower limits. There is a two-stage decision process involved with CPLP. The first stage is to decide which of the subset of the plants should be opened. The second stage is to assign customers to these open plants (Sridharan, 1995). There may also exist an additional restriction that each customer can only be served from one plant. If this is the case, the CPLP is transformed into what is called Capacitated Plant Location Problem with Single Source Constraints (CPLPSS). This is not the case in this project (Sridharan, 1995). The location of the plants is crucial as transportation costs forms a major portion of the price of goods. The fixed costs of opening and operating a plant are just as important.

CPLP consisting of “n” potential plants and “m” customers can be formulated as what is known as a mixed integer program, which looks as follows:
(3) is the function for the CPLM as a mixed integer program.

$$\boldsymbol{Z = min \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij} + \sum_{i=1}^{n} f_j y_j} \quad (3)$$

Subject to the following constraints:

$$\boldsymbol{\sum_{j=1}^{n} x_{ij} = 1,}$$

$$0 \leq x_{ij} \leq y_j \leq 1,$$

$$y_j = \{0, 1\},$$

$$\sum_{j=1}^{n} s_j y_j \geq \sum_{i=1}^{m} d_i,$$

where

c_{ij} is the total transportation cost from plant j to customer i.
d_i is the demand of customer i.
s_j is the capacity of plant j.
f_j is the fixed cost of plant i.
x_{ij} is the fraction of the demand of customer i that is supplied from plant j.
y_j is 0 or 1 depending on whether the plant j is open or closed.
(Harkness & ReVelle, 2003)

The constraints are added to ensure that certain conditions are obeyed. The conditions will be explained in the following paragraph.

The first constraint is included to ensure that the demand of every client is met.
The second constraint ensures that every open plant only supplies what its capacity allows it to supply and that the clients are only supplied from open plants.
The third constraint specifies that the total capacity of the open plants should be at least as large as the total demand of the customers (Harkness & ReVelle, 2003).

When the installation costs are fixed, the lowest total cost per unit output is achieved at the point where average production costs are rising. This can be seen by examining the following cost function of (4):

$$T(x) = F/x + V(x) \tag{4}$$

where
T(x) represents the per unit average total cost of producing output x.
F represents the fixed installation cost.
V(x) represents the per unit average variable cost of producing x.
(Harkness & ReVelle, 2003)

When more results are required from the model, the Lagrangian Relaxation approach can be applied. It is usually used when mixed integer and pure integer problems have to be solved. For the CPLP, there exists two Lagrangian relaxations. In the one approach, the demand constraints are relaxed and included in the objective function. While in the other approach, the capacity constraints are relaxed and included in the objective function (Sridharan, 1995).

Heuristics are a very powerful tool because they can handle large problems and, in many cases, the solution obtained from the heuristics is fairly close to the optimum value. The heuristics for CPLP's are primarily based on the heuristics for Uncapacitated Plant Location Problems. These heuristics can therefore be classified under two basic approaches: the greedy and interchange heuristics (Sridharan, 1995).

Greedy Heuristics

The greedy heuristic is, according to Sridharan (1995), based on the principle that once a decision is made it is not changed. There are two different greedy heuristics for CPLP and they are the ADD procedure and the DROP procedure.

ADD

Sridharan (1995) stated that the ADD is one of the widely known heuristics for simple or Uncapacitated plant location problem (SPLP). According to Sridharan (1995), Kuehn and Hamburger were the initial developers of the ADD procedure for the use of solving the Uncapacitated version of the problem. Jacobson (1983) developed the extension of the procedure to incorporate the Capacitated version of the problem.

One of the difficulties of the ADD procedure is that it always starts with an unfeasible solution to the problem. This situation is then handled by having a super source with capacity equal to the total demand and a very high transportation cost to each of the demand locations (Sridharan, 1995).

The ADD procedure is as follows:

Start with no plants open. That is, all plants are in the set JØ

1. For each $j \varepsilon$ JØ, compute the savings
   $\sigma_j = T^*(J1, l) - T^*(J1 \cup \{j\}, l) - f_j$.
2. Now identify the plant j* that gives the maximum savings σ_{j^*} from
   $\sigma_{j^*} = \max_{j \varepsilon J Ø}\{\sigma j\}$
3. If $\sigma_{j^*} > 0$, transfer j* to J1 and go back to Step 1. If $\sigma_{j^*} \leq 0$, terminate the procedure with the set J1 of open plants, since no more savings can be made by adding another plant.

DROP

The DROP procedure was first used by Feldman, Lehrer and Ray for Uncapacitated Facility Location Problems (Sridharan, 1995). The DROP procedure works as follows: it starts with all the plants in the set. In each step, a plant is dropped at a location where the largest savings are obtained. Similar to the ADD procedure, the DROP procedure also requires transportation problems to be solved in each iteration (Sridharan, 1995).

The DROP procedure is formalized as follows:

1. For each plant $j \varepsilon J1$, compute the savings
   $\sigma_j = f_j + T^*(J1,I) - T^*(J1 \backslash \{j\}, I)$.
2. Find the plant j* that gives the maximum savings
   $\sigma_j = \max_{j \varepsilon J1}\{\sigma j\}$.
3. If $\sigma_{j^*} > 0$, transfer j* from J1 to J0 and go to Step 1. If $\sigma_{j^*} \leq 0$, terminate the procedure with the set J1 of open plants since we do not have positive savings by dropping any more plants.

Interchange Heuristics

The principle upon which greedy heuristics is based is that, once a decision is made, it cannot be changed but, in some cases, it might be required for a decision that was made to be changed. There does exist an extension to the greedy heuristics in which decisions that were made can be changed. This extension is referred to as the interchange heuristics (Sridharan, 1995).
The interchange heuristic consists of two different methods, which are: the Alternate Location-Allocation (ALA) and the Vertex Substitution Method (VSM) (Sridharan, 1995).

Alternate Location-Allocation

The ALA method can be described as follows:

1. Start with a set of open plants, J1. All other plants are in JØ. Set JT=Ø.
   (JT is the set of plants that have been tried unsuccessfully in the interchange.)
2. If JT=J1, stop. Else, let j J1-JT. Add j to JT
3. Transfer j from J1 to J0. 'Reoptimize' using an ADD iteration. If the cost of the new solution is smaller than at the beginning of Step 3, then let J1 be defined by this new solution, JØ=J-J1, J0=Ø. Set JT=Ø and go to Step 2. Otherwise, set J1, J0 and JØ back to their value at the beginning of Step 3. Go to Step 2.

Vertex Substitution Method (VSM)

The Vertex Substitution Method can be described as follow (Sridharan, 1995):

1. Start with a feasible solution. List J0, the set of closed plants, Set JT=Ø

2. If JT=J1. Stop. Else, let j J1 -JT. Add j to JT
3. Transfer j from J0 to J1. 'Reoptimize' by one DROP iteration. If the cost of the new solution is smaller than at the beginning of Step 3, then let J1 be defined by this new solution, J0 = J-J1. Set JT=Ø and go to Step 2. Otherwise, set J1 and J0 back to what they were at the beginning of Step 3. Go to Step 2.

By using an enumeration tree, an exact solution for a Capacitated Plant Location Problem can be obtained.

2.4.1.3 **Static vs Dynamic planning models**

Facility location planning problems can be divided into two further categories, namely: static and dynamic problems. According to Owen & Daskin (1998), the main difference between static and dynamic facility relocation models is that with a dynamic model facilities can be relocated in every period, but this is not the case in static facility relocation models.

With static facility relocation models, if a facility is opened or closed it has to stay in that state for a certain number of periods before it can be relocated again. In some cases, relocating a facility is a big financial expense. Those are examples of static facility relocation problems.

The dynamic/multi-period facility location models are where relocation of facilities in each period is allowed and has a certain objective. This objective is to optimally locate facilities during each period in order to satisfy the demand at a minimum cost. This cost is made up of transportation costs, opening and closing a facility, as well as the operating cost (Torres-Soto & Uster, 2011).

Dynamic/multi-period facility location models where relocation of facilities in each period is not allowed is almost similar to when relocation during each period is allowed. The only difference is that there is no facility opening and closing cost (Torres-Soto & Uster, 2011).

Dynamic planning model

The journal paper of Tayal (2003) discusses three variations of the multi-period model. These variations are the multi-period model with minimum capacity, the multi-period model with penalties, and the multi-period model with inventory.

The multi-period models are seen as more generalized models than the single period model since multi-period models have the ability to portray the dynamic nature of multi-period problems. In multi-period problems, the facilities can expand their capacity, if needed. Tayal (2003) suggested that multi-period models should be used when an organisation has to make a decision of whether a facility should be relocated, expanded, or phased out. Tayal (2003) further states that this is done over a certain planning period during which supply chain activities should not be disturbed.

Certain assumptions are made when a multi-period problem is modelled. Tayal (2003) listed the following assumptions: the costs as well as the cost functions are deterministic; the company's budget is not acting as constraint; no cost is associated with keeping capacity or salvaging it; relocation of facilities or facility opening/closing will happen at the start of a period; no inventory will be kept, and the customers, as well as suppliers, will stay the same during the total time period. Tayal (2003) formulated the objective function for the multi-period model to minimize the variable and fixed costs of the facilities. According to Tayal (2003), the different variations of the multi-period model all have the same objective. The only difference between them are the constraints.

Static planning model

Tayal (2003) states that in a single period model, the current state is used to determine what should happen to the facilities in that period. The organisation has the following options: a facility can either be relocated, phased out or closed down and the capacity moved to other facilities. The organisation can also decide to open a new facility if it is necessary, but capacity at the current facilities cannot be expanded. For the single period model, certain assumptions must be made, such as costs are deterministic, capacity is not expanded, the company's budget is not acting as a constraint, the demand can be satisfied by the total existing capacity and, lastly, to keep capacity or salvage it is not billed in any way.

The objective of the single period model is similar to the objective of the multi-period model, which is to minimize variable and fixed costs of the facilities. From the thesis paper of Tayal (2003), it can be seen that there is one main difference between the single period model and the multi-period model. This difference is that the single period model only considers one period while the multi-period model considers more than one period when a decision regarding the facility relocation has to be made.

Multi-echelon

Items are produced from raw materials and sold to customers as final products. To transform the raw materials into the final product it has to go through certain stages. When the item has to go through more than one stage for it to reach the final product, the system is called a multi-echelon (Gumus & Guneri, 2007).

In the journal Taha, et al., (2015) a supply chain network was designed that is a multi-echelon, multi-product, multi-period supply chain. The supply chain was made up of suppliers, plants, distribution centres, and the customers. In this supply chain, the plants can accommodate more than one production module (Taha, et al., 2015).
There are many papers available in the literature covering multi-echelon, multi-product, multi-period such as the paper wrote by Soleimani, et al., (2013), where multi-objective, multi-echelon supply chain logistic design planning problem was solved. In this case, the supply chain was of the closed-loop type. In this paper, customers can receive products from manufacturers, warehouses and distributors.

According Govindan, et al., (2015) to the a closed-loop supply chain is a supply chain where the product can be returned to the producer in the form of a defect. Closed-loop supply chain is also known as a forward-reverse supply chain because of the fact that defective products can be returned to the producer.

Melo, Nickel and Saldanha-da-Gama(2008) constructed a supply chain design model for a four echelon problem. In the design, the objective was to minimize the cost which consists of variable procurement, production, transportation, capacity expansion, and penalty costs (Melo, et al., 2008).

In the model, the suppliers ship raw material to the plants. The raw material can then be transported between the plants, if needed. The products are then transported from the plants to the distribution centres where they can also be moved between the distribution centres, if needed. From the distribution centres, the products are shipped to the customers. This model does not incorporate the return of defective parts.

2.4.2 Qualitative models

There are different qualitative models in the literature that can be used to determine the qualitative effect of a decision or action (Kayastha, et al., 2013) (Mustafa, et al., 2015). For this project, the models were researched are: the Analytical Hierarchy Process, the weighted Decision Matrix, the Pugh Matrix and TOPSIS.

Each of the models will be described in detail in the following paragraphs.

2.4.2.1 Weighted decision matrix

The structure of a typical decision matrix usually consists of a number (M) of alternatives and a number (N) of decision criteria. Using this matrix, every alternative can then be evaluated according to the defined decision criteria as well as the relative importance of each criterion.
In the matrix, the performance value of alternative-i (A_i) with reference to criterion-j (C_j) is represented by a_{ij} and the weight of criterion C_j is represented by W_j. Table 7 is a graphical presentation of what the structure of the weighted decision matrix looks like.

Table 7: Indicates the structure of the weighted decision matrix.

		Criterion				
Alternatives		C_1	C_2	C_3	…	C_N
		W_1	W_2	W_3	…	W_N
	A_1	a_{11}	a_{12}	a_{13}	…	a_{1N}
	A_2	a_{21}	a_{22}	a_{23}	…	a_{2N}
	A_3	a_{31}	a_{32}	a_{33}	…	a_{3N}
	..	…	…	…	…	…
	A_M	a_{M1}	a_{M2}	a_{M3}	…	a_{MN}

The decision matrix is usually used to determine the best alternative of all the possibilities. In many of the examples, all the criteria have the same unit but in most of the real-life problems the criteria have different units (Fadzli, et al., 2015).

In the Weighted Decision Matrix (WDM), all the decisions must sum to 1.
There are recommended steps to be followed when doing a WDM and these steps are:

1. The criteria which is most important to be achieved should first be identified based on design requirements.
2. The appropriate weighting factor can then be determined by using the objective tree.
3. The decision matrix can now be constructed.
4. The rating of each of the criteria is determined by multiplying the weight factor with the score. (Fadzli, et al., 2015)

With this type of modelling, each concept is compared to the functional requirements of the product. By using this comparison, the concepts are then rated and the concept with the highest rating is usually chosen, unless another concept achieved a higher rating for one of the functional requirements of the product which is more important to the product than the overall rating of the concepts. The rating achieved by the concept is known as the score weight.

The score weighting factor is used as a representation of how well the concept responds to the pre-determined functional requirements of the product as a consideration of the usefulness/importance of the functions compared to the overall need of the product (Olabanji, 2014).

2.4.2.2 **Analytical Hierarchy Process (AHP)**

AHP is seen as the most widely accepted method and is considered as one of the most reliable multi-criteria decision making (MCDM) methods. (Triantaphyllou & Mann, 1995). It is a proficient tool to use when decisions have to be made in situations involving multiple objectives (Winston, 2004).

The definition of measurement, according to most people, is that it must be a physical scale consisting of a zero point and a unit. This is not always the case as it is possible to derive an accurate and reliable scale that doesn't have a zero or a unit. By using one's understanding and judgment of a certain situation, it is possible to derive an accurate and reliable scale that doesn't have a zero or a unit as one's understanding and, instead, judgment forms the fundamental determinants for measuring something (Saaty, 2004).

In an analytical hierarchy matrix, the values represent a judgment that is made with respect to a certain property that the two elements have in common. It is also important that the set of objects being compared must be homogeneous (Saaty, 2004). In AHP models, the scale of pairwise comparison combined with random consistency index is used to quantify the relationship between the concept and the functional requirements of the product (Olabanji, 2014). If the elements that are compared are very close, then those elements should be compared with other elements that are more contrasting. If the elements are not homogeneous, then they should be grouped in homogeneous groups. Additional elements may be added to the groups to fill it (Saaty, 2004).

The concept that has the highest priority rating is then the best concept.

The following five steps are followed during the AHP (Winston, 2004):
1. Determine the component factors of the decision problem.
2. Arrange the factors in hierarchy order.
3. Assign ratings to the factors according to their subjective relevance.
4. Construct a comparison matrix.
5. Determine the weight of each factor.

The benefits of using AHP is that all types of information pertinent to the problem are captured in the discussion process and judgment takes into account all the information pertinent to the problem, with expert's knowledge and experience used as the basis in discussion rules and where inconsistencies can easily be detected (Kayastha, et al., 2013).

2.4.2.3 **Pugh Matrix**

The Pugh Matrix is, to some extent, a mix of the weighted decision matrix and the AHP as it compares different design candidates to determine the design that best meets the set of criteria and it uses pairwise comparison to compare different design candidates against certain criteria or requirements.

One of the main differences between the Pugh Matrix and the Weighted Decision Matrix is that the Pugh Matrix is able to handle a large number of decision criteria.

The Pugh Matrix is usually used when a decision has to be made between a number of different alternatives. The quality of the outcome of the Pugh Matrix is dependent on the skill of the person who uses it. In the Pugh Matrix one of the concepts is chosen as the baseline and all the other concepts are then compared to the baseline. When the criteria score better in a certain concept than in the baseline, it is indicated with a "+" and when it scores worse than the baseline it is indicated with a "-". Numbers can also be used to indicate if a certain concept scores better or worse in a criterion compared to the baseline. In this case, a scale of 1 to 5 is used, where 3 is used to indicate the norm and 4 and 5 indicates a better score of the criteria than the baseline and 1 and 2 indicates a worse score of a certain criterion than the baseline.

2.4.2.4 **TOPSIS**

TOPSIS is known as the Technique for Ordering Preference by Similarity to the Ideal Solution and this method was developed by Hwang (1981). It is a commonly known distance-based approach for decision making it is also a well-known Multi-Criteria Decision Making (MCDM) method. TOPSIS is more commonly used since it requires limited inputs from the user. The weights are the only inputs required from the user.

The 5 step procedure for the TOPSIS method is as follow (Ahmadi, et al., 2013):

1. Construct a normalized decision matrix as in the AHP.
2. Construct a weighted normalized decision matrix by multiplying the weights with the normalized decision matrix.
3. Determine the positive ideal and negative ideal solution
4. Calculate the separation measures for of the alternatives
5. Calculate the relative closeness to the ideal solution

The alternatives are ranked according to the shortest distance from the positive ideal solution as well as farthest from the negative ideal solution. The alternatives of TOPSIS are each compared directly provided the data of the evaluation matrices and weights allows it. TOPSIS is easy to use and can efficiently solve real-life problems (Sekhar, et al., 2015).

2.4.3 **Facility location and capacity planning models in the wine industry**

The Scopus database was used to search for journal papers focusing on capacity expansion and facility location models. The search words “Capacity expansion” and “facility location models” were used. This search yielded 1 161 results but when the search was narrowed down to capacity expansion and facility location models in the wine industry, no documents were found.

The GoogleScholar database was also used to find literature on capacity expansion. For the first search, only the search words “capacity expansion” and “facility location models” were used and the time range was set from 2007 to 2017. This search yielded 1 750 000 results but when the search was narrowed down to “capacity expansion” AND wine, “facility location” AND wine , no useful journals were found.

2.5 **Literature summary and conclusion**

In this section, an overview of the wine value chain with the focus on the South African and Northern Cape wine industry was provided. The Supply chain network design was also investigated with the focus on Supply chain frameworks, Capacity planning, Facility planning and different qualitative models.

Capacity planning focused on capacity expansion, capacity relocation and finally capacity planning in the wine industry. Supply chain network design focused on supply chain management, supply chain management frameworks available in the literature, and design of the supply chain network. Facility location planning focused on some of the different optimisation models available in the literature. The different optimization models were the uncapacitated location model, capacitated location model as well as static and dynamic planning models.

The Capacitated plant location model was used since there was a capacity constraint but the Uncapacitated plant location model can also be used if there is no capacity constraint. The static and dynamic planning models that were researched are not applicable for this framework. Static planning models are not applicable since it does not allow for capacity expansion of a facility and the decision of whether a facility should be relocated is based on the current state which is not possible for the objective of this framework (seeing wine cellars should be relocating). Dynamic planning models are not applicable since it requires suppliers to stay the same which is not possible, seeing that most farmers are replacing the wine grapes with other crops.

The different qualitative models were the Weighted Decision Matrix, the Analytical Hierarchy Process, the Pugh Matrix and TOPSIS.

Scopus and Google Scholar were used to obtain all the available literature regarding capacity planning, supply chain network designs, facility location planning, and different modelling types. It was found that there is limited literature available regarding capacity planning and facility location planning in the wine industry. Thus, the gap in the literature regarding facility location planning and capacity planning models in the wine industry was identified.

The next chapter will provide a background of the case study as well as provide more detail of the company used in the case study. It will be used to graphically map where the different cellars are located, briefly explain the winemaking process, and also give a short explanation of each of the cellars.

Chapter 3 Case study description

This chapter will provide a detailed background of the OWK company used for the case study. An overview will also be provided of the winemaking process and then a more detailed explanation of the structure of OWK.

Six cellars are part of the current OWK supply network. These six cellars are termed as follow: Cellar1, Cellar2, Cellar3, Cellar4, Cellar5, Cellar6.

The winemaking process of each of the cellars will be mapped on a flowchart and discussed. Cellar3 will not be discussed in detail as it is a cellar used for the production of grape juice only and not wine.

3.1 Background

OWK was established in December 1965 with the first harvest in 1968. The first cellar that was built was Cellar6, after which the wine production expanded and Cellars 1, 2, 4, 5 and 3 were built. Juice production is managed from Cellar1, Cellar 3 as well as Cellar4. OWK is the largest wine cooperative in South Africa as well as in the Southern Hemisphere and second largest in the world.

The cellars stretch over a distance of 350km from Cellar1 in the West to Cellar5 in the North East. The head office of OWK is at Cellar6. Figure 4 shows the current location of all the wine cellars of OWK seeing that OWK is primarily in the winemaking industry.

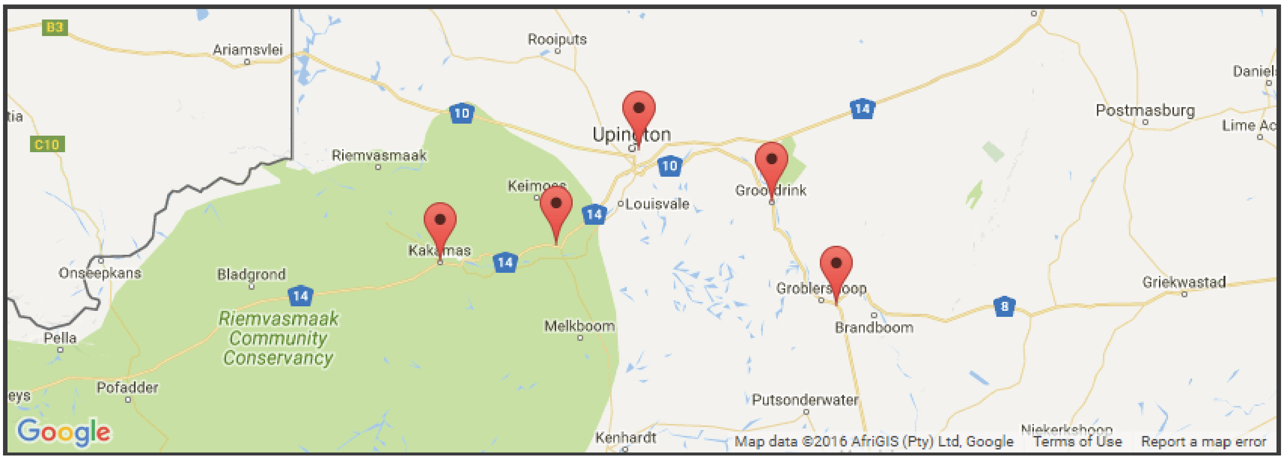

Figure 4: The figure shows the distribution of the OWK cellars.

From Figure 4, it can be seen that the wine cellars are located in a linear fashion since the cellars are located along the Orange River. Removing a cellar from such a linear distribution is more challenging than removing a cellar from a circular distribution of cellars because it is easier to accommodate the suppliers from a removed cellar in a circular distribution than with a linear distribution.

OWK offers the following wines: dry white, natural sweet, dry red, as well as dessert wines. The grapes used by OWK to produce the wine and juice originate from 750 grape farmers along the Orange River.

3.2 Current supply chain network

Figure 5 illustrates the relative distances between the various cellars.

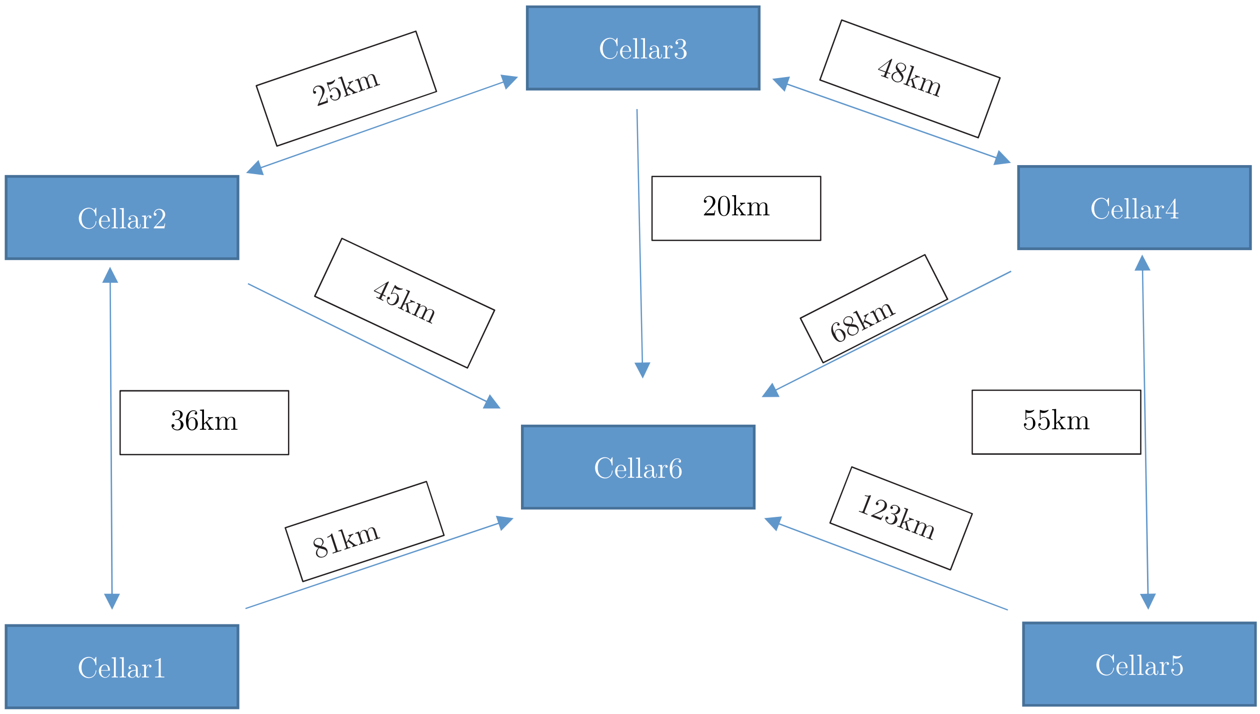

Figure 5: Diagram showing the distance of each cellar from Cellar6.

Cellar6 is the hub or central point of the cellars. This is because it is the head office and Cellar6 will be used as reference point in this subsection.

The cellars are distributed almost linearly along the Orange River. Each cellar is a grape receiving point for the vineyard that is located in that area. The grapes are then used to either make wine or juice at the various cellars. The wine or juice is then transported to Cellar6. The product is then either transported in bulk to the market or it is bottled and then transported to the market, depending on the request of the market. Table 8 depicts the different percentages of the different products that is produced at the different cellars.

Table 8 : Indication of the percentage of different products made at the different cellars

Cellar	% Good wine	% Juice	% Rebate wine	% Distilling wine
1	35	54	5	6
2	55	35	5	5
3	0	100	0	0
4	45	48	5	2
5	46	30	0	24
6	54	35	5	6

The mode of transport used to move the wine and juice between the cellars is by trucks. The trucks that are used are either tankers or interlinks. The tankers can move up to 32 500L per trip. The trucks are also used to transport wine to the different markets.

3.3 Wine production process

An overview of the winemaking process of the OWK cellars will now be provided. As stated in section 2.1.3, the general winemaking process is as follows: Harvesting, Crushing and Pressing, Fermentation, Clarification, and Ageing and Bottling. These processes will now be explained with the focus on the OWK cellars.

First, the grapes are harvested by the suppliers (farmers). Most of the vineyards in the Northern Cape are still being harvested by hand. This is because machine harvest is not possible since the trellis system used by the suppliers (farmers) does not cater for it. After the grapes are harvested, they are transported by the suppliers (farmers) to the different cellars.

At the cellar, the grapes are offloaded into large bins where the de-stemming of the grapes happens. The stems of the grapes are then treated as waste and are discarded. The pomace is then sent to the machines used for pressing. The different cellars use different machines for the pressing of the grapes. The different machines are: pneumatic ATI press, dejuicers, decanter, or static dejuicer.

The juice that will be used to make wine is then pumped to settling tanks. The rest of the pomace will be pressed again to obtain the rest of the juice. Juice obtained during the second pressing cycle will not be used for wine but will be sold as juice. The juice obtained during the second press will then be pumped to flotation tanks.

After the juice that will be used for wine has been filtered, it is pumped into the yeast tanks. The juice that will be sold as juice will be pumped into storage tanks after filtering, where it will be kept until it is sold.

When the juice that is meant for wine is in the yeast tanks, commercial yeast is added to aid the yeast process. The juice is kept in the yeast until the yeast process is over. This is when all the sugar is converted to alcohol.

Once the yeast process is over, the wine is pumped into storage tanks. The wine is kept in the storage tanks until it is sold. Before the sold wine is shipped off it is first filtered.
For a graphical illustration of the winemaking process of OWK see Appendix A.1.

3.4 Describing the supply chain model

The current supply chain model of the OWK cellars will be explained in detail in the following section. The supply chain is the same for all the cellars of OWK.

Figure 6 is a graphical representation of the mapping of the supply chain network for the OWK case study.

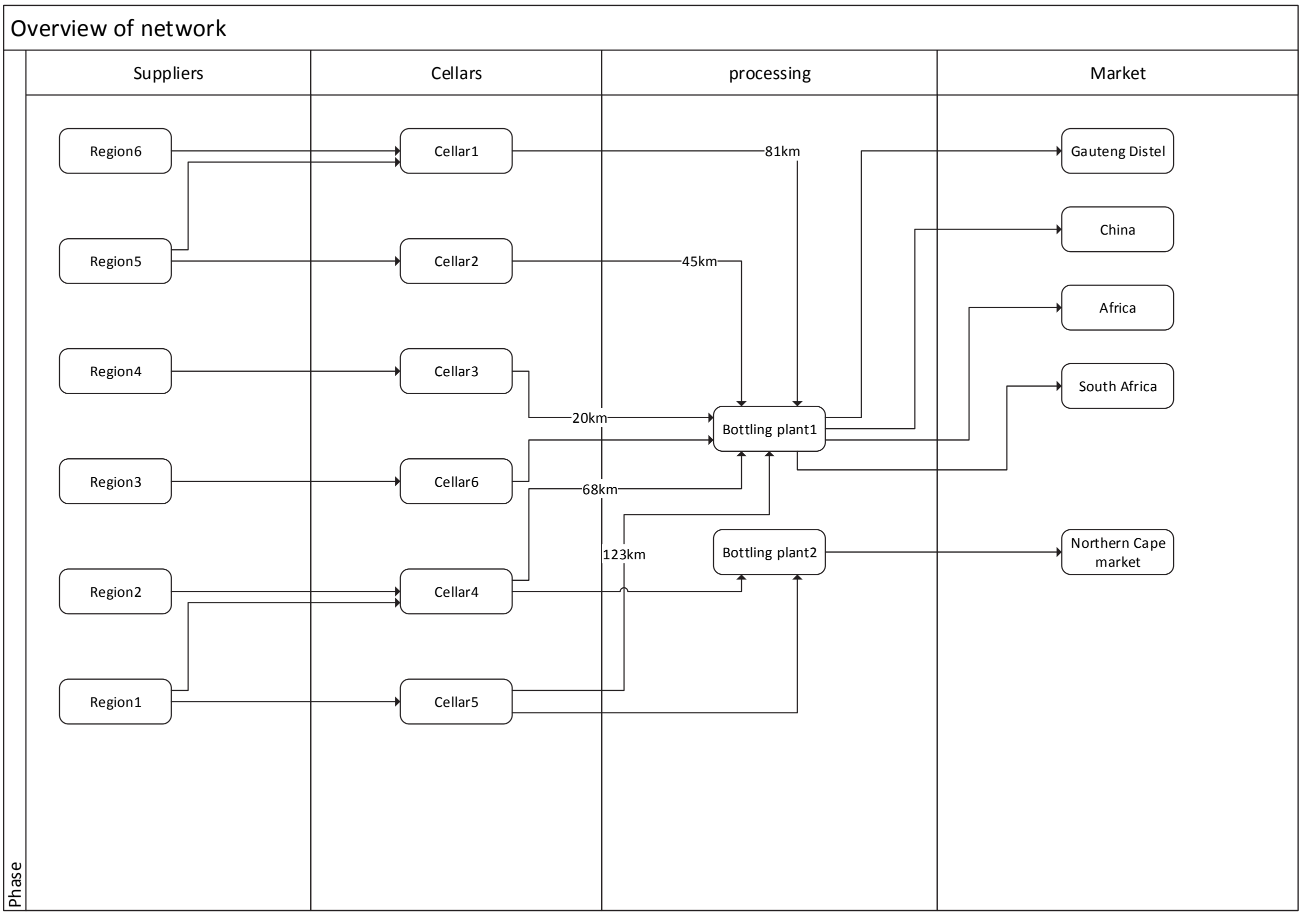

Figure 6: Overview of the supply chain network for the OWK case study.

The supply chain is an open, four echelon supply chain that consists of multiple products. All the different products travel the same path through the supply chain. Thus, it was decided that the different products will be seen as one unit, instead of being distinguished by type.

The raw materials (which are the grapes) that are used to make the different products are transported by the suppliers (the farmers) to the cellars. It is usually transported to the nearest cellar. For a supplier (farmer) to be able to deliver their grapes to the cellar they must have equity at that cellar. Each year, the supplier (farmer) can increase or decrease their equity at the cellar by buying or selling shares. Each cellar only has a certain amount of shares as it is linked to the capacity of the cellar. Currently, all the shares of the cellars are already owned by suppliers (farmers). This means that if a supplier (farmer) wants to increase or decrease their equity they have to find another supplier (farmer) who is willing to buy/sell some of their shares.

If a supplier (farmer) does not deliver the required amount of grapes, which is determined by the amount of equity owned by the supplier (farmer), a penalty fee must be paid. If the supplier (farmer) delivers more grapes than they are allowed, the same penalty principle applies. Exceptions may be made if the supplier (farmer) made the necessary arrangements beforehand by informing the cellar that more grapes will be delivered than initially arranged. If this is the case, then, depending on the amount of overdraft, the penalty fee may be waived or decreased.

Suppliers (farmers) of wine grapes can deliver the grapes at any of the cellars except Cellar3. This is because Cellar3 only produces juice. If a supplier (farmer) has grapes that are mainly used to make juice then they can only deliver the grapes to either Cellar1, Cellar3 or Cellar4, as those are the only cellars that have juice equity. This means that the suppliers (farmers) in the region of Cellar1 will deliver their juice grapes to Cellar1, the suppliers (farmers) in the region of Cellar2 and Cellar6 will deliver their juice grapes to Cellar3, and suppliers (farmers) in the region of Cellar4 and Cellar5 will deliver their juice grapes to Cellar4.

Suppliers (farmers) that are situated further than a certain distance from the nearest OWK cellar receive compensation from OWK. OWK compensates those suppliers (farmers) by paying them a certain rate (R/km/ton) for every kilometre travelled further than the prescribed distance.

Once the cellar receives the grapes, it is processed into either wine, juice, Rebate wine, or distilling wine. Depending on the product that was made and the cellar, the products are then transported to either Bottling plant1 or 2. This is because OWK has bottling plants at those two locations. Only PET wine is sent to Bottling plant2 to be bottled as Bottling plant2 only has equipment to bottle PET wine. Bottling plant2 is close to the Northern Cape PET market which makes the plant ideal from a logistics point of view. Bottling plant1 handles all the other bottled products, which consists of Bag in box wine, PET wine, and high quality bottled wine. Wine that is sold in bulk to other wine corporations such as Distell is also first sent to Bottling plant1. Currently, the PET wines of the two cellars that are the closest to Bottling plant2 are sent to Bottling plant2. These cellars are Cellar4 and Cellar5. The other cellar's PET wine is sent to Bottling plant1. Bottling plant1 is situated at Cellar6 and Bottling plant2 is situated at Hartswater which is 400km East of Cellar5.

The wine that is sold in bulk is stored at Bottling plant1 until the customers' request it and then it is sent to the customer. Wine that is used for bottled products is bottled at the customer's request and then shipped on the Just-in-Time (JIT) basis to the customers. The wine is handled on a first-in-first-out principle. This means that the wine that is either still in storage from last year or the wine that was received first during the harvest will first be either sent as bulk or for bottling.

OWK has customers all over South Africa, as well as in Africa and China. The suppliers (farmers) are responsible for transporting their grapes from their farms to the cellars. The transport used to move the products from the cellars through the entire supply chain until it is sent to the customer is the responsibility of OWK. For transport, they use a company called ORT (Oranje Rivier Tenkers) which is not part of OWK.

3.5 Summary

The purpose of this chapter was to give an insight into the case study that was used for this project. In this chapter the case study company was described by focusing on the background of the company, the current supply chain network of the company, the wine production process and a description of the supply chain model.

The next chapter will focus on the generic capacity planning framework that was developed. Each stage of the framework will be described as well as the required inputs and the outputs obtained at each stage.

Chapter 4 Capacity Planning Framework Development

A generic framework will be developed for supply network design and long-term capacity planning in the wine industry. In this chapter, the framework will be explained by briefly describing each process as well as inputs required and the outputs that were obtained by each process.

4.1 Framework development

The gap in the literature, an analysis of the OWK case study as well as informal interviews with SME's in the wine industry was used to develop the framework that will be explained in this chapter.

The framework that was developed is structured in such a way so that a deeper understanding of the current supply chain network is obtained after each stage. Each of the stages equipped the user to be able to determine financially the profitability of the cellars by incorporating the grapes it receives the amount of products it sold and the transportation cost. The product mix was also required to be used as well as the cost of buying the different grapes.

After the capacity capability of the cellars is know the capacity allocation needed to be determined. The next model that was developed determined the capacity to be allocated to each of the operational cellars. The yeast space is a crucial aspect that needed to be part of the model seeing that the capacity of the cellars is determined by the yeast space. The available supply of grapes in each region must be known as well as the available mode of transport and the capacity of each of the wine cellars. With this information the CPLM was developed which determined the most economical capacity allocation of the available supply. This model was also used to predict how the capacity should be allocated in the future.

If a cellar needs to be closed the best alternative should be determined using both qualitative and quantitative models. The quantitative models determine the best alternative from a financial point of view and the qualitative model from an emotional point of view. The main factors that will be affected if a cellar is relocated or closed was captured in the 2 models.

The framework along with the models is a tool that can be used by practitioners in the wine industry to assist with capacity planning as well as supply chain network design seeing that no such framework exists in the wine industry. The framework can also be adapted to provide answer to the different objectives for different case studies.

4.2 Framework Description

Figure 7 is a graphical illustration of the framework that was developed during this thesis.

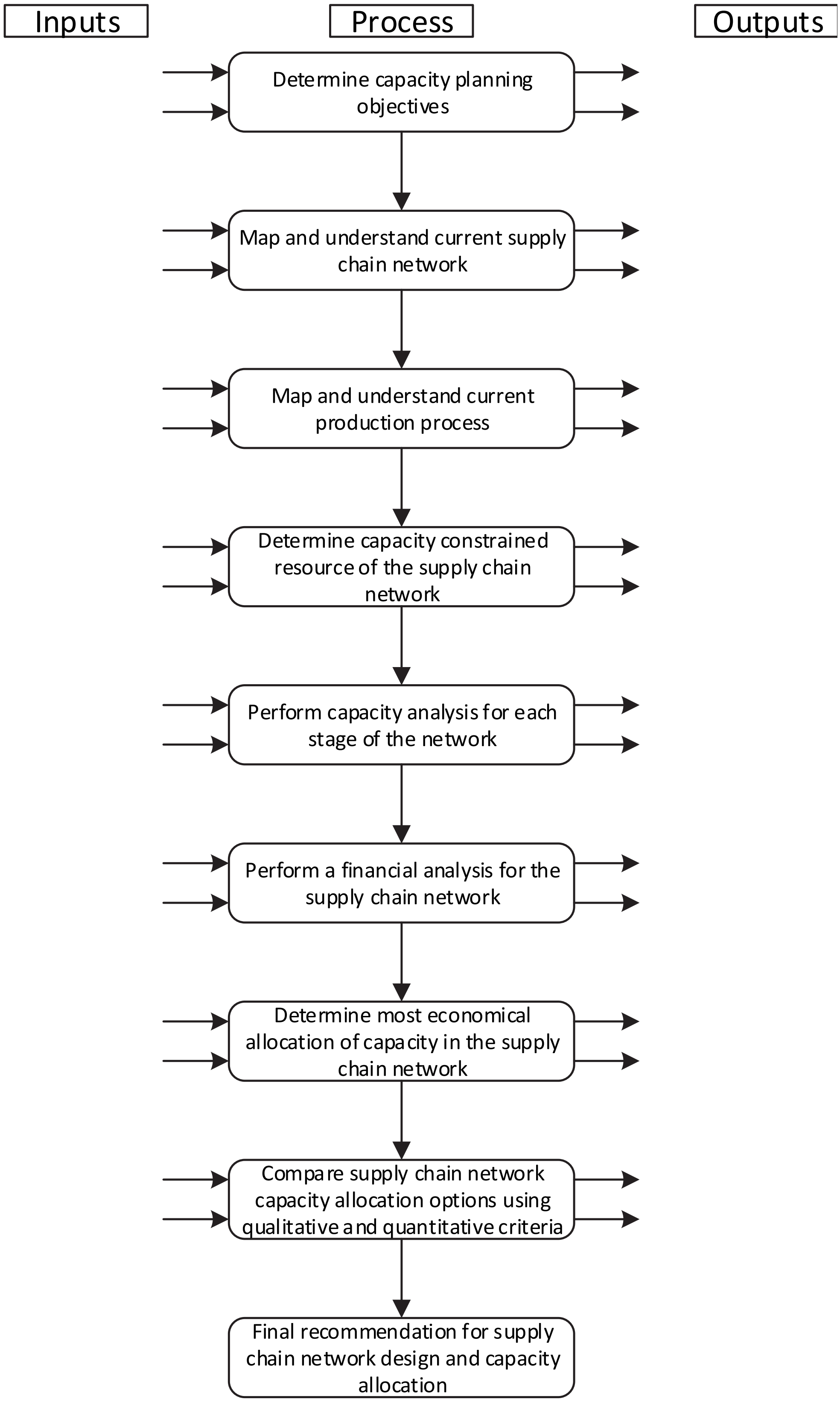

Figure 7: Indicates the flow of the framework that was developed.

4.3 Describing the processes of the framework

4.3.1 Determine capacity planning objectives

This process of the framework consists of determining the capacity objectives that need to be met. This process requires certain inputs which will be explained, as well as the outputs obtained by this process. The inputs required for this process is as follows:

- First a complete understanding of the current capacity planning process must be obtained.
- This understanding will be needed to identify the shortcomings that need to be addressed.
- Understand the strategic objectives of the organisation involved.
- Identify and understand the drivers/conditions that have an impact on the organisation and its current capacity.

The output of this process will be the following:

- A good understanding of the current capacity planning process of the organisation as well as a clear understanding of the goals of the organisation.
- Certain capacity planning objectives that can lead the investigation and can be used to measure the outcome to determine the success of the project.
- Understand the capacity drivers for the organisation.

4.3.2 Map and understand current supply chain network

The purpose of the process of mapping and understanding the current supply chain network is to understand how the supply chain network works, as well as the different role players in the supply chain network.

The inputs for this process are:

- Different SME's should be consulted to get a clear understanding of the current supply chain network.
- The different role players of the current supply chain network should also be identified.
- The supply chain network should also be understood and mapped for the different echelons that form the global supply chain network.

The outputs of the process are the following:

- A clear understanding of the current supply chain network.
- A graphical representation of the current supply chain network.
- The constraints of the current supply chain network will also be identified.

4.3.3 Map and understand current production process

The purpose for this process is to determine the constraint of the production process of the supply chain network. These constraints can then be used to identify the overall constraint of the supply chain network.

The following inputs are required for this process:

- Time should be spent at each production stage of every echelon of the supply chain network to get an understanding of every production process.
- Investigate the constraints that was identified in previous processes.

The output of the process is as follows:

- A good understanding of the production process along with a model of each of the production processes with the capacity capability of every stage.

4.3.4 Determine capacity constrained resources of the supply chain network

In this process, the capacity constrained resource in the supply chain network was identified. It is important to identify the constrained resource seeing that the production rate of each stage is determined by the rate of the constrained resource.

In the wine supply chain network, the capacity constrained resource is the yeast capacity of a cellar. This is because the yeast capacity determines the amount of wine a cellar can produce. Thus, it was decided to specify the size of a wine cellar according to its yeast space.

During the harvest the yeast tanks are used multiple times seeing that the yeast period of wine is less than the harvest period. With reference to the definition of capacity used in this project, as stated in 2.2, the optimal amount of yeast cycles is stated as 4. This is since 4 is the max amount of yeast cycles that can be achieved given the yeast period and harvest period.
Thus, the yeast space is determined by the yeast capacity times the yeast cycles.

The input data required for this process is the following:

- The model of each of the production processes that were developed in previous processes.
- Determine capacity capabilities of the equipment used in each stage of the supply chain network, as well as the capacity capability of every stage.

The output data is the following:

- Capacity constrained resource/equipment of every stage identified as well as maximum capacity capability of resource/equipment.

4.3.5 Perform capacity analysis for each stage of the network

In this stage, the capacity analysis for the supply chain network will be done. Different input data will be used to construct graphs to get a better understanding of the capacity capability of the different stages of the supply chain network.

The input data required for the graphs are as follows:

- The amount of grapes received by each cellar per week.
- Total capacity received by each cellar over a few years.
- Yeast space capacity per week.
- Change in hectares of cultivars over past few years.

The following graphs will be obtained as output:

- Graph of the rate of grapes received per week during harvest.
- Graph showing how yeast space capacity changes during harvest.
- Graph showing the change in the total amount of grapes received by the cellars over the past few years.
- Graph showing the change in the hectares of the different cultivars.

4.3.6 Perform financial analysis for the supply chain network

The financial analysis process consists of determining if the different facilities are still profitable as independent units by using the Profitability Model. This analysis can also be extended, if a cellar is deemed non-profitable, in order to determine possible reasons why it is not profitable by investigating the financial analysis.

The input data required for the financial analysis is as follows:

- The financial statements of each of the facilities need to be obtained.
- Selling as well as production price of the different products.
- Volume of each product sold.
- Transportation cost.
- Cost of buying raw material.
- Amount of raw material bought.

The output of the financial analysis will provide insight into which facilities are not profitable anymore. If the analysis is done thoroughly, possible reasons why the facility is not profitable can be derived.

4.3.7 Determine most economical allocation of capacity in the supply chain network

This process consists of using certain input data to determine the most economical allocation of capacity in the supply chain network.

The input data that is required is the following:

- The capacity of each of the facilities.
- The supply available to each of the facilities.
- Transport cost and capacity.
- Distances between facilities.

The output of the process is an indication of the most economical allocation of capacity by allocating the total supply between the facilities. If a facility is not needed in the supply chain network, it will also be indicated.

4.3.8 Compare supply chain network capacity allocation options using qualitative and quantitative criteria

This process is used to determine the best supply chain network capacity allocation option using certain qualitative and quantitative criteria. The input data required for the qualitative criteria will be obtained from Subject Matter Experts (SME) in the organisation. The input data required for the quantitative criteria will be obtained from the financial statements.

The input for this process is the following:

- The output of the feasibility process showing which facilities are financially unfeasible.
- Output from process of allocating capacity in the supply chain network.
- Alternatives stated by the organisation.
- The weighted qualitative effects of each alternative.
- The financial quantitative effects of each alternative

The output of the process will indicate the best alternative as indicated by the quantitative and qualitative models.

4.3.9 Final recommendation for supply chain network design and capacity allocation

This process will consist of providing insight to which cellar is not profitable anymore and what should happen to the non-profitable cellar. For this process the output of the Profitability Model and the CPLM will be used to determine which cellar is not- profitable anymore and the output of the Scenario

Decision Model and Weighted Decision Model will be used to determine what should happen to the non-profitable cellar.

4.4 Framework overview

Figure 8 is an illustration of an overview of how the models are used.

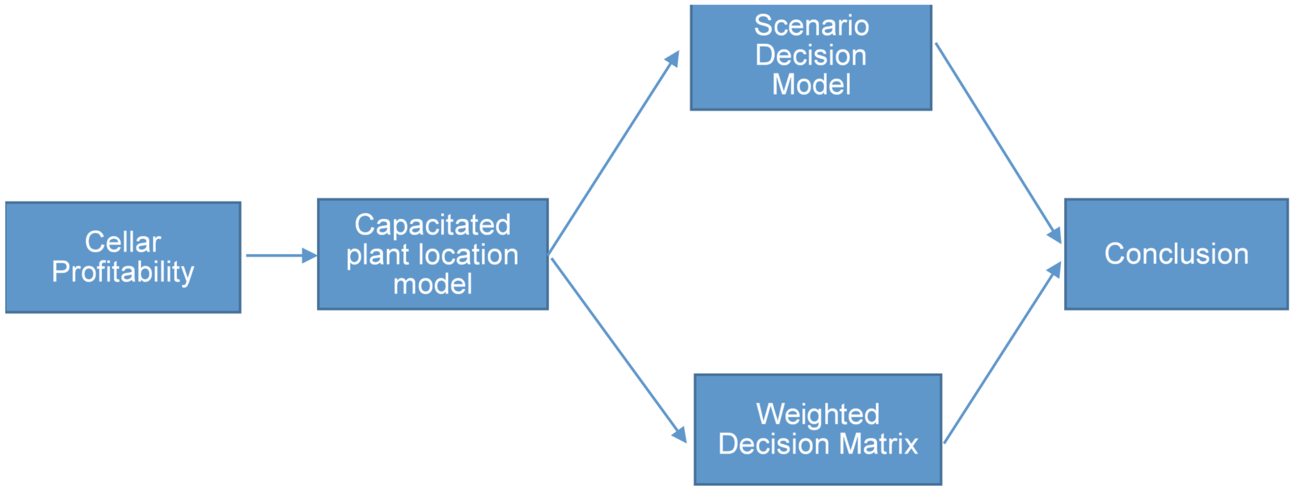

Figure 8: Overview of the models used in the framework.

This section represents an overview of the models used in the framework. First the cellar profitability is determined by using the Profitability Model that was developed. Next the most economical allocation of the available supply of grapes in the supply chain network is determined using the CPLM. The best alternative of what should happen to the cellar deemed as not being profitable is determined by the Scenario Decision Model and Weighted Decision Matrix.

4.5 Summary

In this chapter the generic framework that was developed was described in detail. The required inputs and outputs were described as well as a short description of what each stage entails. A graphical overview of the framework along with the models used in the framework was also provided.

In the next chapter the development of the different models that are required for the framework will be described. These models are the Profitability Model, the CPLM, the Scenario Decision Model and the Weighted Decision Matrix.

Chapter 5 Model development

In this chapter the development of the different models that are required for the framework will be described. These models are the Profitability Model, the CPLM, the Scenario Decision Model and the Weighted Decision Matrix. These models developed in this chapter will be the generic models that will be used with the generic framework that was stated in Chapter 4.

5.1 Profitability Model

This model requires more than just the financial status of the cellar to determine if the cellar is still profitable or not. This model uses financial inputs as well as capacity inputs of the cellar. The output of the model will mainly be based on the amount of grapes received by the cellar.

The main input data is the following: the income gained from selling the different products, namely: juice, bulk wine, processed wine, Rebate wine sold to Distell, Rebate wine sold to KWV, and distilling wine.

The other input data is the cost of producing the different products, which is inputted separately for each product seeing that each product has a different production cost. The cost of buying the different types of grapes from the suppliers (farmers) is also part of the input data. The cost of buying the grapes is formulated as follows: the grapes that are received from the supplier (farmer) are classified according to quality and there are 15 different types of quality ratings. For each quality rating, the supplier (farmer) receives a different compensation.

The volume of each of the products and the tons of grapes of each quality type received are also part of the required input data. The transport cost per kilometre, the distance of the cellar from Cellar6, the fixed cost of the cellar, and the amount of trips it takes to move the different products to the bottling plant, are all part of the input data.

There are also other data required as input to the Profitability Model. These data are the following:

- amount of juice yield from 1ton of grapes,
- the yeast space of the cellar,
- the time the harvest commences,
- the amount of cycles the yeast tanks are used in a harvest period,
- the amount of days of a yeast period,
- the total amount of grapes received during the harvest, and
- the total amount of wine storage space available at the cellar.

The objective function of the model determines if the cellar is still profitable. If the objective function is a negative value, it is an indication that the model is not profitable anymore and a positive value indicates that the cellar is still profitable.

The variables are defined as follow:

I_J = Income gained from one litre of juice sold
I_{BW} = Income gained from one litre of bulk wine sold
I_{PW} = Income gained from one litre of processed wine sold
I_{RWD} = Income gained from one litre of Rebate wine sold to Distell
I_{RWKWV} = Income gained from one litre of Rebate wine sold to KWV

I_{Dist}	= Income gained from one litre of distilling wine sold
C_J	= Cost of producing one litre of juice
C_{BW}	= Cost of producing one litre of bulk wine
C_{PW}	= Cost of producing one litre of processed wine
C_{RWD}	= Cost of producing one litre of Rebate wine for Distell
C_{RWKWV}	= Cost of producing one litre of Rebate wine for KWV
C_{Dist}	= Cost of producing one litre of distilling wine
V_J	= Total volume of juice currently produced
V_{BW}	= Total volume of bulk wine currently produced
V_{PW}	= Total volume of processed wine currently produced
V_{RWD}	= Total volume of Rebate wine currently produced for Distell
V_{RWKWV}	= Total volume of Rebate wine currently produced for KWV
V_{Dist}	= Total volume of distilling wine currently produced
$V_{storagespace}$	= Total wine storage space currently available at the cellar
$V_{yeastspace}$	= Total yeast space currently available at the cellar
d	= Distance from cellar to Upington cellar
L_1	= Transport cost per km
K	= Capacity of transport mode being used
Z	= Indicates the profitability of the cellar by illustrating a profit or a loss.
F	= Fixed cost of operating the specific cellar

(5) is the objective function which is formulated as follow:

$$Z = I_J V_J + I_{BW} V_{BW} + I_{PW} V_{PW} + I_{RWD} V_{RWD} + I_{RWKWV} V_{RWKWV} + I_{Dist} V_{Dist} - [C_J V_J + C_{BW} V_{BW} + C_{PW} V_{PW} + C_{RWD} V_{RWD} + C_{RWKWV} V_{RWKWV} + C_{Dist} V_{Dist} + L_1.d.\frac{V_J}{K} + L_1.d.\frac{V_{BW}}{K} + L_1.d.\frac{V_{PW}}{K} + L_1.d.\frac{V_{RWD}}{K} + L_1.d.\frac{V_{RWKWV}}{K} + L_1.d.\frac{V_{Dist}}{K} + F] \quad (5)$$

The objective function is a comparison between the income and the expenses of the cellar to determine if the cellar is still profitable from a financial point of view. The objective function is a summation of the major income factors of the cellar from the grapes. This is income gained from selling the different products made by the cellar. In this case study, the products are juice, processed wine, Rebate wine and distilling wine. The processed wine is bottled at the bottling plants but the income gained from selling the processed wine and the cost of producing it is for the cellar where the grapes were received and the wine was made. Other costs captured in the objective function are the cost of transporting the products to the processing plants or to the markets and the fixed cost of operating the specific cellar.

This Profitability Model can also be used as a planning tool. The output of the model indicated whether a facility is still profitable but also indicated how profitable it is. Thus, the model can be used to determine, if no changes are made to the facilities and supply chain, in what order the facilities will need to be closed down.

The model can further be used as a tool to identify factors and problem areas in the facility that might prevent the facility from performing according to its full financial potential. Factors such as if the facility/cellar is buying certain materials but is not using them to fullest potential.

A future prediction using the Profitability Model will not be possible seeing that there are too many variables in the model to account for. Figure 9 is a graphical representation of how the Profitability Model works.

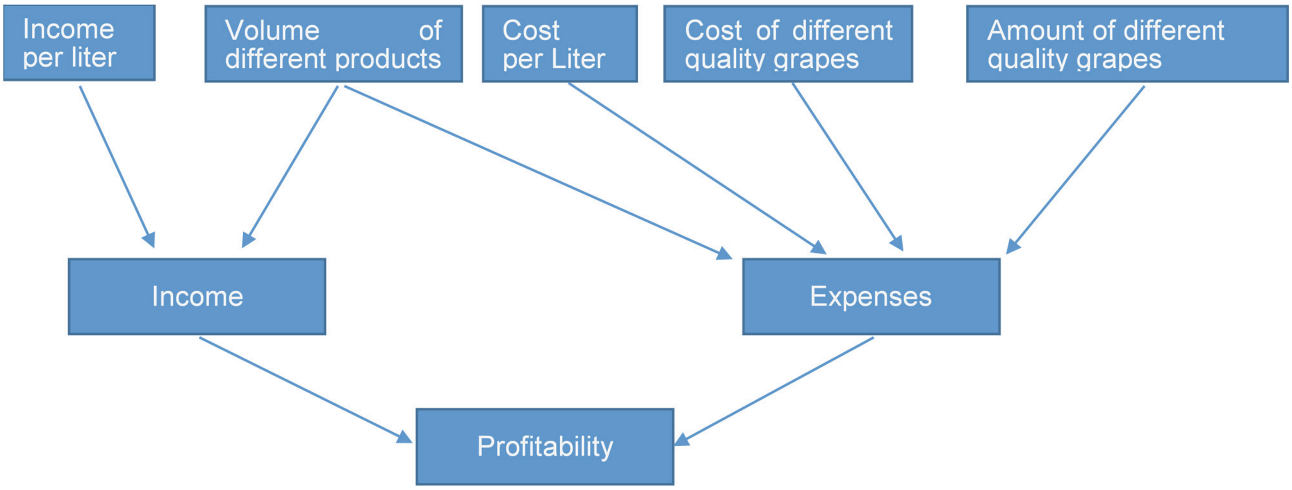

Figure 9: Graphical representation of the Profitability Model.

A detailed description of how the Profitability Model works can found in the Appendix C.

5.2 Capacitated Plant Location Model

The aim of the capacitated plant location model is to determine the most economical allocation of capacity to the current cellars in the supply chain network.

The Capacitated Plant Location Model (CPLM) that will be formulated will be able to accommodate various suppliers as well as various markets. The CPLM is supply driven since the amount of grapes supplied by the suppliers (farmers) is the determining factor for the amount of wine that can be made. This model is constructed to solve a four-echelon location problem since the OWK case study is a four-echelon location problem. This CPLM can easily be adjusted to solve a multi-echelon location problem consisting of either more or less than four-echelons.

For this model, the focus will be on the wine since the income from wine is more than from juice. Thus, Cellar3 will not form part of the Capacitated Plant Location Model seeing that it only produces juice. The yeast space will also be used to specify the capacity of the cellar seeing that the yeast process is the constraint in the winemaking process. It should also be noted that cellars only fill 85% of a yeast tank. This is to prevent spillage when the juice starts to yeast. Thus, the true capacity of a cellar can be determined as 85% of the total yeast capacity. Thus, the amount of grapes received by the cellars used as input for the model will only consist of the grapes used to make wine.

The supply chain is divided into three sections. Section one is the process of the suppliers (farmers) transporting their grapes to the different cellars. Section two is the process of the products made at each cellar being transported to the different bottling plants. Section three is the process of transporting the products from the Bottling plants to the different markets. For the OWK case study, all the PET wine that is bottled at the Bottling plant2 is sent to the Northern Cape market, which is mainly the Kuruman and Kimberley region.

The products at Bottling plant1 are sent to a wide variety of markets all over the globe. Bulk wine is mainly sent to the Distell branch in Gauteng while the other processed wine is sent to a Chinese market, an African market, as well as different markets in South Africa.

5.2.1 Suppliers to cellars

Section of the supply chain, the transportation cost was determined using the formula of (6):

$$\text{Cost1} = (P)(d1_{ij})(t_{ij}) \quad \textbf{(6)}$$

P = The price per km per ton paid by wine cellar to the supplier (farmer)
$d1_{ij}$ = Distance travelled from supplier (farmer) "i" to cellar "j"
t_{ij} = Ton of grapes transported from supplier (farmer) "i" to cellar "j"

The fixed cost for the first echelon is the fixed cost of operating the different cellars and the capacity is the yeast capacity of the different cellars. The yeast process is a crucial part of the winemaking process and it is the bottleneck in most of the wine production systems.

Companies usually have a minimum and maximum distance within which the suppliers can claim compensation for travel costs. The distances and compensation are determined by the company. For this framework, the distance represented by the variable $d1_{ij}$ is the distance travelled further than the minimum distance set by the company within which a supplier can claim compensation.

In the OWK case study, there is a predetermined price paid to the supplier (farmer) who has to travel further than a certain distance to supply their grapes to the nearest cellar.

For the OWK case study, the suppliers (farmers) have to supply their grapes to the cellar where they have shares. This means that farmers in a certain region are only allowed to supply their grapes to the cellar that is in that region. Thus, the transport cost from the suppliers (farmers) to cellars in other regions will be zero, seeing that the suppliers (farmers) will not be supplying grapes to the cellars in other regions.

5.2.2 Cellars to bottling plants

For the second section of the supply chain, the transportation cost was determined using the formula of (7):

$$\text{Cost2} = \left(\frac{e_{js}}{K}\right)(L_1)(d2_{js}) \quad \textbf{(7)}$$

e_{js} = Amount of product transported from cellar "j" to production plant "s"
K = Capacity of transport mode being used
L_1 = Transport cost per km
$d2_{js}$ = Distance from cellar "j" to production plant "s"
$\left(\frac{e_{js}}{K}\right)$ = Integer

In the second section, the fixed cost consists of the fixed costs of the production plants and the capacity consists of the capacity that can be handled by the production plants.

The model makes provision for a supply chain network consisting of more than two production plants but, in the OWK case study, there are only two production plants hence the rest of the matrix is a null matrix. The model is structured in such a way that PET wine can be transported from any cellar to Bottling plant2.

5.2.3 Bottling plants to market

The last section of the supply chain is where the products are transported from the production plants to the different markets. For overseas markets, the transportation cost only consists of the cost of transporting the products from the production plants to the harbour from where it is exported. This is because the model focuses on locating facilities in only one country. This means that the sea freight cost of transporting the products from the harbour to the overseas market is not taken into account. The amount of bottled products being transported to the market is usually expressed as the number of pallets sent. With this in mind, the amount of bottled products transported to the different markets in the framework is also expressed as the number of pallets. However, the framework can easily be modified if the products that are being transported to the markets use a different quantity scale. The framework is also constructed in such a way that the user should provide the volume of the pallets used. This function is added to incorporate different pallet sizes used by different companies. The transport size is also specified as the amount of pallets that can be transported per shipment.

For the OWK case study, the distance to the different South African markets as well as the volume transported to them are separated per different South African market. To determine the transportation cost for the South African market, the transportation costs for the different South African markets are added together.

(8) is the formula for the transportation cost for section three of the supply chain:

$$\text{Cost3} = (L_2)(d3_{sm})(T_{sm}) \quad \textbf{(8)}$$

L_2 = Transport cost per km

$d3_{sm}$ = Distance from production plant "s" to market "m"

T_{sm} = Number of trips to move product from production plant "s" to market "m"

(9) is the number of trips that is determined as follows:

$$T_{sm} = \frac{\textbf{\# of pallets of product that needs to be transported from production plant "s" to market "m"}}{\textbf{\textit{number of products that can be transported per trip}}} \quad \textbf{(9)}$$

(10) is the number of pallets of product that needs to be transported from production plant "s" to market "m" which was determined as follows. (Let denote the number of pallets of product that needs to be transported from production plant "s" to market "m" as Q just for this explanation.)

$$Q = \frac{\textbf{\textit{Volume of product that needs to be transported from production plants to market "m"}}}{\textbf{\textit{Volume of 1 pallet}}} \quad \textbf{(10)}$$

Seeing that the main purpose of this project is to determine the optimal number of cellars, the transportation cost associated with the position of the cellars needs to be minimised. Thus, the total transportation cost for this type of supply chain network model can be determined by adding together the transportation cost of the first two sections of the supply chain. The total fixed cost of the supply chain is obtained by adding the fixed cost of the cellars as well as the production plants.

To be able to solve the model using the Excel tool solver, certain inputs are needed from the user. These inputs will be described for all three sections of the supply chain. For the first section, the cost per km that is paid by the cellar to the suppliers must be provided by the user as well as the minimum within which the incentive is paid. The table of the distances between the different cellars should also be completed by the user.

For the second section, the cost per km paid to transport the wine/juice from the cellars to the production facility must be provided by the user, as well as the capacity of the transport mode used. The capacity should be specified in tons. The distance from the cellar to the different production plants should also be specified by the user.

For the third section, the cost per km paid to transport the different products to the different markets must be supplied by the user. For the processed products, the volume per pallet as well as the number of pallets that are transported per trip must also be specified by the user. The distance between the production facilities and the markets must also be specified. For the markets situated outside the South African border only the distance from the production facility to the harbour or border post needs to be specified.

5.2.4 Solving the models

This Capacitated Plant Location problem will be solved using the Excel tool called Solver. The objective will be to minimise the overall transportation cost of the supply chain network. There are, however, certain constraints that must be met. These constraints are that all the grapes received by a cellar must be used for either juice or wine and that the total demand of the supply chain network must be met.

For the Excel Solver software to work, certain inputs are required and these inputs will be described in the following paragraphs. First, the cell containing the objective function must be provided so that the software knows which cell to optimize. Then, the software must be told whether the objective function must be minimized, maximized, or equal to a certain value. Next, the table that indicates the amount of wine/juice which should be produced and at which cellar, must be inputted into Solver. This value will be in 1000 units.

The following inputs are the constraints which are needed for the model to work. For the OWK case study, Cellar1, Cellar2 and Cellar6 must be open so they are set to 1, which indicates that the cellars are open. The next constraint is that the amount of product produced at each cellar must be greater or equal to zero. The demand constraint that is added ensures that all the demand is met at the different cellars. Another constraint that is also usually applicable to Capacitated Plant Location Models is the capacity constraint. This constraint ensures that a facility/cellar cannot receive more products than its available capacity.

The amount of grapes that are available in each of the six regions where OWK have cellars must also be provided as input data. This information is used to ensure that the amount of grapes assigned to the cellars does not exceed the amount of grapes available.

The utilization of the yeast space that is determined in this model is the utilization for the entire harvest (3 months). From Figure 10 it is clear that that the peak for the yeast space for all the cellars are during the same period of the harvest. This is because all the cellars harvest the same type of grapes and most of the grapes received are Colombard and Chenin Blanc.

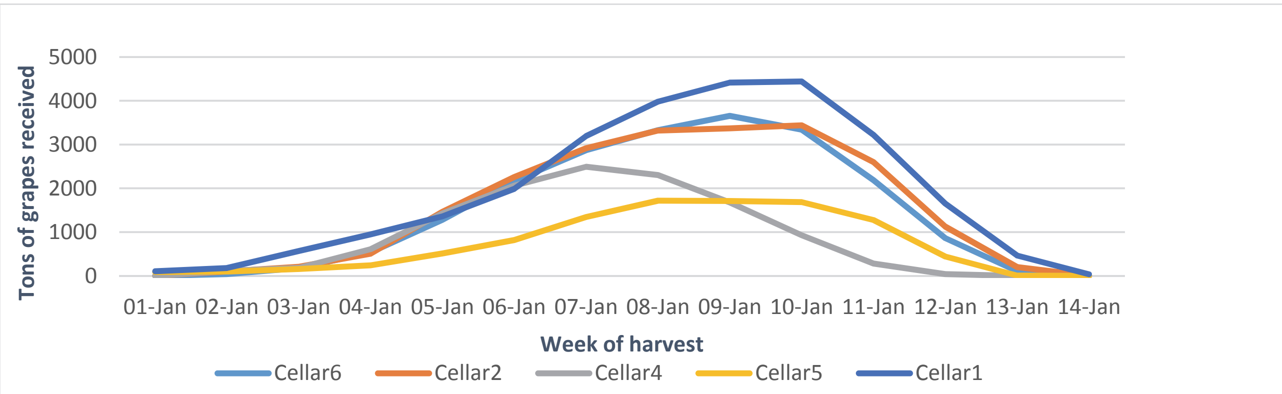

Figure 10 : Capacity of yeast tanks of all the wine cellars.

Solver cannot solve section one and two at the same time. Thus, section one will first be solved and the output of section one will then be used as input for section two. With the input data gained from solving section one, section two will then be solved.
The total cost will be determined by summing the cost of section one and section two.

5.3 Scenario Decision Model

The main purpose of the Scenario Decision Model is to determine from a cost point of view which alternative will be the best one to choose. The best decision will be the alternative that has the least cost. The costs of each scenario are an indication of what it will cost if that alternative is chosen. The model that was built is a generic model that is applied to all the different alternatives, which means that the model will have some criteria not applicable to certain alternatives. In such a case, that criteria will receive a zero cost.

The Scenario Decision Model consists of three main categories. In some of the alternatives, the option might be to close down all the activities of the cellar. It must be noted that when this happens, the cost of the cellar will not be zero as there are still basic costs that need to be paid seeing that the cellar remains the property of the cooperative. Such costs include insurance, depreciation, and basic maintenance of the building.

The cost categories of the Scenario Decision Model are:

- Cellar direct cost
- Infrastructure cost
- Transport cost.

The cellar direct cost is all the expenses directly related to the cellar.

The infrastructure cost is the cost to upgrade the current equipment and buildings at the other cellars so that those cellars can accommodate the excess capacity. The other infrastructure cost is the cost to increase the winemaking capacity at the other cellars so that the other cellars can accommodate the excess capacity.

The transport cost is the cost of transporting the grapes to the cellar where they need to be processed or the cost to transport the wine or juice to the production facility or other cellars, if needed. The cellar direct cost consists of the following sub-costs: administrative cost, personnel cost, security, water and electricity and maintenance costs. Each of these costs will briefly be described in the following paragraphs.

The administrative cost is comprised of insurance cost and depreciation of the cellar. The insurance cost is the monthly cost paid to ensure the equipment and the building. For the scenarios where the cellar needs to be closed down there will still be insurance cost since the cellar remains the property of the cooperative although it is no longer operational. As in the case of insurance, depreciation will also still be a factor that needs to be accounted for even if the cellar is closed down since it stays the property of the cooperative.

The personnel cost consists of the cost of all the employees that are employed at the cellar. If the cellar is closed down, the personnel cost will reduce significantly since only the very basic employees will be kept employed. Employees such as the administrative personnel, cellar management, winemakers, etc. will not be needed if the cellar is closed down. If the cellar is kept operational to deliver certain services, only those employees needed to deliver those services will be employed.

Security cost is the cost paid to security companies to watch over the cellar to ensure it is not broken into or vandalised. Whether the cellar is open or closed, there will be a security cost since the cellar stays the property of the corporation. The security cost will vary depending on whether the cellar is open or closed. If the cellar is operational, the security is there to ensure the buildings are safe and that the products are not stolen.

Water and electricity costs are the costs of the water and electricity used at the cellar when it is operational. When the cellar is closed down, the electricity connection fee and water access fee will still have to be paid.

Maintenance cost is all the maintenance that is done to the buildings and equipment. This cost will vary but will also not be zero as the cellar will be maintained since it is still the property of the corporation. If the cellar operates as usual, the maintenance cost will be high but if the cellar is closed down, only basic maintenance will be done to the buildings. If only part of the cellar is used, then that part's maintenance will be high but the rest of the cellar's maintenance will be lower.

The infrastructure section entails the cost incurred due to equipment changes for each of the different alternatives. The infrastructure section consists of mainly two sections. These sections are the cost of upgrading the current equipment and the cost of adding equipment to the cellars which has to accommodate the volume of the cellar that was closed.

If the cellar can be upgraded to accommodate the extra volume, then it is not needed to increase the yeast capacity, so in the model the cost of increasing the yeast capacity will be zero. The cost of upgrading the cellar mainly consists of infrastructure changes so that the current equipment that is available at the cellar can be better utilized. However, if the yeast capacity needs to be increased, change to the infrastructure will have to be made and in some cases the amount of other winemaking equipment might also need to be increased. So, if the yeast capacity needs to be increased, this part of the cost of the section will consist of the infrastructure upgrading cost as well as the cost of increasing the capacity of the other winemaking equipment. If the CPLM indicated that the supply of a cellar needs to increase it must be determined if the yeast capacity must also increase. If the yeast capacity needs to increase it must be determined if the other equipment can accommodate the extra supply. The ratio of yeast space to storage capacity is (1: number of yeast cycles). It should be ensured that if yeast space is increased at a cellar that the storage space is enough by using the ratio. If the bottleneck is moved from the yeast tanks to the other equipment the cost of upgrading the equipment must be determined. The upgrading cost of the other equipment will form part of the cost of upgrading the cellar.

For the equipment expansion cost, the cost of buying new equipment is compared to the cost of relocating the equipment of the cellar that was closed. The scenario resulting in the lowest cost will then be chosen. Before the comparison is made, the equipment of the cellar that is to be closed should be inspected to determine the lifetime of the equipment. If the lifetime of certain equipment is less than the minimum period defined by the company that equipment will not be moved as it will not be feasible. If equipment is relocated to other cellars, it must be used for a certain period so that the cost of moving it is justified. If the lifetime of the equipment is not satisfactory, new equipment should be bought instead of relocating the old equipment.

The transport section consists of the transporting cost of the raw material to the cellars and the transporting cost of the products to either different cellars or to the production facility.
This cost will differ for each of the alternatives because the one alternative might state that the farmers are responsible for transporting their grapes to the other cellars if the one cellar is closed and then an

incentive must be paid to the farmers. In another alternative, the cellar might take responsibility for transporting the grapes to the other cellars. For each of these two alternatives, the transporting cost will be different. A detailed description of the Scenario Decision Model can be seen in Figure 11.

Cellar direct cost		R 8,338,686
Admin	R 956,098	
Insurance	R 193,139	
Depreciation	R 762,960	
Personel	R 3,987,258	
Security	R 474,172	
Water and electricity	R 1,150,498	
Maintenance	R 1,770,660	

Infrastructure of other cellars accomodating the extra supply			0
Cost of upgrading other cellar that has to accommodate the extra capacity	0		
Expansion(moved closed cellar equipment or buy new equipment)			
Move existing equipment from cellar	0	Buy new equipment	0
Transport cost	0	Transport cost	0
Installation cost	0	Installation cost	0
	0		0

Transport		R 2,691,755
Grapes		
Wine/juice	R2,691,755	

Total cost	R 11,030,441

Figure 11: Illustration of the Scenario Decision Model.

5.4 Weighted Decision Matrix

Different qualitative models were researched and compared to see which one was the best suitable for this specific project. The models that were researched were the AHP method, the weighted decision matrix, and the Pugh matrix.

The AHP mainly uses pairwise comparisons where different decision criteria are compared in order to obtain the weights of importance of the different criteria. The pairwise comparison is used to indicate the relevance/importance of the decision criteria being compared. It is also very important that the comparisons are perfectly consistent for the matrix and AHP model to function properly. The AHP is used when decision criteria that are being used have a direct effect on each other and when the decision criteria are related to each other. Table 9 is the comparison matrix of the textbook example being used to indicate how the decision criteria are related in AHP. In the example the person have to decide on a job based on the criteria that is important to the person. The criteria that is used is as follow:

- The importance of a good salary
- The importance of a good life quality
- The importance of having an interesting job
- The importance of being close to the person's friends

The example used in Table 9 indicates that for the person used in the example quality of life is 5 times more important than the sallry paid by a job and being near to friends is 4 times more important to than person than the salary of the job. The quality of the life of the person is also 2 times more important than having an interesting job.

Table 9: Comparison matrix of the textbook example indicating how the decision criteria are related in AHP (Winston, 2004).

	SALARY	QUALITY LIFE	INTERESTING WORK	NEAR FRIENDS
SALARY	1	5	2	4
QUALITY LIFE	1/5	1	½	½
INTERESTING WORK	½	2	1	2
NEAR FRIENDS	¼	2	½	1

The Pugh Matrix is, to a certain extent, similar to the weighted decision matrix. The Pugh Matrix is used when there are a lot of decision criteria that needs to be evaluated before making a decision. With the Pugh Matrix, one alternative is chosen as the baseline and all the other alternatives are then compared to that baseline. Unlike the case with the AHP, the decision criteria in the Pugh Matrix are not related to each other and they don't have any correlation to each other. Unlike in the case of the weighted decision matrix, the Pugh Matrix does not assign weights to the decision criteria to indicate the importance of the decision criteria. The Pugh Matrix could also have been used for the OWK case study, however, there are not a lot of decision criteria that have to be taken into account when evaluating the different alternatives.

The Weighted Decision Matrix (WDM) is a good technique to use when certain decisions need to be made. Decisions that require choosing between good alternatives while taking into account a number of different decision criteria need to be considered. Unlike in the case of the AHP, the decision criteria in the WDM do not have an impact on each other. This means that the importance of one decision criteria has no effect on the importance of the other decision criteria. The WDM allows the user to make a fast, confident, and rational decision when the alternative for the specific scenario is not clear.

In conclusion, it was decided to use the Weighted Decision Matrix for the qualitative model for this framework since it is the most applicable to the OWK case study, but the other qualitative models can be used instead of the weighted decision matrix for other case studies.

The Weighted Decision Matrix model that was built for the OWK case study consists of four main categories. These categories are: the effect on the people, the financial effect, the effect on the products, and the effect on the infrastructure. Each of these categories consists of different elements which are the following decision criteria: the category "people" is built-up of the decision criteria elements of suppliers, employees, and community. The category "finance" only consists of the decision criteria network cost, the category "product" is built-up of the decision criteria product range and product quality. The category "infrastructure" is built-up of the decision criteria transport infrastructure and cellar infrastructure.

The scale that was used was a numerical 1-5 scale with 3 being no effect or neutral effect, 2 being slightly negative effect and 1 being mostly negative effect. To the other side of the scale, 4 will represent a slightly positive effect and 5 will represent a mostly positive effect. For example, the unemployment effect of the scenario where the cellar operates as always will be 3 since no-one will be let go. The unemployment effect of the scenario where the cellar is closed down will be 1 since all the employees will be let go as there will not be any work for them.

The category "people" consists of the effect that the different alternatives will have on the human factor of the cellars. Whether it is the effect on the supplier or the community where the cellar is located, the fate of the cellar affects them all. The decision criteria elements of the people category will be described in detail in the following paragraphs.

The decision criteria "supplier" is the effect that the different alternatives will have on the suppliers. For example, if the cellar operates as usual there will be no significant effect on the suppliers because they can still deliver their grapes to the cellar, as usual. However, if the cellar closes, the effects will be 1 due to the fact that the suppliers will no longer be able to deliver their grapes to the cellar. This in return means that they will have to travel farther to deliver their grapes to the next cellar. This may cause some of the suppliers to replace their vineyards with another type of crop.

The decision criteria "employee" is the effect that the different alternatives will have on the employees who work at the cellar. For example, if the cellar operates as usual there will be no effect on the employees as they still have their jobs at the cellar. If the cellar needs to be closed the employees will need to be let go since there will not be any work for them to do at the cellar, so the effect will be 1.

The decision criteria "community" entails the effect that the different alternatives will have on the community where the cellar is situated. In some of the cases, the cellar might have an important impact on the economy of the community. This will be the case where it creates work for the people and is responsible for a large source of income to the community. If the cellar is closed, it will result in a lot of unemployment of the community and a negative effect on the economy of the community.
For example, if the cellar operates as usual the effect on the community will be neutral since the employees will work as usual. In the case of the cellar being closed, the effect will be 1 since the employees will no longer work at the cellar so the community will have large unemployment. In some cases, such as Cellar4 and Cellar5, if one of those cellars is closed some of the employees might be offered a job at the cellar that is still operational. This is because those cellars are relatively close to each other.

The category "finance" consists of the financial effect of the different alternatives but more specifically the effect on the network cost. The decision criteria "network cost" consists of the effect the different alternatives will have on the overall cost of the network. For instance, if the cellar operates as usual there will be no change in the network cost so the effect will be neutral (3). If the cellar is closed there will be an increase in the network cost since the grapes have to be transported further to the next cellar. Irrespectively of whether the grapes are transported by the suppliers or by a tanker service, the grapes still have to be transported and will increase the network cost. However, if the grapes are transported to the next cellar by the supplier the increase in the network cost will be less than if they are transported by a tanker service.

The category "product" consists of the effect that the different alternatives will have on the products. The decision criteria "product range" entails what the effect will be on the product range which is produced by that cellar if that cellar is closed and the equipment moved to another cellar. The decision criteria "product quality" depicts the effect of the different alternatives on the quality of wine. There are different factors that determine the quality of wine such as the temperature at which the grapes are received and the time from harvesting until they are received by the cellar. For example, if the cellar operates as usual, the effect on the product quality will be neutral. If the cellar is closed and the grapes have to be transported to other cellars, the product quality might go down since the grapes might be received at a higher temperature because they had to be transported further.

The last category is the "infrastructure" category. This category provides the effect that the different alternatives will have on the infrastructure of the transport network as well as the cellar. The decision criteria “transport infrastructure” is the effect that the different alternatives will have on the transport infrastructure. The transport infrastructure is the modes used to transport the grapes to the cellars and the products from the cellar to the production facility. The transport infrastructure mainly consists of the roads used to access the cellar and the production facility. For instance, if more capacity needs to be transported to a certain cellar, then that will result in a higher traffic load on the roads which will have a negative effect on the transport infrastructure. If the cellar operates as usual the effect on the transport infrastructure will be neutral.

The decision criteria “cellar infrastructure” looks at the effect of the different alternatives on the rest of the cellars. The focus is mainly on whether the cellars can accommodate the capacity that might be allocated to it.

For the weights assigned to each of the decision criteria, the same scale was used. Thus, for unemployment a weight of 3 will mean that it is quite important to OWK that employees don’t lose their jobs. For the decision criteria “the negative effect on the wine production volume of the network”, the importance value will for example be 5. This is because it is very important that the wine production volume of the network does not decrease.

This section focuses on the models that were developed for this project as well as how each model works. The assumption that was made in order to develop the models was also stated in this section.
The next section will focus on the validation and verification of the models that was developed in the previous section.

5.5 Verification of the models

According to RG Sargent(2013) model verification can be defined as a method of ensuring that the program of the model is correct as well as the implementation of it. In more plain terms verification of a model means to ensure that the model was build correctly.

Verification of computer models beg the question of whether the model is implemented correctly into the computer. Typical questions that can be asked is whether the input parameters and logical structure are correctly represented in the model that was built.

5.5.1 Verification of the Profitability Model

The Profitability Model was verified with the help of the chief production manager and the production manager at OWK.

The Profitability model was verified by using data from Cellar2 and Cellar4 of OWK. The data of the cellar was inputted into the model and then the output of the model was compared to the financial report of the cellar. The output of the model corresponded with the financial statement report.

Cellar2 income statement

Table 10 is an extract of the income statement of Cellar2. It should be noted that these values are not the actual values of the income statement of Cellar2 as it is multiplied by a certain factor. This is done for ethical and confidential reasons.

Table 10: Extract of the income statement of Cellar2.

Direct costs	
Insurance	R 221 357
Marketing	R 62 397
Vehicle maintenance	R 290 517
Transport cost	R 6 443 040
Cost of buying grapes	R 83 419 854

Figure 12 is a representation of the output of the Profitability Model of Cellar2. The values that were compared to the income statement of Cellar2 are the transport cost and the cost of buying grapes from the suppliers.

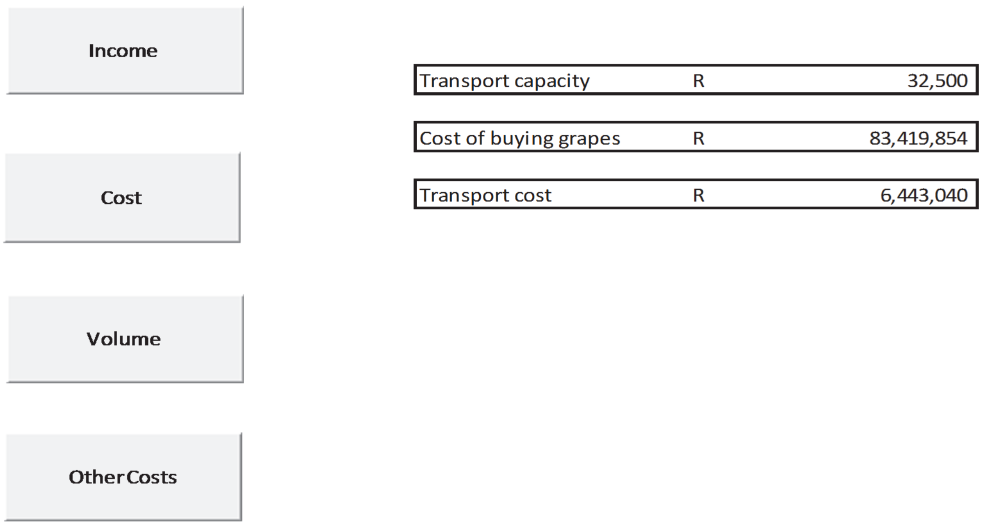

Figure 12: Output of the Profitability model of Cellar2.

Cellar4 income statement

Table 11 is an extract of the income statement of Cellar4. It should be noted that these values are not the actual values of the income statement of Cellar4 as they are multiplied by a certain factor. This is done for ethical and confidential reasons.

Direct costs	
Insurance	R 98 571
Marketing	R 929 603
Vehicle maintenance	R 309 163
Transport cost	R 680 162
Cost of buying grapes	R 56 500 432

Table 11: Extract of the income statement of Cellar4.

Figure 13 is a representation of the output of the profitability Model of Cellar4. The values that were compared to the income statement of Cellar4 are the transport cost and the cost of buying grapes from the suppliers.

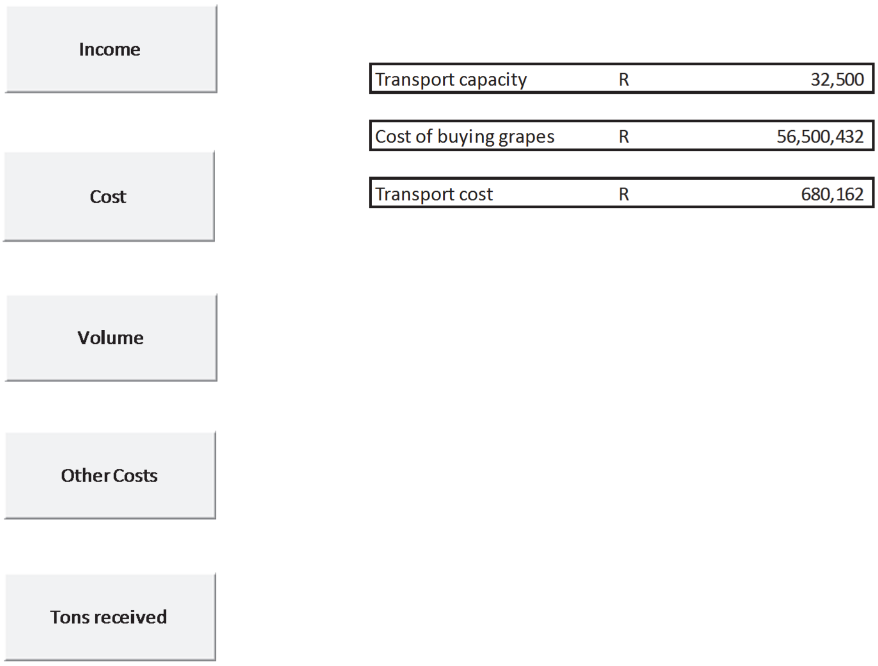

Figure 13: Output of the Feasibility model of Cellar4.

5.5.2 Verification of the Capacitated Plant Location Model

The Capacitated Plant Location Model is used in this framework to determine if all the cellars are still profitable from a location point of view. By using the location of each of the cellars as well as the capacity and fixed cost, this model determines if all the cellars are still optimally located. This Capacitated Plant Location Model is an extension of the commonly known Capacitated Plant Location Model. This is because, if a cellar is non-profitable, this model will indicate to which of the other cellars the capacity needs to be transported. This model is also able to indicate, if a cellar needs to be expanded, which cellar needs to be expanded and by what capacity.

The verification of the Capacitated Plant Location Model was done by using the volume transported by the different cellars to the production plant as input. The cost of transporting the volume from the cellars to the production plants were then compared to the financial statements received from OWK.

For the verification of the CPLM, the second section of the CPLM is used. This is because section one of the CPLM consists of the transportation cost that is paid as compensation by OWK to the suppliers (farmers). The compensation is paid to suppliers (farmers) who have to transport their products further than the minimum distance as defined by OWK. Currently, the network structure of the cellars is in such a format that there is a cellar in every region where there are OWK suppliers (farmers). With this structure, the compensation paid by OWK to the suppliers (farmers) are minimal since almost all the suppliers (farmers) are situated within the minimum travelling range. This is the reason why the first section cannot be used to verify the CPLM.

5.5.3 Verification of Scenario Decision Model

The Scenario Decision Model that was built is a financial model that is used to compare the financial effect of the different alternatives. Depending on the output of the qualitative model, the alternative that has the lowest financial effect will be suggested.

For the OWK case study, there are four different alternatives that can be followed if the Capacitated Plant Location Model indicates that a cellar is not profitable anymore. One of the alternatives is that the cellar be kept open and operating as usual. This alternative will be used to verify the model since the financials of the cellars are available. Thus, the output data of the model can be compared to the financials of the cellar.

This model was verified by using actual information from one of the cellars of OWK as input for the model. The output of the model was then compared to the financial statement of the cellars whose information was used as input.

OWK has moved equipment in the past between cellars. That information was used to verify the infrastructure cost section of the model.

5.6 Validation of the models

According to RG Sargent (2013), model validation can be defined as the process of showing that the model that was built falls within the required range of accuracy described by the domain within which the model is applicable. In more simpler terms, model validations ensure that the model that was built was the correct model.

Validation of models is used to ensure that the model that was built is an accurate representation of the real-world system. Validation of a model is accomplished by calibrating the model. Calibrating a model consists of iteratively comparing the model that was built by an actual system or actual data.

For the validation of the models used in the framework, different SME's in the wine industry were consulted. They were all asked the same questions regarding the applicability of the different models. The feedback gathered from the SME's were analysed and the proposed alterations were done.

The first SME that was consulted works at a cellar in the Western Cape as Cellar Master. He studied winemaking at Elsenburg Agricultural College. After he finished his studies, he worked at three different cellars before he started to work at the current cellar. He has been Cellar Master at the current cellar for the past 19 years.

The second SME that was consulted also works at a cellar in the Western Cape as Cellar Master. He also studied winemaking at Elsenburg Agricultural College. After he completed his studies, he worked at one other cellar before starting at the current cellar. He has been at Brandvlei Cellar for 22 years. The third SME consulted is an engineer with a Master's degree in Industrial engineering. He studied at Stellenbosch University and after he completed his degree he started working as a consultant at a wine farm in the Western Cape.

The fourth SME that was consulted is the chief production manager at a cellar in the Northern Cape. He worked at three other wine corporations before working at the current wine corporation. He is now eight years at the current wine corporation.

The following sub-sections will contain the analysed feedback gathered from the different SME's regarding the different models. The following questions were asked to the SME's to validate the different models.

1. Do you believe there is a need in the wine industry for such a model?
2. Do you believe the model adequately captures the information required for facility relocation decisions?
3. Do you see any shortcomings or limitations in the model?
4. Do you believe this model can assist companies in decision making regarding capacity planning and facility relocation in the wine supply chain?
5. Are there any additional functionalities you would like to add to the model?

5.6.1 **Profitability Model**

Since the Profitability Model for all the cellars are the same model, it was not necessary to test the model of all the cellars. This is because, if the model supplies the correct output for one cellar, it will supply the correct output for all the cellars since the other feasibility models are simply duplications of the one that was tested.

The concept of the Profitability Model was also validated by getting SME's to provide their thoughts and insights about the model with the focus on the applicability of the model and the usefulness of the output of the Profitability Model. Table 12 is an indication of the feedback that was obtained by the SME's. If the SME's agreed with the question no explanation will be given. However, questions to which an SME disagree will be explained. The reason why the SME disagree will be explained in more detail.

Table 12: Feedback of the SME's regarding the validation of the Profitability Model.

Questions	SME1	SME2	SME3	SME4
1	Yes	Yes	Yes	Yes
2	Yes	Yes	Yes	Yes
3	Yes	No	No	No
4	Yes	Yes	Yes	Yes
5	No	No	No	No

The first SME that was consulted suggested that a detailed representation of the harvest should be added to the model as it would be beneficial. This representation would entail the amount of grapes received during every week of the harvest. The other SME's that were consulted was satisfied with the Profitability model and did not have any suggested changes.

5.6.2 Capacitated Plant Model

The same SME's that were consulted regarding the Profitability Model were also consulted for the Capacitated Plant Model. The same questions posed for the Profitability Model was used for the Capacitated Plant Model. Table 13 indicates the feedback that was gained from the SME's regarding the CPLM.

Table 13: Feedback from SME's regarding the CPLM.

Questions	SME1	SME2	SME3	SME4
1	Yes	Yes	Yes	Yes
2	Yes	Yes	Yes	Yes
3	No	No	No	No
4	Yes	Yes	Yes	Yes
5	No	No	No	No

All the SME's that were consulted was satisfied with the CPLM and did not have any suggested changes.

5.6.3 Scenario Decision Model

The concept of the Scenario Decision Model was also further validated by getting the SME's thoughts and opinions about the model. All the SME's that were consulted was satisfied with the Scenario Decision Model and did not have any suggested changes. Table 14 illustrates the feedback that was gained from the SME's regarding the Scenario Decision Model.

Table 14: Feedback from SME's regarding the Scenario Decision Model.

Questions	SME1	SME2	SME3	SME4
1	Yes	Yes	Yes	Yes
2	Yes	Yes	Yes	Yes
3	No	No	No	No
4	Yes	Yes	Yes	Yes
5	No	No	No	No

5.6.4 Weighted Decision Matrix

The concept of the Weighted Decision Model was validated by getting the SME's thoughts and opinions about the model. Table 15 is an illustration of the feedback gained from SME's regarding the Weighted Decision Model. All the SME's that were consulted was satisfied with the Weighted Decision Matrix and did not have any suggested changes.

Table 15: Feedback gained from SME's regarding the Weighted Decision Model.

Questions	SME1	SME2	SME3	SME4
1	Yes	Yes	Yes	Yes
2	Yes	Yes	Yes	Yes
3	No	No	No	No
4	Yes	Yes	Yes	Yes
5	No	No	No	No

5.7 Summary

The feasibility model, capacitated plant location model and scenario decision model was verified by using certain financial inputs obtained by OWK. The outputs of the models were then compared to the financial statement of OWK.

The feasibility model, capacitated plant location model, scenario decision model and weighted decision model was validated by consulting with different SME's in the wine industry. Two of the SME's are cellar masters at cellars situated in the Western Cape. The third SME is an industrial engineer working at a wine cellar in the Western Cape. The last SME is the chief production manager at OWK. The conclusion of the validation of the models was that it achieves the purpose that is intended for.

The SME's concluded that to their knowledge there are no framework in the wine industry that is similar to the framework that was developed in this project. They also stated that according to them there is a great need for such a framework in the wine industry. Some of the assumptions that were made when the models were developed was also validated by the SMEs. Assumptions such as the size of the cellars being classified according to the yeast capacity and the utilization percentage of the yeast tanks.

The following chapter describes the evaluation of the models used in the case study.

Chapter 6 Model and Framework Evaluation using Case Study

6.1 Model and framework development

The framework that was described in the previous chapter is evaluated in this chapter using the OWK case study described in Chapter 3. The evaluation is described by following the steps of the developed framework as it was applied on the OWK case study.

6.2 Determine capacity planning objectives

This process of the framework consists of determining the capacity objectives that needs to be met. The objectives for the OWK case study was formed by using the questions that OWK wants answered as well as informal interviews held with management of OWK and SME's in the wine industry.

The change in tonnage of grapes received by the cellars led OWK to the following questions:

- Which cellars are not financially profitable anymore?
- How should the supply of the non-profitable cellar be allocated between the profitable cellars?
- What is the financial and social effect of relocating the cellar?

6.3 Map and understand current supply chain network

The purpose of the process of mapping and understanding the current supply chain network was to understand how the supply chain network works as well as the different role players in the supply chain network. The current supply chain network was mapped by conducting several site visits to get a clear understanding of the flow of the current supply chain and the different role players of the supply chain network. The site visits were also used to get a clear understanding of the challenges of the supply chain network and what gave rise to the questions that OWK wants answers to. The supply chain network is described in detail in Chapter 3. For a graphical illustration of the supply chain network see Figure 6 in Chapter 3.4.

6.4 Map and understand current production process

The purpose for this process was to get a clear understanding of the production process of the supply chain network. Different SME's in the wine industry were consulted along with various site visits were used to map and understand the current production process. The production process of Cellar1 will now be explained.

White wine

When the farmers bring their grapes to Cellar1, the batch of grapes must first be weighed in and a sample is taken to test the sugar and ph. After this is done, the grapes are offloaded at the offloading stations. Once the grapes are offloaded, they go through the process of removing the stems from the grapes.

The must is then pumped to the static dejuicer where the pomace and juice is separated. The free run is pumped to (wine) settling/flotation tanks. The pomace is pumped to the pneumatic ATI soft presses to extract all the juice. The juice that is gained from the presses is pumped to juice settling tanks.

The juice in the (wine) settling tanks is then filtered and pumped over to the yeast tanks. The juice in the (juice) settling tanks is filtered and pumped into storage tanks where it is kept until it must be transported to the concentrate facility.

Certain chemicals are added to the juice in the yeast tanks which aid the yeasting process of the juice. The juice stays in the yeast tanks for between 14 and 18 days. The yeast tanks must be kept at about 11 degrees Celsius. After the yeast period is over, the wine is pumped into storage tanks where it is kept until it must be transported to Bottling plant1 or to the market.

Before the wine is transported, it is filtered by a centrifugal filter or a crossflow filter. The lees obtained from the filtering of the wine are further filtered to ensure all the wine is removed. Figure 14 is an indication of the white wine production process at Cellar1.

Red wine

When the farmers bring their grapes to Cellar1, the batch of grapes must first be weighed in and a sample is taken to test the sugar and ph. After this is done, the grapes are offloaded at the offloading stations.

Once the grapes are offloaded, they go through the process of removing the stems from the grapes. The must is then pumped into fermentation tanks where it stays for a few hours to yeast. After the fermentation is done, the wine is pumped into storage tanks and the pomace is put through the dejuicer to extract all the wine from the pomace. The wine is then stored until it must be transported to a bottling plant or the market. Before the wine is transported, it is filtered to remove sediment from the wine. Figure 15 is a representation of the production process of red wine at Cellar1.

The mapping of the production processes of the other cellars can be seen in Figure 27 to Figure 34 in Appendix A1.

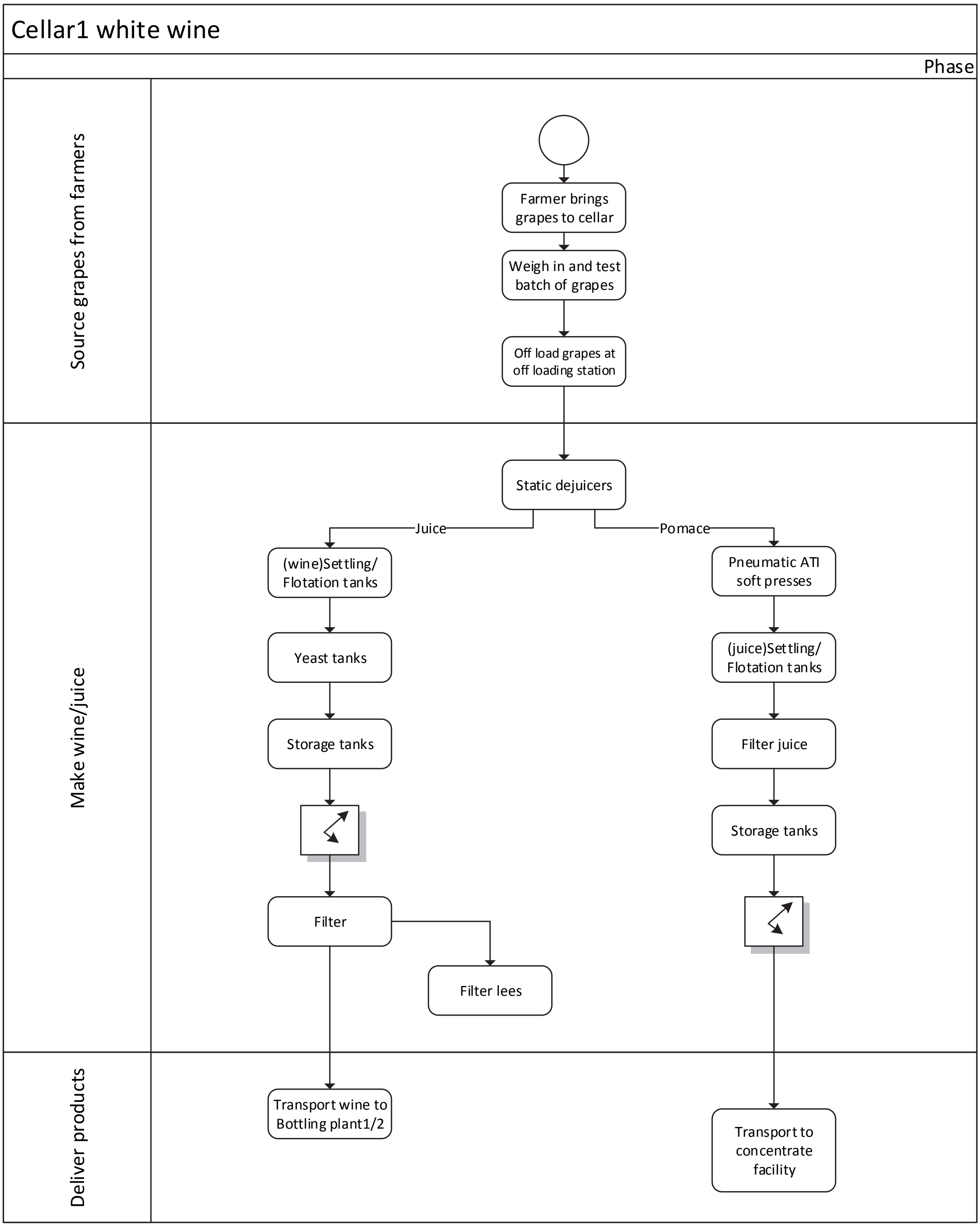

Figure 14: Graphical representation of the process of how white wine is made at Cellar1.

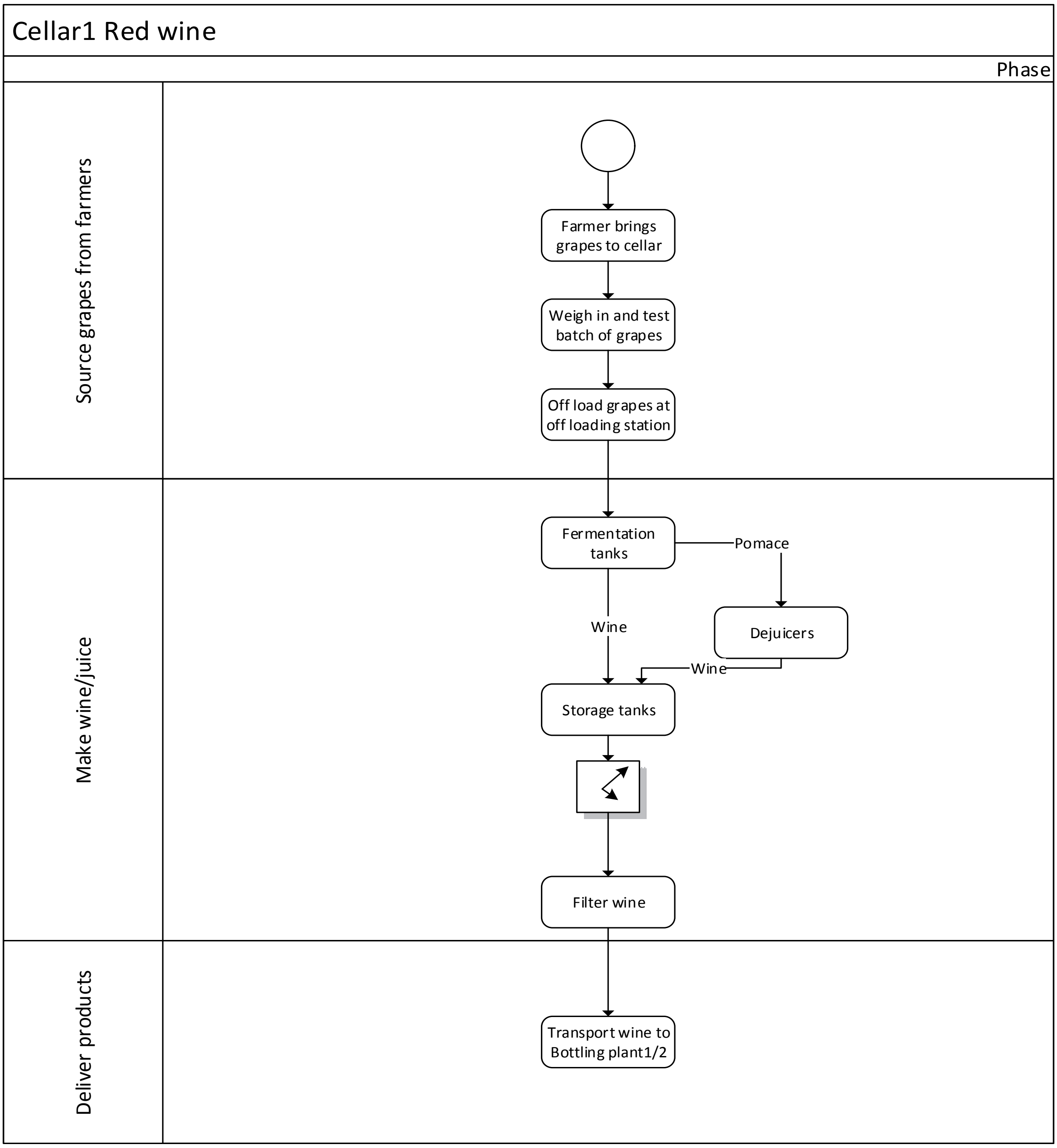

Figure 15: Graphical representation of the process of how red wine is made at Cellar1.

6.5 Determine capacity constrained resources of the supply chain network

In this process the capacity constrained resource in the supply chain network was identified. It is important to identify the constrained resource seeing that the production rate is determined by the rate of the constrained resource. In the OWK case study the capacity constraint was identified during the site visits as well as the informal interviews held with the different SME's. The yeast space was found to be the capacity constraint for 4 of the 5 winemaking cellars. The capacity constraint at the 5th Cellar was found to be the supply of grapes. It was found that the capacity constraints identified in the OWK case study is a constraint faced by various cellars. Even cellars in the Western Cape.

6.6 Perform capacity analysis for each stage of the network

In this stage the capacity analysis for the supply chain network was done. Data regarding the grapes received during the harvest was used to formulate graphs used as part of the capacity analysis. The graphs mainly focused on the amount of grapes received per week per cellar as well as the net capacity of the yeast space per week. The amount of grapes received per week for Cellar1 is shown below in Figure 16 . The grapes received per week for the rest of the wine cellars can be seen in Appendix B.

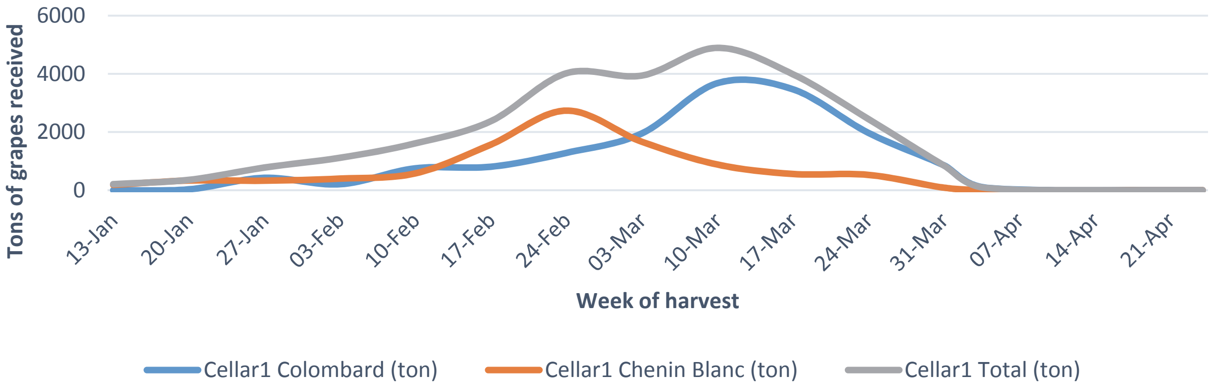

Figure 16: Grapes received by Cellar1 in 2017.

Figure 17 indicates the amount of grape juice in the yeast tanks for each week of the harvest.

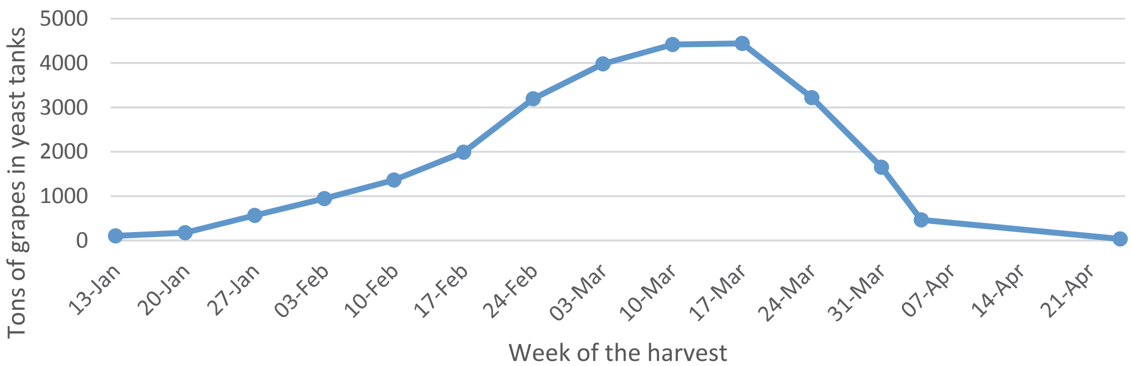

Figure 17: Yeast tanks capacity of Cellar1 during harvest.

From Figure 16 illustrating the amount of grapes received per week during the harvest it can be seen that there is a peak in the data on 17 March. This is due to both Chenin Blanc and Colombard grapes are received by the cellar during that time. This peak is visible at all the cellars (see figures in Appendix B). The graph in Figure 16 illustrates the uneven ratio between the amount of Chenin Blanc and Colombard grapes received by the cellar. This tendency is visible, from the figure illustrating the amount of grapes received, by the other cellars as well. Thus, it is clear by having a more even ratio between the amount of Chenin Blanc and Colombard grapes received by the cellar the peak would be lower and the cellar will receive the grapes at a more stable rate. It will also lower the yeast capacity peak. This will increase the yeast capacity utilization over the entire harvest.

From Figure 17 illustrating the capacity of the yeast space during the harvest a peak can also be seen in the data. That is because during those weeks the yeast capacity is at its fullest. The reason for this is that during those weeks both Chenin Blanc and Colombard grapes are received. The capacity of the yeast space for the rest of the wine cellars can be seen in Appendix B. From the yeast tank capacity graphs of the other cellars it is clear that all the cellars experience the capacity peak during the same period. This means that if the supply of a cellar is to be moved the yeast tanks of that cellar should be moved along with it.

6.7 Perform financial analysis for the supply chain network

The Profitability analysis process consists of determining if the different facilities are still financially profitable as independent units. This financial analysis can also further be used to determine possible reasons why a cellar is not profitable anymore. The Profitability Model that was formulated in Chapter 5.1 was used for the financial analysis.

For the formulation of the Profitability Model certain assumptions were made. These assumptions were the following:

- After a thorough investigation, it was found that the income generated by OWK by selling the pomace accounts for less than 1% when compared to the income generated by selling wine, juice and Rebate wine. With this information in mind, it was decided not to take the income of the pomace into account.
- The diverse income received by the cellar also accounts for less than 1% when compared to the income received by selling the wine and the juice. For this reason, it was decided to ignore the diverse income.
- A third-party logistics provider is responsible for transporting the wine between the different cellars and to distribute the products to the different markets. Aside from the transportation cost of the third-party logistics provider, there is another type of transportation cost also payable by OWK. This is the transportation cost paid by OWK to the farmers who are situated further than a certain distance from the closest OWK cellar. OWK has a certain rate (R/km/ton) which they pay to these farmers. This cost was also found to be less than 1% when compared to the transportation cost of the third-party logistics provider. Thus, it was decided to not take the transportation cost paid to the farmers into account when considering the transportation cost paid by OWK in the Profitability Model. This transportation cost however is taken into account for the CPLM since the model might suggest that farmers (suppliers) should deliver the grapes to other cellars. This can have a noticeable effect on the transportation cost paid by OWK and the profitability.
- The size of the cellars will be specified according to the yeast capacity of the cellar. This decision was made after examining the cellars and consulting with an SME. This SME is an expert in the field of wine corporations as he was employed at OWK since the beginning of OWK (1970) up to 2014. The yeast capacity is the constraint that determines the amount of wine that a cellar can produce. This is the reason why it was decided to specify the size of the cellars according to the yeast capacity of the cellar.
- The red wine produced by the OWK cellars accounts for about 2% of the total amount of wine produced. Thus, it was decided that the red wine will not be taken into account in the feasibility model.

6.7.1 Profitability Model

The Profitability Model was used to determine whether or not the cellars are still profitable as single units. Table 16 provides feedback into the profitability of the different cellars by depicting the output of the Profitability Model. If the model indicates that a certain cellar is non-profitable possible reasons for why the cellar is not profitable will be described.

Table 16: Indication of cellar profitability.

Cellar	Profitable
Cellar1	Profitable
Cellar2	Profitable
Cellar3	Profitable
Cellar4	Profitable
Cellar5	Non-Profitable
Cellar6	Profitable

Figure 18 is an illustration of the profitability of the different cellars of OWK. From the cellars it is clear that Cellar 5 is non-profitable and will be the first cellar to be closed. Cellar1 is the most profitable cellar.

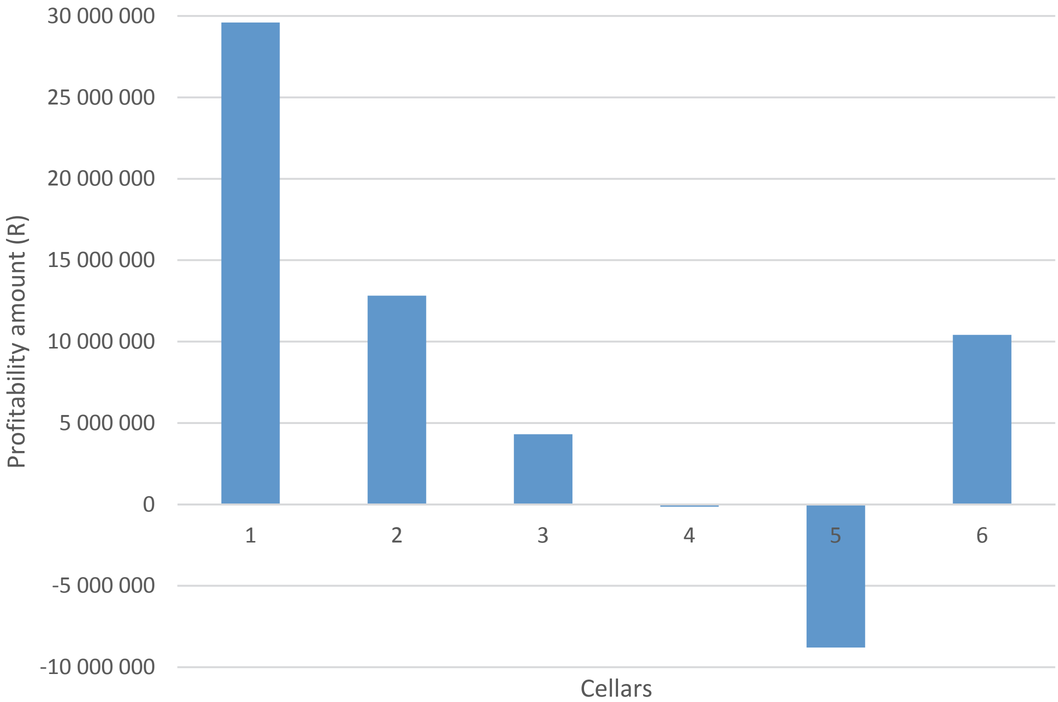

Figure 18: Illustration of the profitability of the cellars.

From the results of the Profitability Model that was used to determine if the cellars are still profitable, it is clear that all the cellars except for one cellar are still profitable. The cellar that is not profitable anymore is Cellar5.

A brief investigation was done to determine why Cellar5 might be not profitable anymore. The outcome of the investigation will now be provided. During the investigation, it was concluded that Cellar5 is buying grapes of a certain quality type but are not using them to their full potential to produce the products for which those types of grapes should be used. For detailed outputs of the profitability models of the various cellars refer to Appendix D.

6.8 Determine most economical allocation of capacity in the supply chain network

This process consists of using certain input data to determine the most economical allocation of capacity in the supply chain network. For this case study the capacitated plant location model was used since there was a capacity constraint, and the allocation of capacity was an important consideration.

The aim of the CPLM that was developed was to find the most economical allocation of the capacity of grapes received in each region. For this case study the focus will only be placed on section 1 and section 2 of the CPLM. This is because section 3 has no influence on the location of the cellars.

The juice, bulk wine, and processed wine is currently being transported to Bottling plant1 because the filter needed to perform the final filtering of the products is at Bottling plant1. The PET wine that is to be sent to the Northern Cape market is bottled at Bottling plant2 since it is close to the market.

All the PET wine of Cellar4 and Cellar5 is currently being sent to Bottling plant2 since they are the closest cellars to Bottling plant2. In this model the focus is only placed on the wine cellars thus Cellar3 will not be taken into account since it only produces juice.

The first step was to determine whether all the cellars should still be operational or not given the amount of grapes received by it. Supply of grapes from each region was then allocated among the still operational cellars. The second step was to determine what amount of wine should be transported to which bottling plant.

Seeing that Solver is not capable of solving both section 1 and section 2 of the supply chain network simultaneously, section 1 will be solved first and then section 2.

6.8.1 Section 1 (Supply to Cellars)

Section 1 consists of the cost of transporting the grapes from the different suppliers (farmers) to the different cellars. The aim of this section is to determine if all the cellars are still needed and what amount of grapes should be supplied to which cellars.

For section one, the input data required is the following:

- Transportation cost paid to the suppliers travelling further than the pre-determined distance specified by OWK.
- Pre-determined distance.
- Number of grapes in each supply region(tons).
- Yeast capacity of each cellar.
- Yeast utilization.
- Yeast cycles for each cellar.
- Litre of wine gained per ton of grapes.
- Fixed cost of each cellar.
- Distances between each cellar.

Figure 19 is an indication of the input data required for the CPLM.

Supply-Cellars

Variable inputs	
Cost per km (R/km/ton)	3
Min distance(km)	30
Amount of grapes in Supply region(ton)	**Year 1**
Cellar5	**12 193**
Cellar4	**14 117**
Cellar6	**19 000**
Cellar2	**23 506**
Cellar1	**28 683**
Cellar yeast capacity	
Cellar5	4 069 000
Cellar4	4 432 200
Cellar6	7 107 400
Cellar2	6 122 900
Cellar1	9 218 700
Yeast utilization	85,00%
Liter of wine gained per ton of grapes	550

Once off inputs

	Distance between cellars(km)				
	Cellars				
Supply region	**Cellar5**	**Cellar4**	**Cellar6**	**Cellar2**	**Cellar1**
Cellar5	0	40	123	168	205
Cellar4	40	0	68	113	150
Cellar6	123	68	0	45	81
Cellar2	168	113	45	0	40
Cellar1	205	150	81	40	0

	Cellar Fixed cost
Cellar5	R 3 955 474
Cellar4	R 3 261 984
Cellar6	R 9 452 965
Cellar2	R 7 346 147
Cellar1	R 7 465 994

Figure 19: Input data required for first section of CPLM.

The output of the first section of the CPLM can be seen in Figure 20.

Decision Variables output

	Supply-Cellars					
Supply region	**Cellar5**	**Cellar4**	**Cellar6**	**Cellar2**	**Cellar1**	**Plant open/closed**
Cellar5	0	0	0	0	0	0
Cellar4	12,193	14,117	0	0	0	1
Cellar6	0	0	19,000	0	0	1
Cellar2	0	0	0	23,506	0	1
Cellar1	0	0	0	0	28,683	1

Constraints

Supply region	**Excess cellar Capacity**
Cellar5	0
Cellar4	1,089
Cellar6	24,937
Cellar2	14,345
Cellar1	28,305

Utilization	**Calculated**
Cellar5	0.00
Cellar4	0.96
Cellar6	0.43
Cellar2	0.62
Cellar1	0.50

	Cellar5	**Cellar4**	**Cellar6**	**Cellar2**	**Cellar1**
supply capacity	0	0	0	0	0

Objective Function	
Cost =	R 34,892,880

Figure 20: Output of first section of CPLM.

The model output in Figure 20 indicates that Cellar5 should be closed and all of its supply moved to Cellar4 (which had enough spare capacity to accommodate the re-allocation of the supply from cellar 5). This will increase the utilisation of Cellar 4 to 96%, which although high would still be acceptable. Cellar4 is also closer to the bottling plant. All the supply of Cellar6 should be delivered to Cellar6 and all the supply of Cellar2 and Cellar1 should be delivered to Cellar2 and Cellar1.

6.8.2 Section 2 (Cellars to Bottling Plants)

Section 2 consists of the costs associated with transporting the wine from the different cellars to the different bottling plants.

The input data required for section 2 is the following:

- The cost of transporting the wine from the cellars to the bottling plants.
- The capacity of the mode of transport used (in tons).
- The distance between the cellars and the bottling plants.
- The capacity and fixed cost of the cellars.

Figure 21 is a representation of the input data that is required for the 2nd section of the CPLM.

Cellar-Production

Variable inputs	
Cost per km (R/km)	30
capacity of transport (ton)	32.5

Once off inputs

	Distance between cellars and Production plants	
Cellars	**Bottling plant1**	**Bottling plant2**
Cellar5	123	300
Cellar4	68	350
Cellar6	0	400
Cellar2	45	450
Cellar1	81	500

	Capacity	**Fixed cost**
Bottling plant1		R 5,000,000
Bottling plant2	4,620	R 2,000,000

Figure 21: Input of second section of CPLM.

The output of the second section of the CPLM can be seen in Figure 22. No products are supplied from Cellar5 since it should be closed.

Supply region(ton)	
Cellar5	0
Cellar4	26,310
Cellar6	19,000
Cellar2	23,506
Cellar1	28,683

Supply region	Bottling plant1	Bottling plant2	Plant open/ closed
Cellar5	0	0	0
Cellar4	21,690	4,620	1
Cellar6	19,000	0	1
Cellar2	23,506	0	1
Cellar1	28,683	0	1

Cellar-Production

	Cellar5	Cellar4	Cellar6	Cellar2	Cellar1
capacity cellars	0	0	0	0	0

	Bottling plant1	Bottling plant2
Capacity production plant		0

Objective function	R 12,975,089

Figure 22: Output of second section of CPLM.

From Figure 22 it can be seen that 21 690 litres (approximately 82%) of the wine capacity of Cellar4 should be sent to the Bottling plant 1 and the rest of the wine capacity should be sent to Bottling plant 2. All the capacity from Cellar1, Cellar2 and Cellar6 should be sent to Bottling plant 1. No wine capacity from Cellar5 should be sent to either Bottling plant 1 or Bottling plant 2 since Cellar5 should be closed.

The total cost of section 2 can be seen in Figure 22 as R 12 975 089. The total cost of the supply chain network can be determined by adding the total cost of section 1 and section 2. The total cost of the supply chain network is then found to be R 47 867 969.

6.8.3 Capacitated Plant Location Model

The CPLM was used to determine the best allocation of the capacity in the supply chain network. Only the wine cellars that produce wine were used in the model and if a cellar produce both wine and juice only the information pertaining to the wine section was used. It should also be noted that the utilization determined in the CPLM is the utilization of the yeast tanks over the entire harvest. The reason for the low utilization is because the rate at which the grapes are received at the start and end of the harvest is very low. This is because all the cellars only receive mainly two cultivars of grapes which are harvested at almost the same time.

From Figure 20 it can be seen that Cellar5 should be closed and that all the supply of grapes should be moved to Cellar4. If the capacity of the cellars is allocated according to Figure 20 then all the supply in every region is utilized.

The total cost of section 1 is R 34 892 880 (refer to Figure 20). It should also be noted that if capacity from one cellar should be moved to another, the corresponding amount of yeast tanks needed to process the juice to wine should also be moved. This is because 90% of the grapes received by the cellars are

Colombard and Chenin Blanc grapes. Thus, the other cellar will not be able to accommodate the extra supply with its current capacity of yeast space.

6.8.3.1 **Future prediction**

It is important to ensure that the profitable status of a cellar will not change in the near future. Thus, if a cellar is deemed non-profitable it will not become profitable again in the near future.

From Figure 23 it is clear that the total capacity of grapes received by all the cellars have decreased. An assumption was then made that this trend will continue in the future.

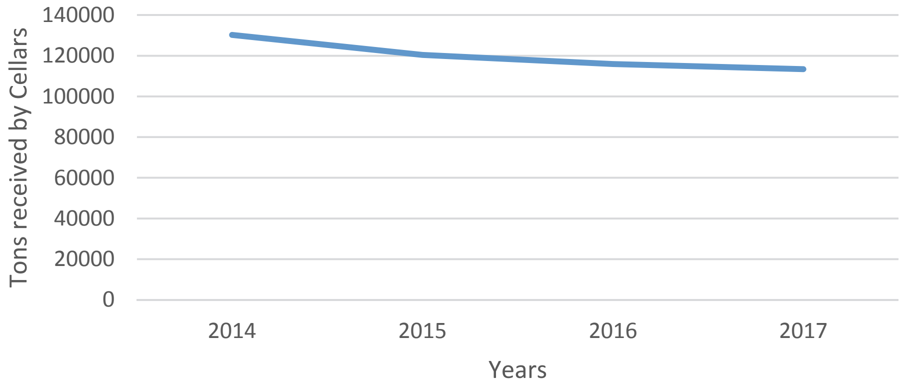

Figure 23: Indication of decrease of grapes.

Seeing that a forecast of the capacity cannot be made, the capacity received for the last four years was used in the CPLM to determine how the supply chain network changed over the past four years. The result was that for each year the CPLM suggested that Cellar5 needs to be closed down and the capacity allocated to Cellar4.

Table 17 indicates which cellar/cellars should (according to the output of the CPLM which determines what cellar is not profitable anymore) be closed by using the forecasted supply of each year. The supply of grapes for 2018 until 2022 was forecasted and used as input supply for the CPLM. The current transportation cost and capacity of the cellars were used since the aim is to determine how the allocation will change for the supply of different grapes under the current conditions.

Table 17: Indicating which cellars should be operational in for the following 5 years.

Cellar	2018	2019	2020	2021	2022
1	Keep Operational	Keep Operational	Keep Operational	Keep Operational	Keep Operational
2	Keep Operational	Keep Operational	Keep Operational	Keep Operational	Keep Operational
4	Keep Operational	Keep Operational	Keep Operational	Keep Operational	Keep Operational
5	Close down	Close down	Close down	Close down	Close down
6	Keep Operational	Keep Operational	Keep Operational	Keep Operational	Keep Operational

With the result of the CPLM as stated above an assumption was made that the profitability status of Cellar5 will not change in the near future.

6.9 Compare supply chain network capacity allocation options using qualitative and quantitative criteria

This process is used to determine the best supply chain network capacity allocation option using certain qualitative and quantitative criteria. For the OWK case study the input data required for the qualitative criteria is obtained from SME's in the organisation. The input data required for the quantitative criteria is obtained from the financial statements.

6.9.1 Scenario Decision Model

The different alternatives were evaluated using the Scenario Decision Model. The Scenario Decision Model determines from a financial point of view which of the alternatives that was stated by OWK should be chosen. The Scenario Decision Model compares the financial effect of the different alternatives that is considered if a cellar is non-profitable. The alternative with the lowest cost will be the most favourable alternative. The alternatives that was stated by OWK are the following:

1. Leave the cellar open and operate as usual.
2. Close down the cellar and move the equipment to other cellars that has to accommodate the closed cellar's capacity.
3. Close down the cellar but perform certain operations at the closed cellar and move the product then to another cellar and move the equipment to the other cellars that must accommodate the closed cellar's capacity.
4. Close down the cellar and leave the equipment at the closed cellar.

Table 18 is the rankings of the different alternatives as determined by the Scenario Decision Model is displayed. The cost associated with each alternative is also displayed in the table.

Table 18 : Output of the Scenario Decision Model.

Rank	Alternative	Cost
1	4	R1 198 883
2	2	R2 053 311
3	3	R5 620 548
4	1	R11 030 441

Figure 24 is a representation of the Scenario Decision Model used to evaluate alternative one for the OWK case study.

Cellar direct cost		R 8,338,686
Admin	R 956,098	
Insurance	R 193,139	
Depreciation	R 762,960	
Personel	R 3,987,258	
Security	R 474,172	
Water and electricity	R 1,150,498	
Maintenance	R 1,770,660	

Infrastructure of other cellars accomodating the extra supply			0
Cost of upgrading other cellar that has to accommodate the extra capacity	0		
Expansion(moved closed cellar equipment or buy new equipment)			
Move existing equipment from cellar	0	Buy new equipment	0
Transport cost	0	Transport cost	0
Installation cost	0	Installation cost	0
	0		0

Transport		R 2,691,755
Grapes		
Wine/juice	R2,691,755	

Total cost	R 11,030,441

Figure 24: Representation of the Scenario Decision Model for the first alternative.

From Table 18 it can be seen that from a financial point of view alternative 4 is the most favourable alternative. Alternative 4 states that the non-profitable cellar should be closed and that all the equipment of the cellar should be left at the cellar.

The second most favourable alternative is alternative 2. This alternatives state that the non-profitable cellar should be closed, and all the equipment moved to the other cellar that must accommodate the supply of the non-profitable cellar.

The third most favourable alternative is alternative 3. This alternative state that the non-profitable cellar should be closed but that certain operations, such as pressing and crushing the must, will then be transported to the other cellar that must accommodate the supply of the non-profitable cellar.

The least favourable alternative is alternative 1. This alternative state that the non-profitable cellar be kept open and operating as usual.

6.9.2 Weighted Decision Model

The Weighted Decision Model was used to qualitatively determine which alternative should be chosen. The model was used to determine what effect the different alternatives will have on the main categories which are the people, the financial effect, effect on the product, and the effect on the infrastructure. These are the categories that will be affected the most if a cellar is moved or closed. Thus, the effect of the different alternatives on the different categories is determined by using the Weighted Decision

Matrix. A scale ranging from 1 - 5 was used to illustrate the effect. Figure 25 is a representation of the scale used in the Weighted Decision Model. On the scale, 3 is neutral with 2 and 1 being mostly negative and very negative, 4 and 5 represents mostly positive and very positive.

Very negative ←—— Neutral ——→ Very positive

1 2 3 4 5

Figure 25 : Representation of the scale used for the Weighted Decision Model.

The weights of the different categories for the different alternatives were provided by the chief production manager. Figure 26 is a depiction of the output of the Weighted Decision Matrix.

	People			Finance	Product		Infrastructure		
Factors:	Supplier	Employee	Community	Network cost	Product range	Product quality	Transport infrastructure	Cellar infrastructure	**Total**
Weights	5	5	4	4	3	3	3	4	
Alternative1	3	3	3	3	3	3	3	3	93
Alternative2	1	1	1	3	3	3	3	4	69
Alternative3	2	2	2	2	3	2	3	4	76
Alternative4	1	1	1	3	3	2	3	4	66

Figure 26 : Output of the Weighted Decision Matrix.

Since the scale is defined in such a way that the higher values (4 and 5) represents positives effects, the alternative with the highest overall score will be the most favourable alternative. Table 19 indicates the output of the Weighted Decision Model. The table indicates the rank of the alternative as well as the score that every alternative achieved.

Table 19: Representation of the output of the Weighted Decision Model.

Rank	Alternative	Score
1	1	93
2	3	76
3	2	69
4	4	66

6.10 **Final recommendation for supply chain network design and capacity allocation.**

This process consisted of providing insight to which cellar is not profitable anymore and what should happen to the non-profitable cellar. For this process the output of the Profitability Model and the CPLM was used to determine which cellar is not- profitable anymore and the output of the Scenario Decision Model and Weighted Decision Model was used to determine what should happen to the non-profitable cellar.

6.10.1 Alternatives

The different alternatives stated in section 6.9.1 will now be described in more detail in the following paragraphs.

1. Leave the cellar open and operating as usual.

The first alternative suggests that the cellar stays open and operates as always, although the framework suggested that the cellar should be closed. This alternative has the lowest financial and social effect since the cellar keeps on operating as usual.

2. Close down the cellar and move the equipment to other cellars that have to accommodate the closed cellar's capacity.

This alternative suggests that the cellar is closed completely and that all the equipment of the cellar is moved to the other cellars that have to accommodate the capacity of the cellar that was closed. This alternative has a financial and social effect. This is because the equipment that has to be moved has a financial implication and the cellar being closed has a social impact since the employees might lose their jobs. The financial effect will, however, be justifiable after a few years but the social impact will not since the employees might not be re-employed at the other cellars.

3. Close down the cellar but perform certain operations at the closed cellar and move the product then to another cellar. The equipment should then be moved to the other cellars that must accommodate the closed cellar's capacity.

This alternative entails that the cellar be closed down but that some basic operations be done at the cellar on the grapes. Operations such as removing the stems so that the pomace is then transported to the other cellars for the rest of the operations required to turn it into wine. The equipment that is needed for the basic operations is then kept at the cellar, but the other equipment is moved to the other cellars that have to accommodate the capacity of the closed cellar. This alternative has a financial as well as a social effect, however, the effects are minor since only some of the equipment is moved. The financial effect is not that large and the social impact is also not that large as some of the operations will still happen at the cellar so not all the employees will be let go.

4. Close down the cellar and leave the equipment at the closed cellar

This alternative suggests that the cellar should be closed down completely and that the equipment should not be moved to the other cellars. This alternative will have a large social impact but not a large financial effect. This is because seeing that the cellar is closed, all the employees will be let go but since the equipment is not moved, the financial effect will not be as large.

6.11 Summary

The Profitability Model was used to determine if all the cellars are still profitable as singular units. The Profitability Model indicated that all of the cellars except one are still profitable. The cellar that was found to be non-profitable by the Profitability Model is Cellar5. A brief analysis was done to determine what caused Cellar5 to be non-profitable. The analysis revealed that Cellar5 is buying grapes of a certain quality type but are not using them to produce the products for which those grapes should be used. The rest of the cellars are still profitable mainly because they use the grapes optimally.

The CPLM was used after the Profitability Model to determine if all the cellars are still required and to determine the best capacity allocation under the current circumstances. The CPLM revealed that Cellar5 is no longer required in the supply chain network. The CPLM also suggested that all the supply capacity of Cellar5 should be allocated to Cellar4. The yeast space as well as storage space of Cellar5 should also be relocated to Cellar4. This is because all the cellars receive the same grapes which means that the yeast space of all the cellars are full during the same period of the harvest. Therefore, if supply capacity is to be moved from one cellar to another, the corresponding yeast space should be moved with it.

After the CPLM was used, the Scenario Decision Model and Weighted Decision Model was used to determine which alternative, stated by OWK, is the favourable option. According to the Scenario Decision Model, the most favourable alternative is alternative 4. This alternative however is not possible since some of the equipment of Cellar5 will have to be moved to Cellar4 to accommodate Cellar5's capacity. Thus, alternative 2 will be the favourable alternative.

The Weighted Decision Matrix ranked alternative 1 as the most favourable alternative but this alternative will not be considered since the CPLM indicated that Cellar5 should close and the case study company wanted to know which cellars should be closed and which should be kept operational.

The next favourable alternative is then alternative 3. This alternative is also not applicable since the reason Cellar5 is not profitable is the slow rate of receiving grapes causing the grapes to oxidise in the yeast tanks before the yeast process starts. The same problem will be encountered with alternative 3 as alternative 3 does not address the slow rate at which the grapes are received by the cellar. This means that alternative 2 is the favourable and recommended alternative.

This chapter contained the results of the models used in the OWK case study. The different alternatives of what should happen to the non-profitable cellars, as specified by OWK, were also stated in this chapter. The following chapter will contain the final recommendations and conclusions regarding the study as well as the case study.

Chapter 7 Summary, Conclusions and Recommendations

This chapter provides a brief summary of the thesis as well as the results obtained in Chapter 6. Recommendations regarding the future of non-profitable cellars are also provided.

First, a summary of the framework that was developed is given. This summary provides a broad overview of the purpose of the framework that was developed. A short summary of the research is provided, followed by research conclusions that were made as well as certain research contributions. The last section contains the research limitations that were encountered and recommendations for further research.

7.1 Research summary

South Africa is a key player in the global wine industry. According to a recent study South Africa is the seventh biggest wine producer in the world. It was also found that only about a third of the South African wine farmers are making a sustainable income. This causes a decrease in the South African wine production since wine grapes are being replaced by other crops that are more profitable. The decrease in the amount of grapes received by the cellars has a negative effect on the effective utilization of the available capacity of the supply chain network.

The aim of this study was to contribute towards a better understanding and execution of network capacity planning decision making in the wine supply chain, specifically with regards to capacity planning decisions of wine cellars within a supply chain network. From an initial literature conducted, a gap was identified in the supply chain network design in the wine industry. No papers could be found that focused on the capacity planning of cellars in a wine supply network. Capacity planning is a very important part of supply chain management and should be revised on a regular basis. This is becoming a more important aspect of supply chain network design in the wine industry of South Africa due to the replacement of wine grapes with other crops and the resulting change in the supply mix and volume of wine grapes. This led to the following research question:

How can an approach be developed for supporting better long-term capacity planning decision making in the wine supply chain?

In order to answer this research question, first a more in-depth literature review was conducted in which various knowledge areas relevant to the study were explored: the wine value chain, capacity planning, supply chain network designs, facility location planning, and different modelling types. Different databases such as Google Scholar and Scopus were explored in order to identify previous research related to capacity planning and supply network design, specifically with a focus on the wine industry. Very limited academic papers could be found on capacity planning and facility relocation in the wine industry, which highlighted the current gap in the literature.

A generic framework was developed for supply network design and capacity planning in the wine industry. The framework was developed through requirements obtained in the literature review on capacity planning and facility location/ supply network design, as well as practical information obtained through interviews with various subject matter experts in the wine industry. The generic framework is structured in such a way that a deeper understanding of the current supply chain network is obtained after each stage. The stages of the framework ensure that the basic supply chain network is understood. By determining the capacity constrained resource of the supply chain network and performing a capacity analysis of this resource, a deeper understanding the current supply chain network is gained. In order to determine the profitability of the cellars as well as the most economical allocation of capacity a good understanding of the first five stages of the framework is required.

The framework first determines the profitability of the cellars by using the Profitability Model that was developed. This model uses different input data such as income gained from selling the products, cost of producing the product and cost of buying different quality grapes. The output of this model indicates whether a cellar is still profitable or not. The next model developed for the framework is a CPLM. This model is used to determine the most economical allocation of capacity in the supply chain network. If a cellar is not required anymore seeing that it is not profitable anymore and the CPLM indicated that it should not be part of the supply chain network anymore, certain alternatives of what should happen to that cellar is specified. The Scenario Decision Model was developed to determine the best alternative from a financial point of view and the Weighted Decision Matrix is used to determine qualitatively what alternative should be chosen. The CPLM is also used for future predictions of when a cellar should be closed due to an insufficient supply of grapes as the farmers are replacing wine grapes with other more profitable crops.

The accuracy, usefulness and efficiency of the generic framework and models were evaluated by applying it to a wine corporation in the Northern Cape (called OWK) as a case study. OWK is the largest wine cooperative in South Africa as well as in the Southern Hemisphere and second largest in the world. OWK has 6 cellars situated in the Northern Cape which are used to make different types of wine and produce juice. Since the wine grapes are being replaced by other crops the amount of grapes received during the harvest by the cellars are decreasing each year. The framework indicated which cellar was no longer financially profitable and what should happen to the non-profitable cellar. A structure for the planning of the capacity in the supply chain network was also provided for the rest of the cellars of the OWK case study. The required input data from the different cellars were entered into the models. The Profitability Model indicated which cellar was not profitable anymore and the CPLM indicated the cellar that was not needed in the network anymore. The Scenario Decision Model and Weighted Decision Matrix were used to determine quantitatively and qualitatively what should happen to the cellar that is not needed in the network anymore.

The framework and model were also validated with various industry experts in the South African wine industry. The experts were satisfied with the accuracy and usefulness of the models. Thus, no additional suggestions were made.

The research objectives for this study (which was stated in section 1.3) were met as follow:

- The first objective was to obtain an in-depth understanding of the wine supply chain focusing on the planning, sourcing, making, and delivery activities. A specific focus was on the South African wine supply chain. This objective was met through various site visits at OWK and other cellars as well as meetings with SME's.
- The second objective was to identify current approaches for supply chain network design, capacity planning, and facility relocation planning – specifically investigating approaches and models applied to the wine industry. This objective was also met through the literature study that was done in Chapter 2.

- The third objective was to identify particular challenges, needs, constraints, and considerations for facility relocation planning and capacity planning in the South African wine supply chain. This objective was also met through various site visits and meetings with SME's as well as the literature study that was done in Chapter 2.
- The fourth objective was to develop a model and framework that will support improved capacity planning of wine cellars in a wine supply chain network. This objective was met through the development of the generic framework that was explained in Chapter 4.
- The last objective was to evaluate the accuracy and usefulness of such a model and framework for the wine industry. This objective was met by applying the framework to the OWK case study as well as meetings with SME's.

7.2 Research conclusions and contribution

7.2.1 Research conclusions

From the literature study it was found that a limited amount of research has been done on capacity planning and facility relocation in the wine industry. The research that has been done mostly dates from the middle 1980's and 1990's. Thus, a gap in the literature was identified.

The developed framework and models were found to be a useful tool in the wine industry since it can be used to measure the financial as well as the operational performance of the cellars. The framework can also be used to compare the financial and operational performance of the different cellars. It was successfully used to explore various alternatives and scenarios in the OWK case study, from which specific recommendations could be made for OWK. These recommendations were presented to and validated with relevant stakeholders within OWK, who agreed with the findings. The Profitability Model indicated that Cellar5 is no longer profitable. This was mainly because high-quality grapes are bought but not used to make high-quality wine.

The performance of the other cellars were also investigated using the Profitability Model and it was found that Cellar 4 will be the next cellar that will have to close. This is also due to the fact that it does not utilize the grapes that is bought to its full potential as it uses high-quality grapes to make lower quality wine. The lack of supply of grapes is also a big influence on the cellar being not as profitable.

The CPLM indicated that the supply of grapes to the other cellars should not change as it is the most economical allocation of the supply of grapes in that regions. The CPLM indicated that Cellar5 should be closed and that the supply should be moved to Cellar4. The yeast tanks should be moved with the supply seeing that all the cellars experience a peak during the harvest at approximately the same time.

From the Scenario Decision Model it was seen that the most favourable alternative is to close the cellar and not relocate the equipment or the supply of grapes to that cellar. The most unfavourable alternative is to keep the cellar operating. However, from a qualitative point of view the most favourable alternative is to keep the cellar operational and the most unfavourable alternative is to close it. This is because if the cellar is still operating as usual there are no unemployment of employees and the farmers can deliver the grapes to the cellar as usual. If the cellar is closed the employees will be unemployed and the farmers will have to drive further to deliver the grapes to the next cellar. The recommended alternative however was alternative 2. Alternative 2 suggests that the cellar is closed completely and that all the equipment of the cellar is moved to the other cellars that have to accommodate the capacity of the cellar that was closed.

Some limitations were also identified in the current framework and model. Currently the optimisation model for allocating capacity do not include the relocation of capacity (equipment) from one cellar to the next (for example if the model indicates that a cellar should be closed, it does not automatically relocate the capacity to a different cellar). The relocation of capacity is currently a manual task. Due to all the different factors that needs to be taken into account before a decision can be made about where to allocate the equipment it was decided that it would be better at this stage to allocate the equipment using a manual system. The biggest factors that is preventing an automated relocation model is the fact that not all the cellars use the same equipment to produce wine. However, further research can be done to determine how the capacitated plant location model can be extended so that the allocation of the equipment can be done by the model.

The CPLM developed in the framework is currently solved using two steps. First the allocation of the grapes to the different cellars are done based on a minimum cost function. Next the allocation of the different products to the different bottling plants are done based on a minimum cost function. Furthermore, the product mix is not addressed in the CPLM to determine the best mix that would yield the most revenue. A further study can be conducted to determine how the CPLM can be solved in just one step as well as to determine the best product mix.

When the cellar is deemed as not being financially profitable anymore and the supply of grapes are moved to another cellar there are 4 basic scenarios that can happen to the non- profitable cellar: (1) Leave the cellar open and operating as usual; (2) Close down the cellar and move the equipment to other cellars that have to accommodate the closed cellar's capacity; (3) Close down the cellar but perform certain operations at the closed cellar and move the product then to another cellar, and move the equipment to the other cellars that must accommodate the closed cellar's capacity; (4) Close down the cellar and leave the equipment at the closed cellar. The framework is used to determine the future of the non-profitable cellar by comparing the different alternatives qualitatively as well as quantitatively. The framework was found to be very useful in evaluating the different alternatives to determine the best alternative.

7.2.2 Research contributions

This section focuses on the academic and practical contributions of the research.

7.2.2.1 Academic contribution

The framework that was developed contributes to the body of knowledge regarding capacity planning in the wine industry since no similar frameworks could be found in the literature. This research also contributes towards the limited body of theoretical knowledge on supply network design in the wine industry. This was done through gaining a better understanding of the challenges, needs, constraints, considerations and approaches for facility relocation planning and capacity planning in the wine industry.

7.2.2.2 Practical contribution

This research also has a practical contribution. This is because the framework provides the practitioners in the wine industry a tool that supports capacity planning when redesigning the supply chain network.

The excel models that was developed acts as part of the framework as the tool that can be used by the practitioners. The practical value of the framework was demonstrated in the case study of OWK that was done as part of the project.

7.3 Limitations and recommendations for further research

Based on the limitations identified in section 1.7, the following recommendations for further research and improvements are made:

- A topic that can be further researched is facility redesign with the main focus on wine cellars.
- The farmers are replacing their wine vineyards with other crops such as raisin grapes or pecan nuts. This forces wine cellars to close down, because the cellars are not receiving enough wine grapes to make wine to keep the cellar operational. Instead of closing it down the possibility of transforming the wine cellar into a pecan nuts processing plant should be investigated.
- The framework that was developed in this thesis was only tested on the OWK case study.
- Thus, the focus of another study might be to test the framework on different case studies so that the framework can be tested for different scenarios.
- The CPLM does not address the product mix of a cellar.
- The focus of another study might be to find other more applicable models that can allocate the capacity as well as address the product mix.
- Allocation of equipment between cellars not part of CPLM and must be done by hand.
- The focus of another study can be to develop a model to allocate the equipment between cellars by first determining what equipment each of the different cellars already have and then assigning the same type of equipment to those cellars.

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Appendix A

Appendix A contains a detailed description of the winemaking process of all the cellars of the case study as well as a flow diagram of the winemaking process of each of the cellars for both red and white wine.

A.1 White wine production process at Cellar2

When the farmers bring their grapes to Cellar2, the batch of grapes must first be weighed in and a sample is taken to test the sugar, ph. After this is done, the grapes are offloaded at the offloading stations.

Once the grapes are offloaded, they go through the process of removing the stems from the grapes. The "must" is then pumped to one of the pneumatic ATI soft presses. Cellar2 has 6 pneumatic ATI soft presses. 5 x 50 ton/hour presses and 1x100 ton/hour press. The free run juice (first press) is then pumped to storage tanks. The juice yielded from the second press cycle of the pneumatic ATI presses is pumped to settling tanks used for juice. The juice is then filtered and pumped to storage tanks where it is kept until it is transported to the concentrate plant.

The storage tank where the juice of the free run or first press is pumped into is used as a buffer to relieve some of the pressure of the yeast tanks during peak periods. After the juice is pumped into the storage tanks, it is pumped to settling/flotation tanks. The juice is then pumped to the yeast tanks where yeast and other chemicals are added to aid the yeasting process. The juice stays in the yeast tank for between 12 and 14 days at about 13 degrees Celsius. During this process, the juice is turned into wine.

After the yeast process, the wine is pumped into storage tanks where the wine is kept at a certain temperature until it must be transported to either a bottling plant or to the market as bulk wine. Before the wine is transported, it is filter by a centrifugal and a crossflow filter or drum filter. The lees obtained from filtering the wine are then further filtered to ensure all the wine is removed. Figure 27 indication of the white wine production process at Cellar2.

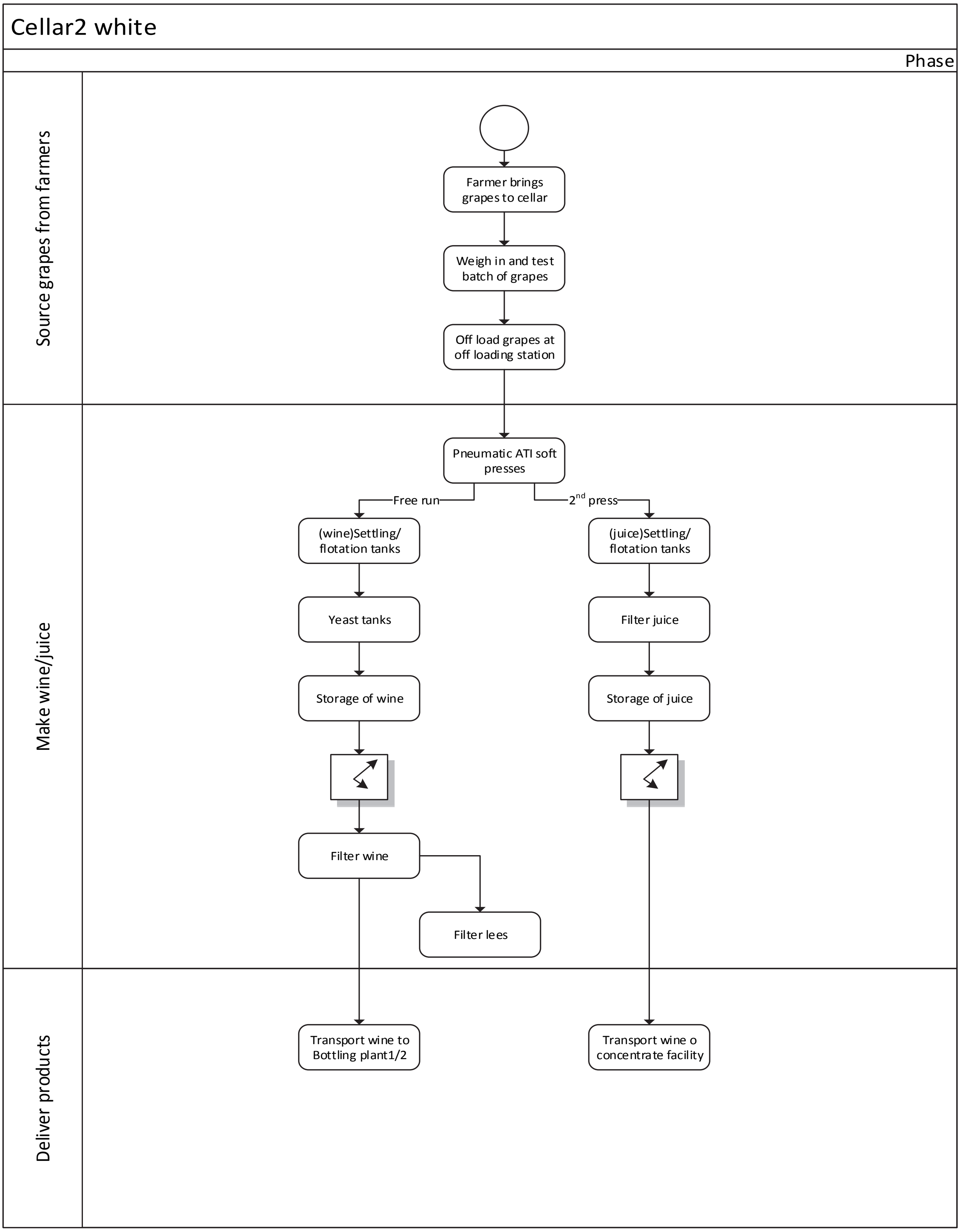

Figure 27: Graphical representation of the process of how white wine is made at Cellar2.

A.2 Red wine production process at Cellar2

When the farmers bring their grapes to Cellar2, the batch of grapes must first be weighed in and a sample is taken to test the sugar, ph. After this is done, the grapes are offloaded at the offloading stations.

Once the grapes are offloaded, they go through the process of removing the stems from the grapes. The “must” is then pumped into the fermentation tanks where it stays for the fermentation to commence. After a few hours, when the fermentation is done, the free run wine is pumped to storage tanks and the pomace is pumped to the dejuicer to extract all the wine. The wine that is extracted from the dejuicer is also pumped to the storage tanks. The wine, however, is kept in different tanks as it is different quality wines. The wine is filtered by the centrifugal filter and crossflow filter before being transported to a bottling plan. Figure 28 representation of the production process of red wine at Cellar2.

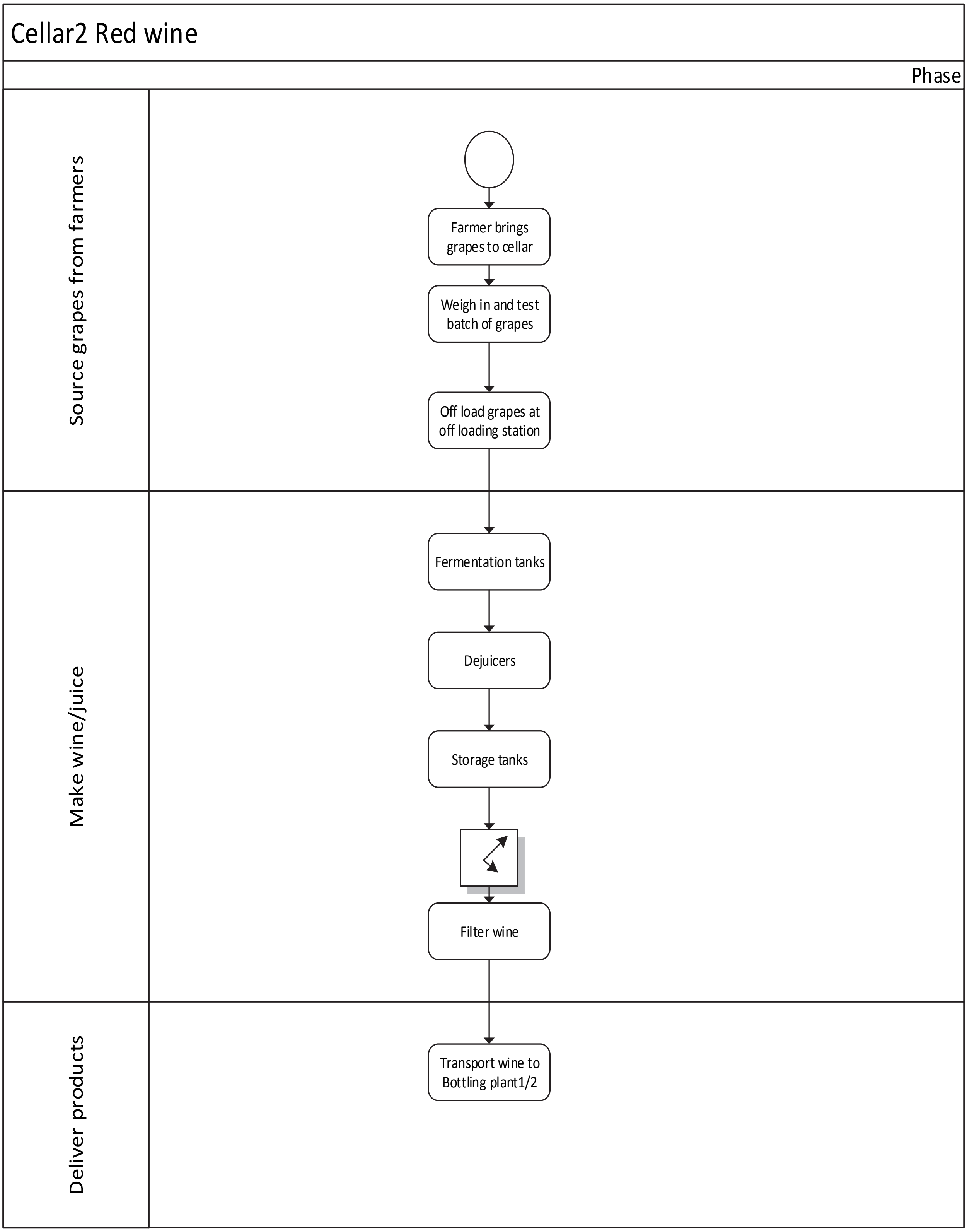

Figure 28: Graphical representation of the process of how red wine is made at Cellar2.

A.3 White wine production process at Cellar4

When the farmers bring their grapes to Cellar4, the batch of grapes must first be weighed in and a sample is taken to test the sugar, ph. After this is done, the grapes are offloaded at the offloading stations.

Once the grapes are offloaded, they go through the process of removing the stems from the grapes. The “must” of the grapes that is going to be used for wine is then pumped to either the static dejuicer or the dejuicer. The static dejuicer is the favourable machine to be used, but if the static dejuicer is full then the “must” is pumped to the dejuicer. The “must” of the grapes that are intended for juice is pumped to the pneumatic ATI soft presses.

The free run of the static dejuicer and dejuicer are then pumped into (wine) settling/flotation tanks. The free run as well as the juice yielded from the second press of the pneumatic presses are pumped to (juice) settling/flotation tanks.

Once the flotation of the juice in the (wine) settling/flotation tanks is done, the juice is pumped into the yeast tanks. Certain chemicals are also then added to aid the fermentation of the juice. The juice remains in the yeast tanks for between 12 and 14 days. The yeast tanks must be kept at about 11 degrees Celsius.

When the fermentation process is done, the wine is pumped into storage where it is kept until it is transported to a bottling plant or the market. Before it is transported, it is filtered by a centrifugal filter to clean out the lees that are in the wine. The lees are then filtered to ensure all the wine is removed. Figure 29 is a representation of the production process of white wine at Cellar4.

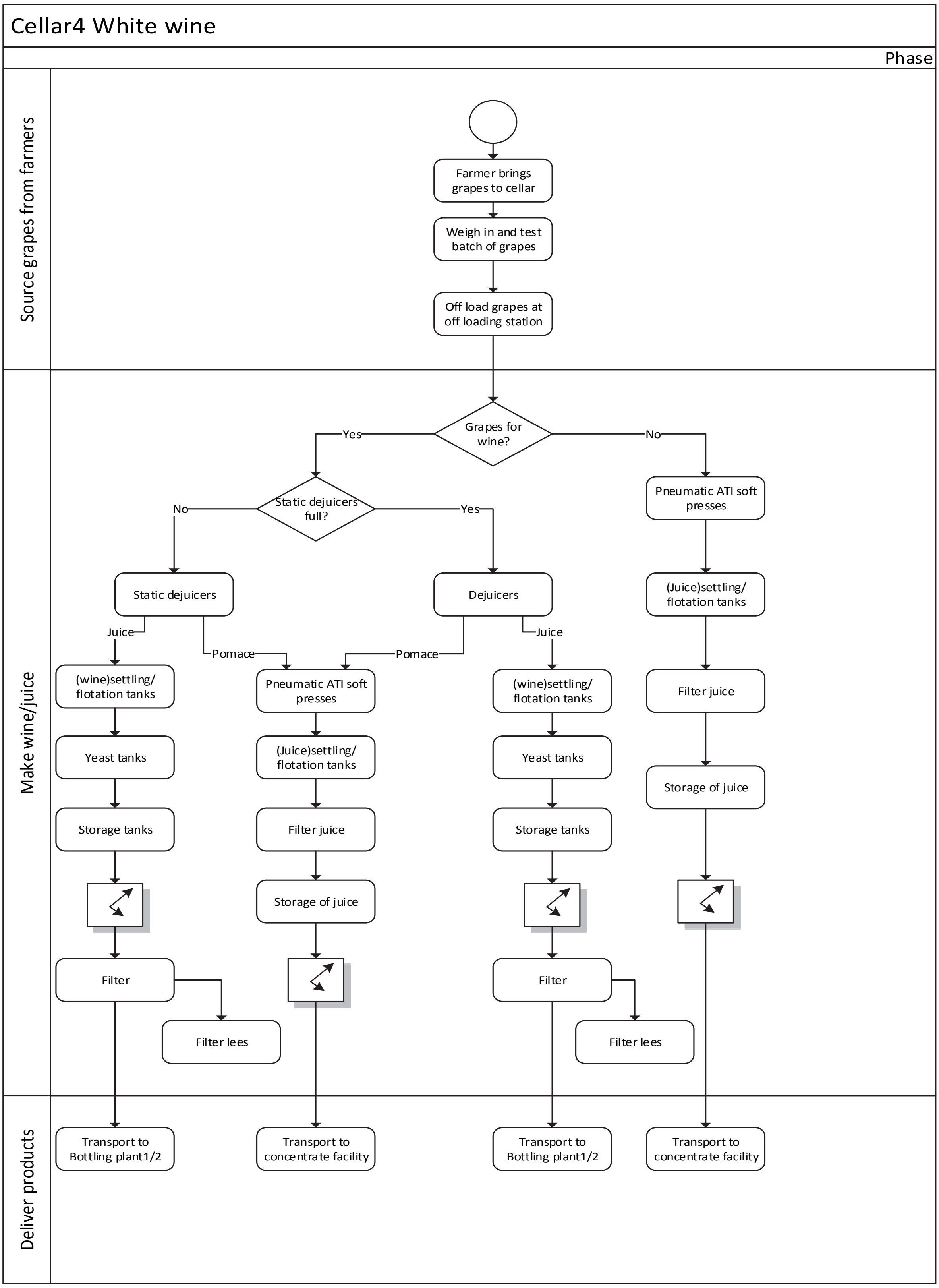

Figure 29: Graphical representation of the process of how white wine is made at Cellar4.

A.4 Red wine production process at Cellar4

When the farmers bring their grapes to Cellar4, the batch of grapes must first be weighed in and a sample is taken to test the sugar, ph. After this is done, the grapes are offloaded at the offloading stations.

Once the grapes are offloaded, they go through the process of removing the stems from the grapes. The "must" is then pumped into fermentation tanks where it is kept for a few hours until the fermentation is done.

When the fermentation is done, the free run wine is pumped into storage tanks and the pomace is put through the dejuicer. The wine that is obtained through the dejuicer and the free run wine are kept in different tanks, because they are different quality wines.

The wines are kept in the tanks until it must be transported to a bottling plant or the market. Before the wine is transported, it is filtered to remove sediment from the wine. Figure 30 is a representation of the production process of red wine at Cellar4.

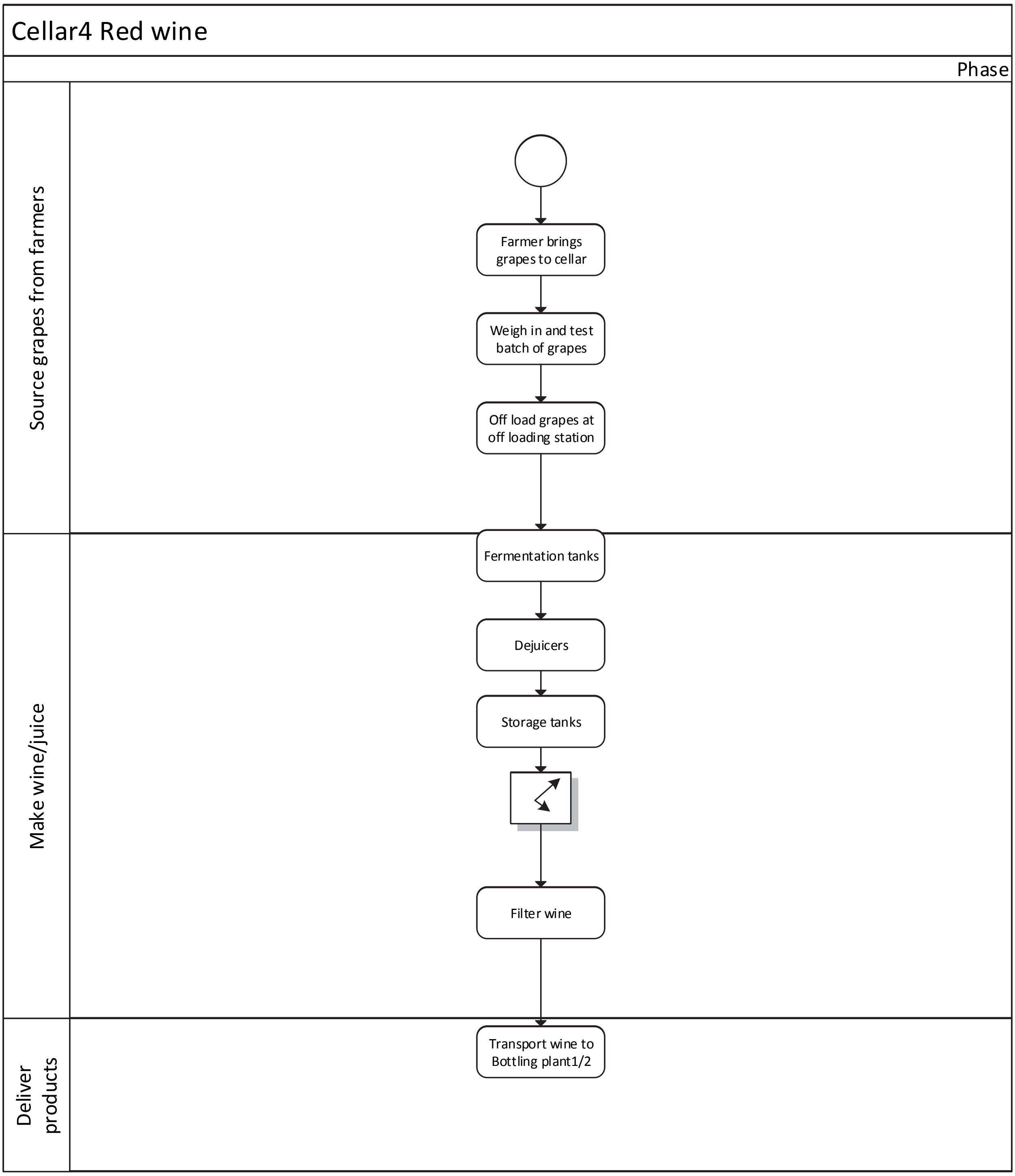

Figure 30: Graphical representation of the process of how red wine is made at Cellar4.

A.5 White wine production process at Cellar5

When the farmers bring their grapes to Cellar5, the batch of grapes must first be weighed in and a sample is taken to test the sugar, ph. After this is done, the grapes are offloaded at the offloading stations.

Once the grapes are offloaded, it goes through the process of removing the stems from the grapes.
The “must” is then pumped to the dejuicer. The free run as well as the presses juice are then pumped to (wine) settling/flotation tanks.

The pomace is pumped to the pneumatic ATI soft press and, if the press is full, the pomace is pumped to the Vinify.

The juice obtained from the press is pumped into (juice) settling/flotation tanks. After the flotation is done, the juice is pumped into storage tanks where it is kept until it must be transported to the concentrate facility in Upington.

The wine obtained from the Vinify is pumped into storage for the use of Rebate wine. The wine is stored until it must be transported to KWV.

After the juice in the (wine) settling/flotation tanks is done with the flotation process, it is pumped into the yeast tanks. Chemicals are then added to aid the yeasting process of the juice. The juice stays in the yeast tanks for about 12 to 14 days at about 11 degree Celsius. After the fermentation process, is done the wine is pumped into storage tanks where it is kept until it must be transported to a bottling plant or the market.

Before the wine is transported, it is first filtered to remove the lees from the wine. The lees are then also filtered to ensure they do not contain any wine. The wine that is extracted from the lees is then also pumped with the other wine. Figure 31 is a representation of the production process of white wine at Cellar5.

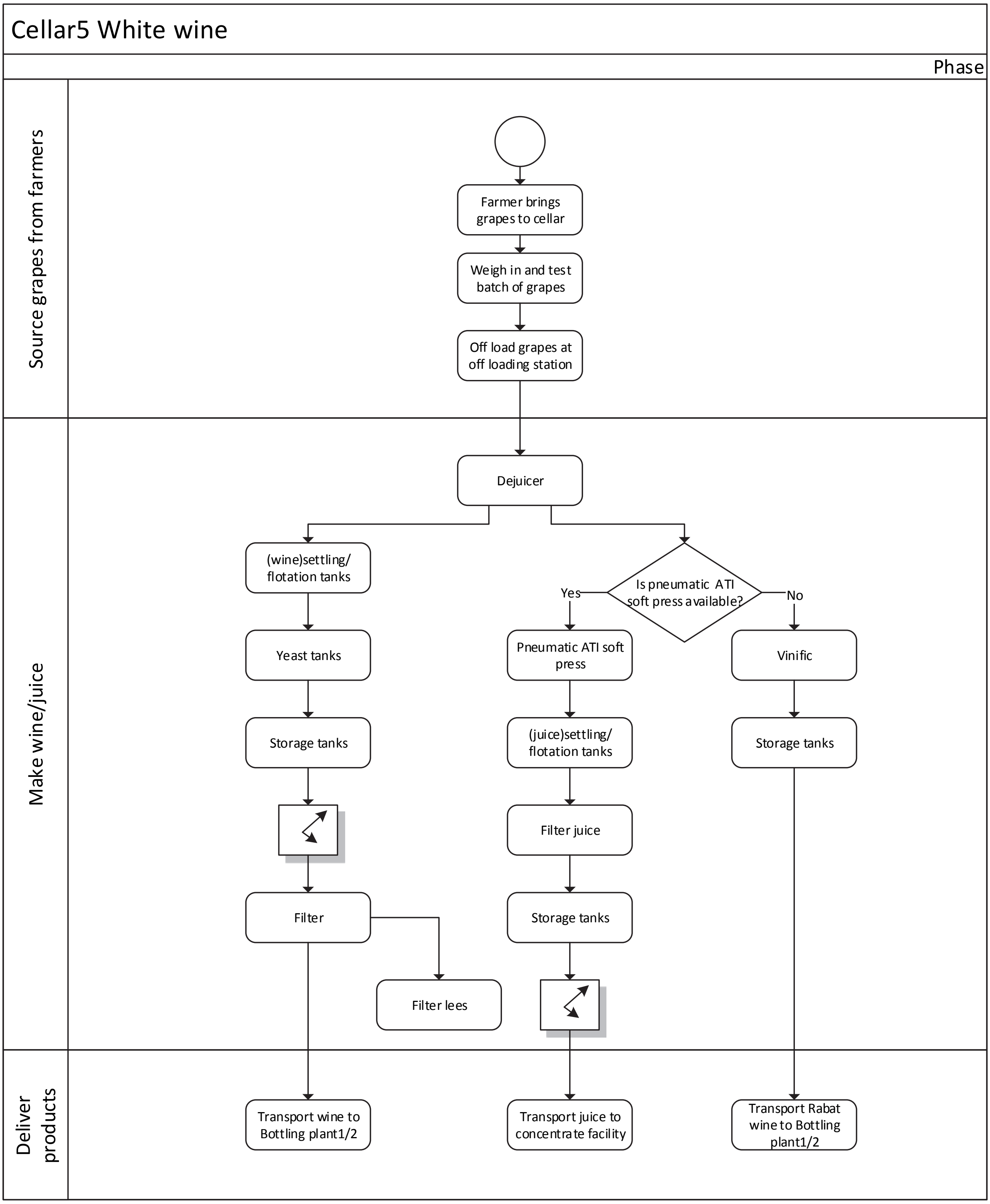

Figure 31: Graphical representation of the process of how white wine is made at Cellar5.

A.6 Red wine production process at Cellar5

When the farmers bring their grapes to Cellar5, the batch of grapes must first be weighed in and a sample is taken to test the sugar, ph. After this is done, the grapes are offloaded at the offloading stations.

Once the grapes are offloaded, it goes through the process of removing the stems from the grapes. The "must" is then pumped into fermentation tanks where it is kept for a few hours until the fermentation process is completed.

The free run wine is then pumped into storage tanks while the pomace is pumped to the dejuicer. The wine that is obtained by this process is also pumped into storage tanks along with the free run wine.
Before the wine is transported to a bottling plant or the market, the wine is filtered by a crossflow filter to remove sediment from the wine. Figure 32 is a representation of the production process of red wine at Cellar5.

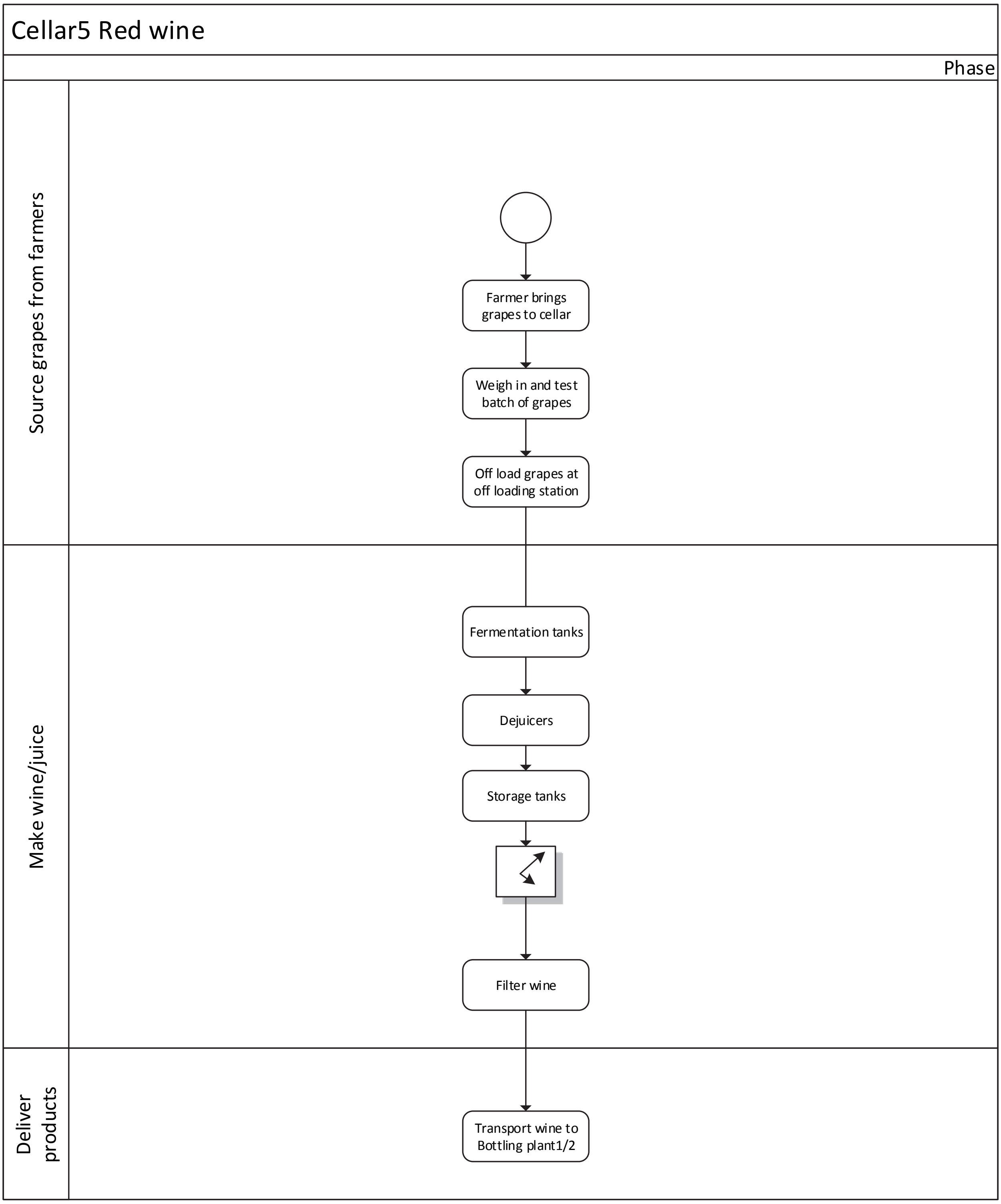

Figure 32: Graphical representation of the process of how red wine is made at Cellar5.

A.7 White wine production process at Cellar6

When the farmers bring their grapes to Cellar6 the batch of grapes must first be weighed in and a sample is taken to test the sugar, ph. After this is done, the grapes are offloaded at the offloading stations.

Once the grapes are offloaded, they go through the process of removing the stems from the grapes. If the grapes are of quality type premium or A1, the grapes are pumped to the dejuicers. The free run is used for wine and the juice obtained from the press process is either used for Rebate or sent to the concentrate facility. In some cases, the juice obtained from the press process can be used for wine. The pomace is pumped to the pneumatic ATI press and the juice obtained from both processes of the pneumatic ATI press is sent to the concentrate facility. If the grapes are of quality type A2 or A3, the must is pumped to the decanter and if the decanter is full they must be pumped to the pneumatic ATI soft presses.

If both the decanter and pneumatic ATI soft presses are full, the must is pumped to the dejuicers.
The juice obtained from the decanter is used for wine. If the wine capacity in the cellar is full, the juice is sent to the concentrate facility. The pomace of the decanter is sent to the final press and the juice obtained from that process is used for Rebate wine.

The juice obtained from the first press of the pneumatic ATI press is used for wine and the juice obtained from the second press is used for Rebate wine. When the Rebate wine capacity is full, the juice is sent to the concentrate facility.

The juice obtained from the free run of the dejuicers is used for wine and the juice obtained from the press process is sent to the concentrate facility. The pomace is pumped to the pneumatic ATI press. The juice obtained from this process is sent to the concentrate facility.

The juice that is obtained from the different process that is going to be used to make wine is then pumped to the (wine) settling/flotation tanks where the juice is left for a few hours until it is ready to be pumped to the yeast tanks.

Once in the yeast tanks, yeast and other chemicals are added to the juice. The juice is then left in the tanks for 12 to 14 days. When the yeast process is completed, the wine is pumped to storage tanks where it is kept until it is needed for either bulk sale or bottling.

Before the wine is transported to either the bottling plant or for bulk sale, the wine is first filtered to remove the lees. The lees are further filtered and the wine obtained from that filtering process is also pumped to the other wine. The wine is then transported to the location where it is required, being either the bottling plant or for bulk sale.

The juice that is obtained by the different processes that is intended to be used for juice or Rebate wine is pumped into (juice) settling/flotation tanks. Once the flotation process is completed the Juice is filtered and pumped into storage tanks where it is kept until it has to be transported to the concentrate facility. Figure 33 representation of the production process of white wine at Cellar6.

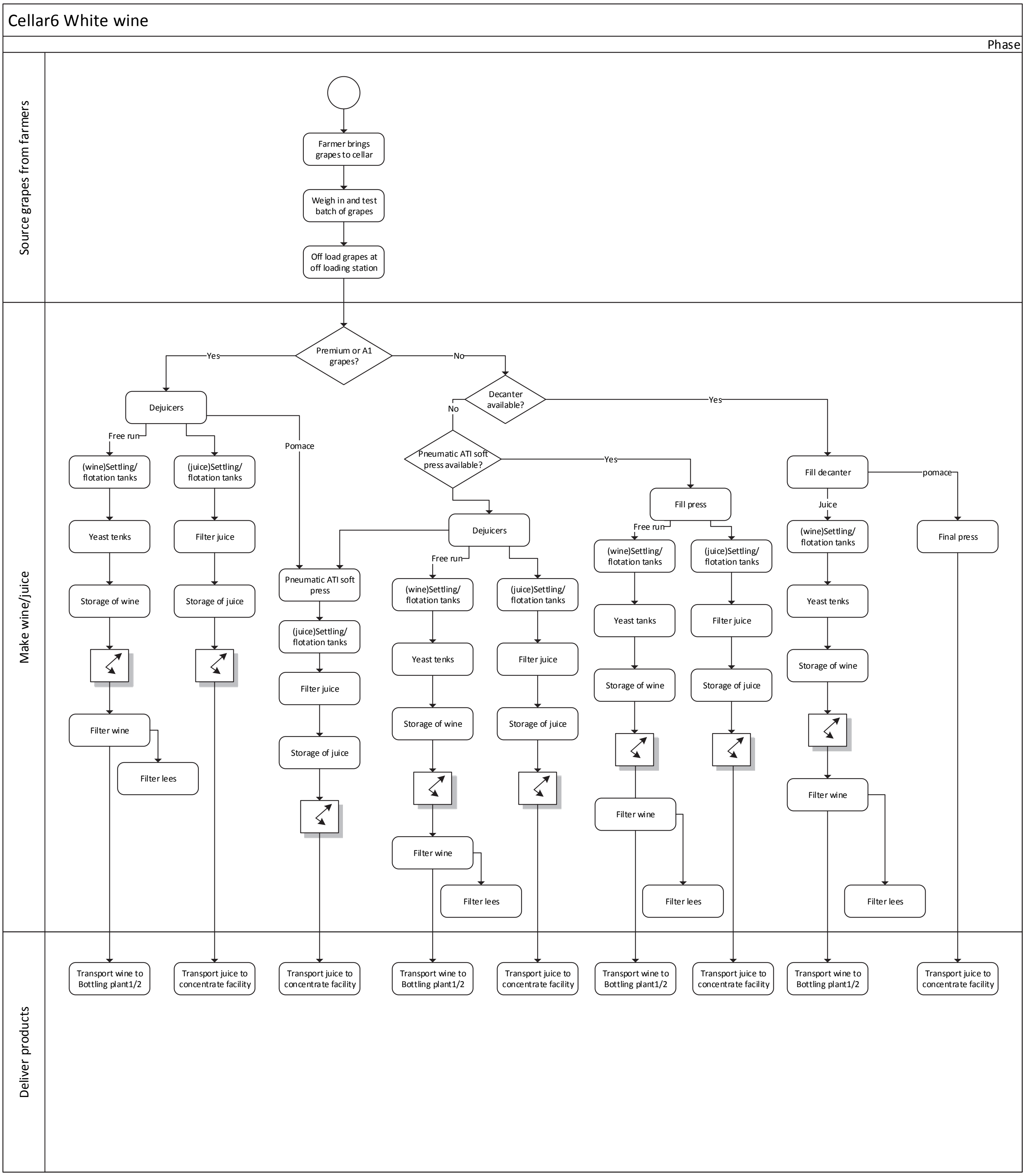

Figure 33: Graphical representation of the process of how white wine is made at Cellar6.

A.8 Red wine production process at Cellar6

When the farmers bring their grapes to Cellar6 the grapes must first be weighed in and a sample is taken to test the sugar, ph. After this is done the grapes are offloaded at the offloading stations.

Once the grapes are off-loaded, they go through the process of removing the stems from the grapes. The "must" is then pumped to the fermentation tanks where the must is kept for a few hours to undergo fermentation. After the fermentation process, the "must" is put through the dejuicer to separate the pomace from the "must".

The wine is then pumped to storage tanks where it is kept until it must be transported.
Before the wine is transported, it is filtered to remove sediment from the wine. Figure 34 is an indication of the proses of making red wine at Cellar6.

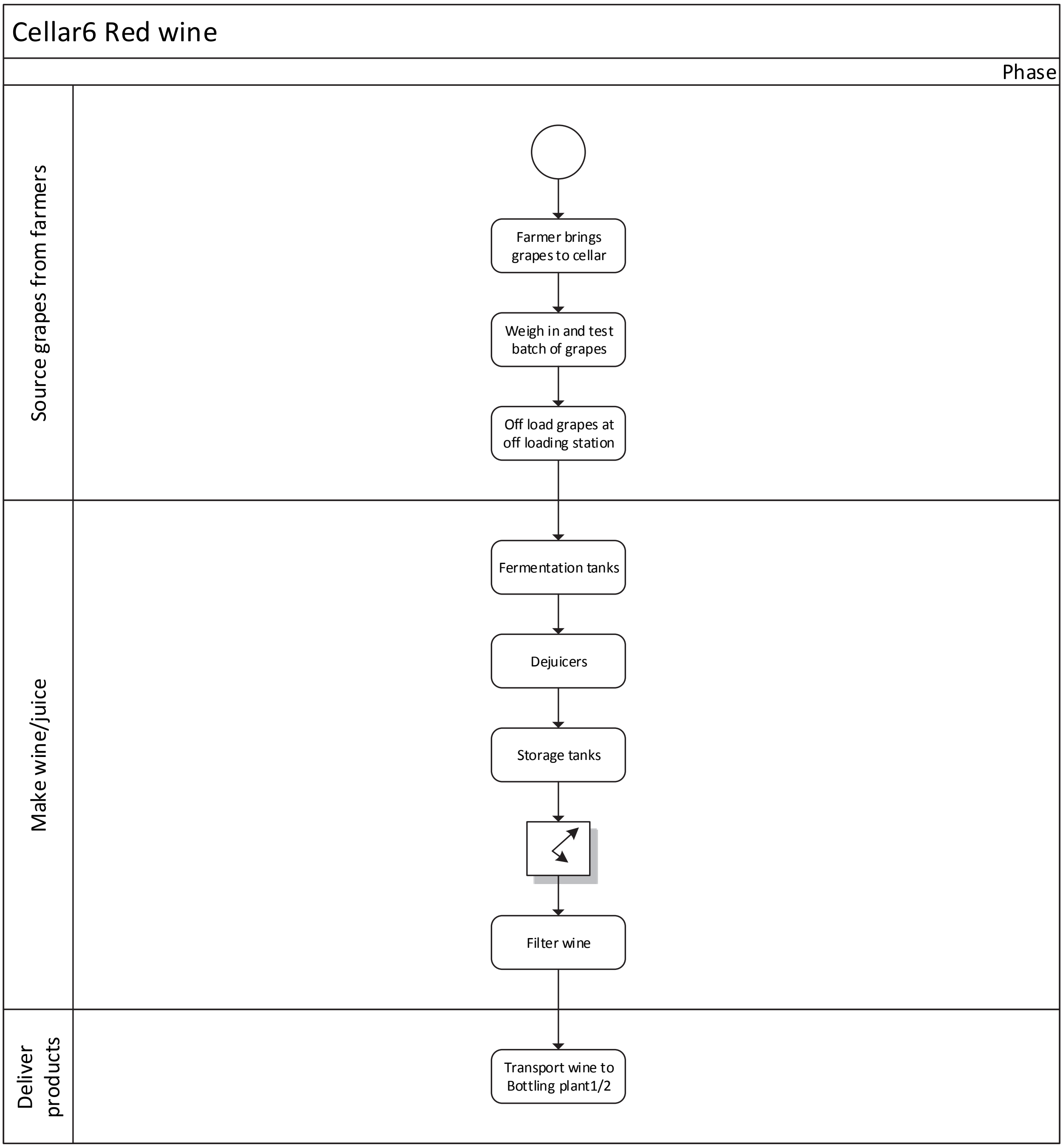

Figure 34: Graphical representation of the process of how red wine is made at Cellar6.

Appendix B

Appendix B contains all the graphs of the amount of grapes received per week during the harvest for every cellar. The amount of juice in the yeast tanks is also shown for every week of the harvest for every cellar.

B.1 Grapes received by Cellar2

Figure 35 is an illustration of the amount of grapes received by Cellar2 during the harvest of 2017.

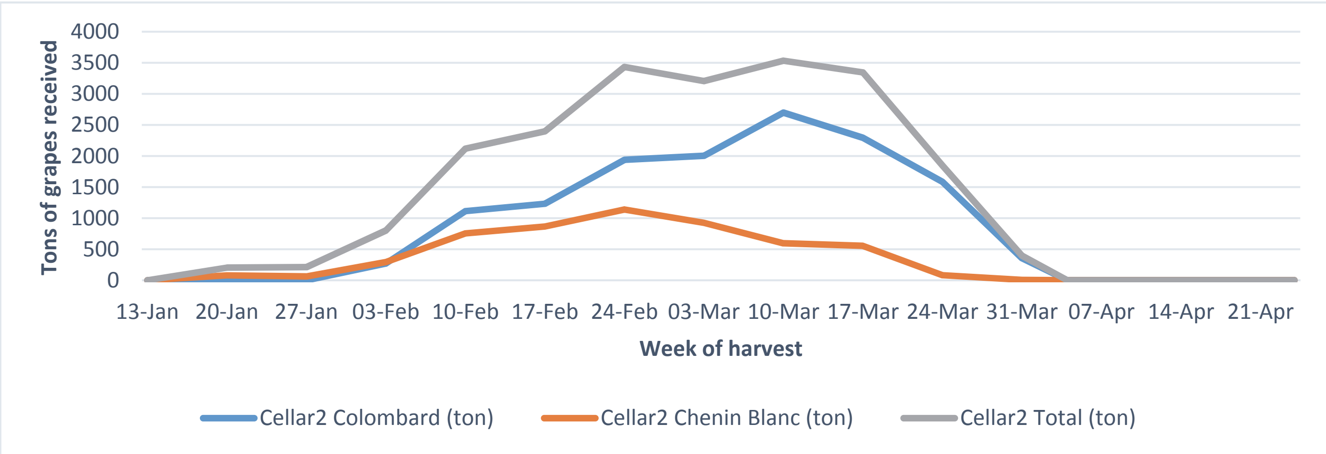

Figure 35: Grapes received by Cellar2 in 2017.

Figure 36 represents the profile of how the yeast capacity of Cellar2 is filled.

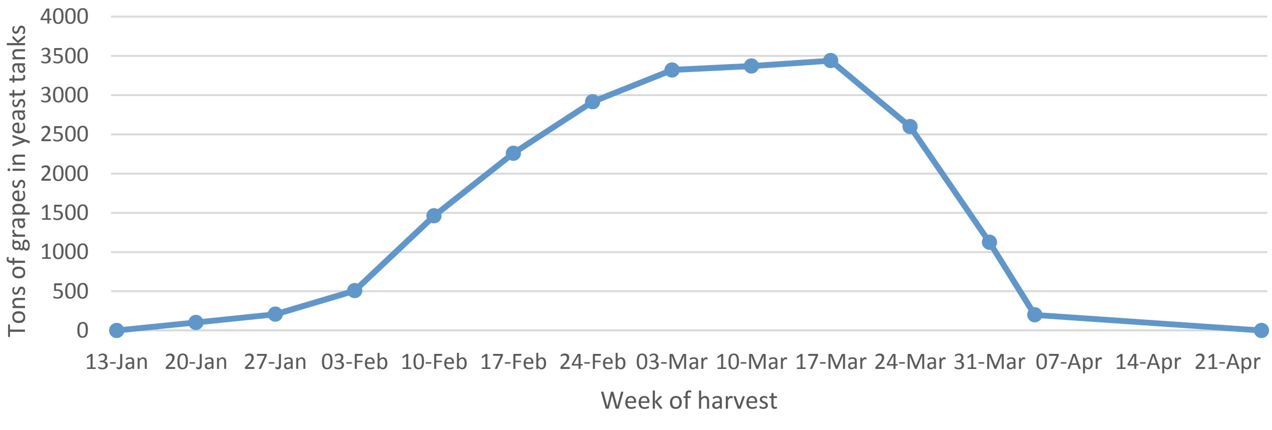

Figure 36: Yeast capacity of Cellar2 in 2017.

B.2 Grapes received by Cellar4

Figure 37 is an indication of the grapes received by Cellar4 per week of the harvest of 2017.

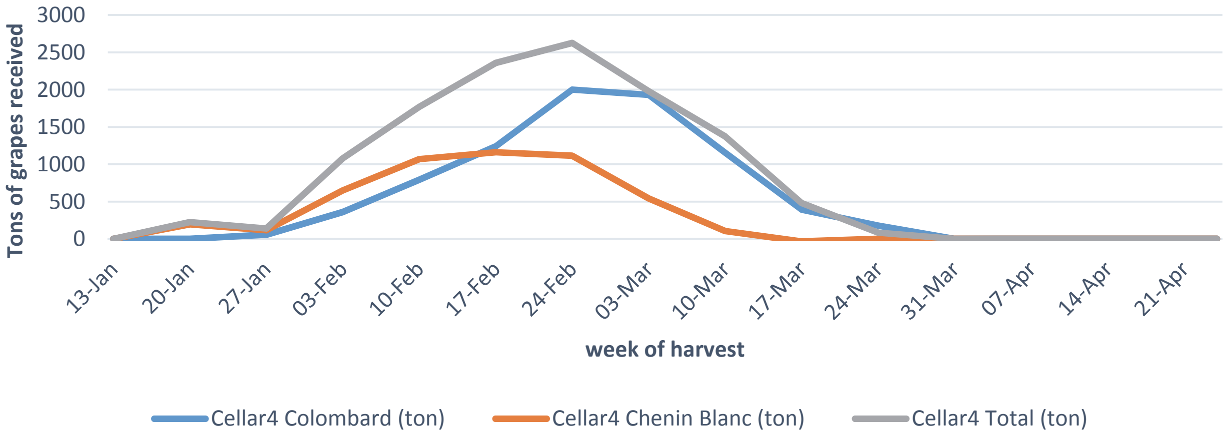

Figure 37: Grapes received by Cellar4 in 2017.

Figure 38 represents the profile of how the yeast capacity of Cellar4 is filled.

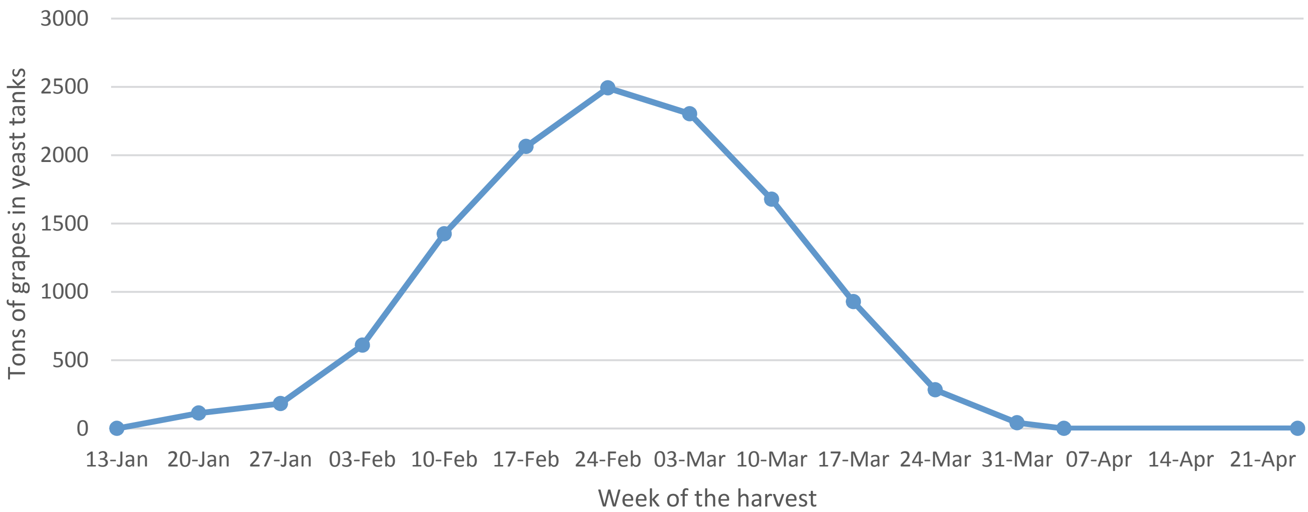

Figure 38: Yeast capacity of Cellar4 in 2017.

B.3 Grapes received by Cellar5

Figure 39 is a profile of how grapes are received by Cellar5 during the harvest of 2017.

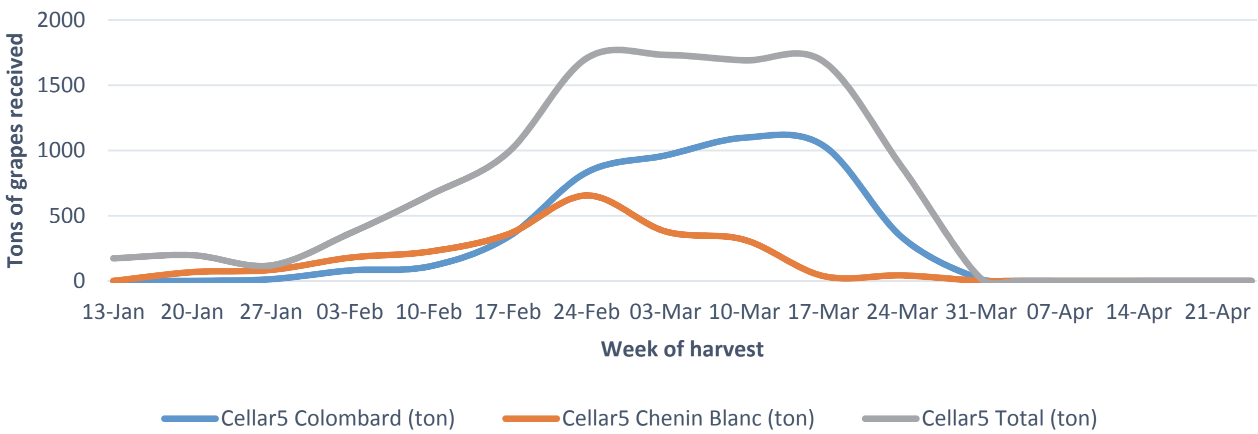

Figure 39: Grapes received by Cellar5 in 2017.

Figure 40 represents the profile of how the yeast capacity of Cellar5 is filled.

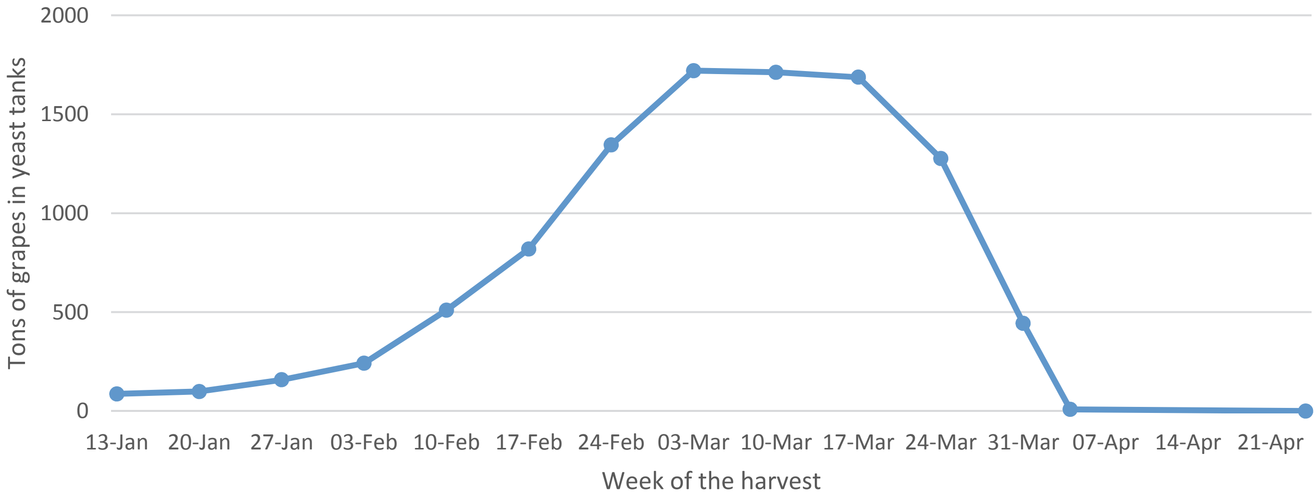

Figure 40: Yeast capacity of Cellar5 in 2017.

B.4 Grapes received by Cellar6

Figure 41 represents the amount of grapes received by Cellar6 per week during the harvest of 2017.

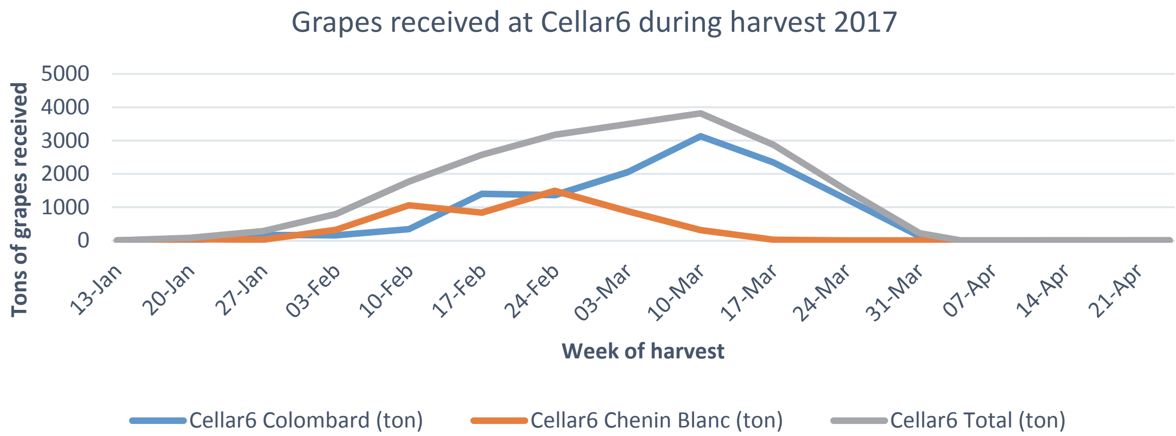

Figure 41: Grapes received by Cellar6.

Figure 42 is an indication of the yeast capacity of Cellar6 per week of the harvest.

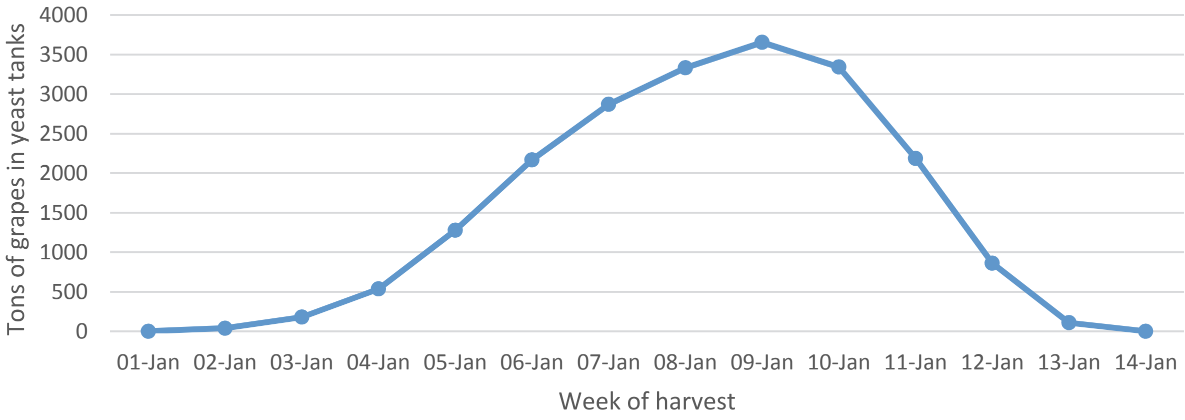

Figure 42: Yeast capacity of Cellar6 in 2017.

B.5 Change in hectares in Northern Cape

From Figure 43 it can be seen how the Colombard and Chenin Blanc hectares in the Northern Cape area have changed over the past 5 years.

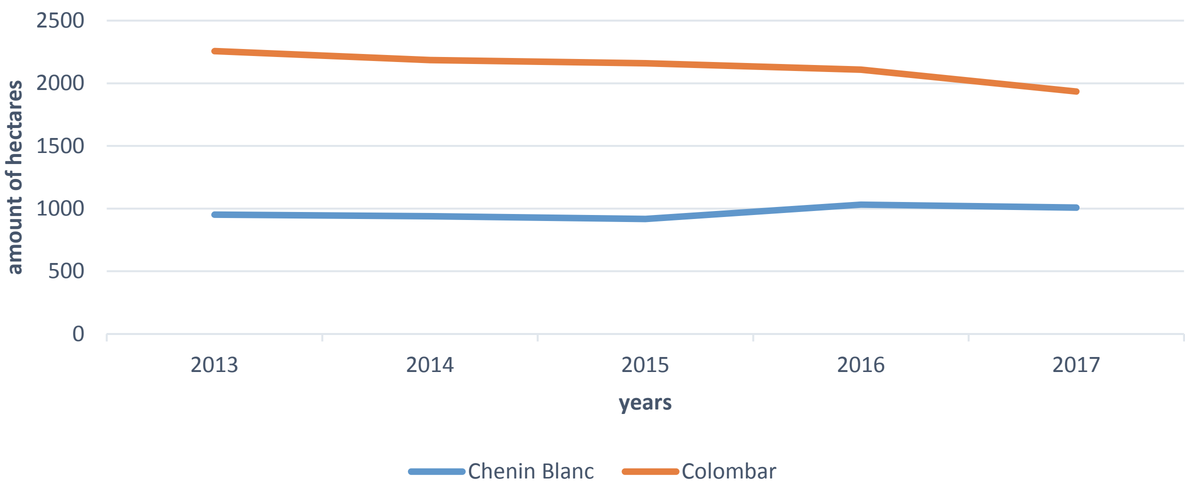

Figure 43: Change in hectares for period 2013 to 2017.

Figure 44 is a graphical representation of how the total hectares changed from the year 2013 to 2017.

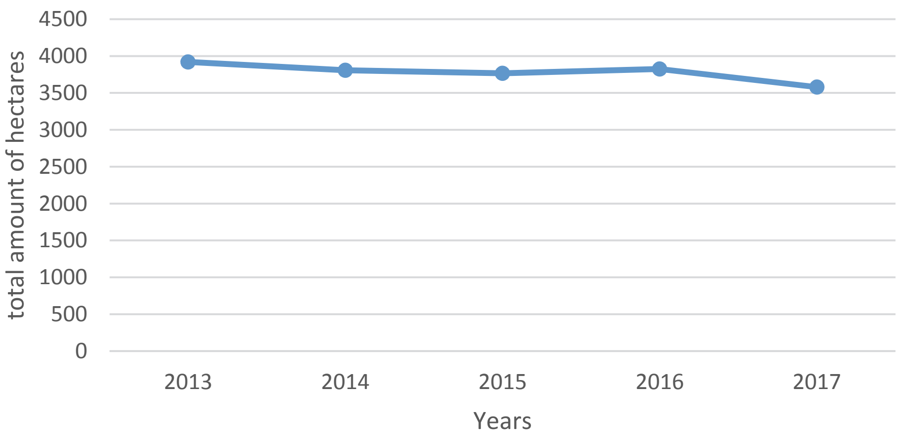

Figure 44: Change in total hectares for period 2013 to 2017.

B.6 Change in grapes received from 2014 to 2017

From Figure 45 it can be seen that the total amount of grapes received by all the cellar has decreased since 2014 and continues to decrease.

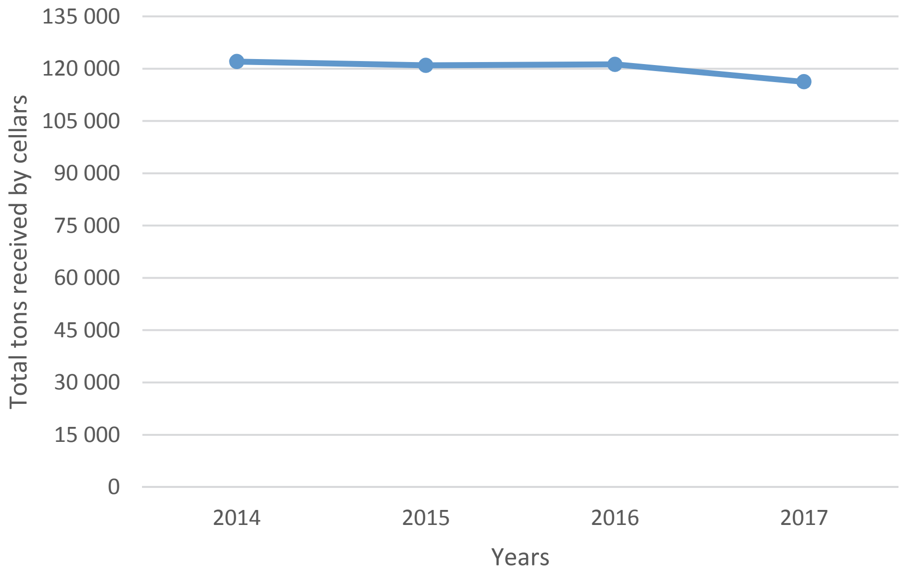

Figure 45: Representation of the tot capacity received by all the cellars for the period 2014 to 2017.

Figure 46 indicates the change in the amount of grapes received by Cellar1 from 2014 up to 2017.

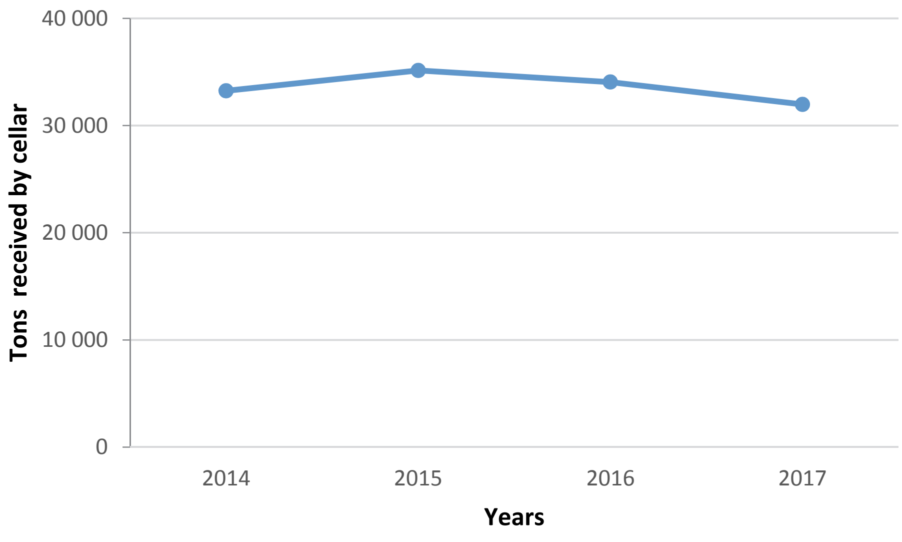

Figure 46: Change in grapes received by Cellar1 for period 2014 to 2017.

Figure 47 is a graphical representation of the change in the amount of grapes received by Cellar2 from 2014 up to 2017.

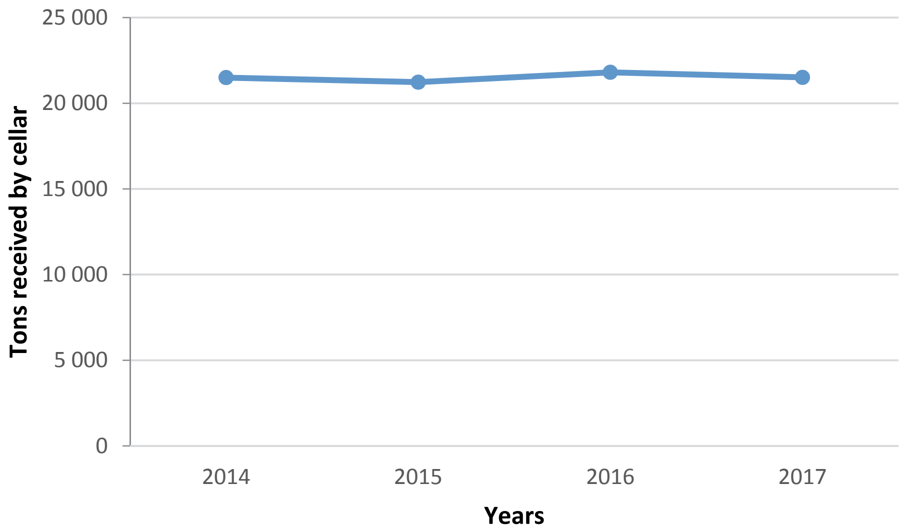

Figure 47: Change in grapes received by Cellar2 for period 2014 to 2017.

Figure 48 indicates the change in the amount of grapes received by Cellar3 for the period 2014 to 2017.

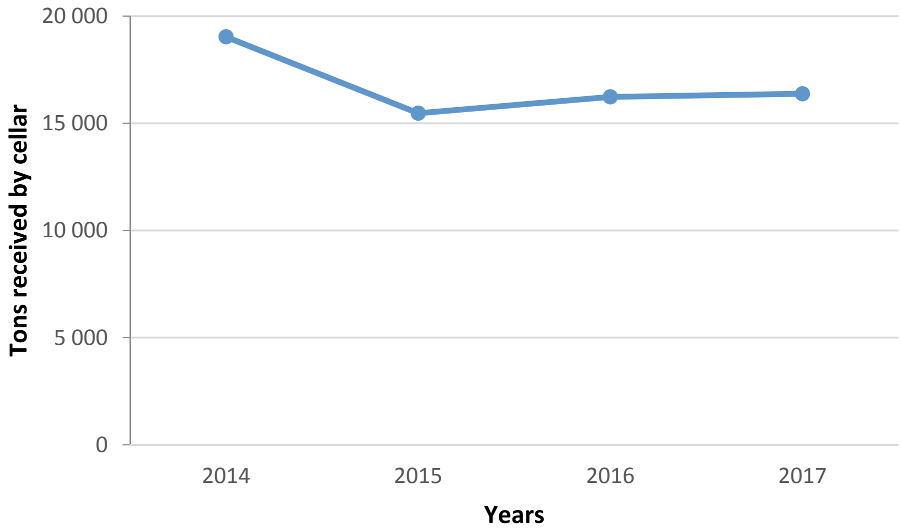

Figure 48: Change in grapes received by Cellar3 for period 2014 to 2017.

Figure 49 is an indication of the change in the amount of grapes received by Cellar4 for the period of 2014 to 2017.

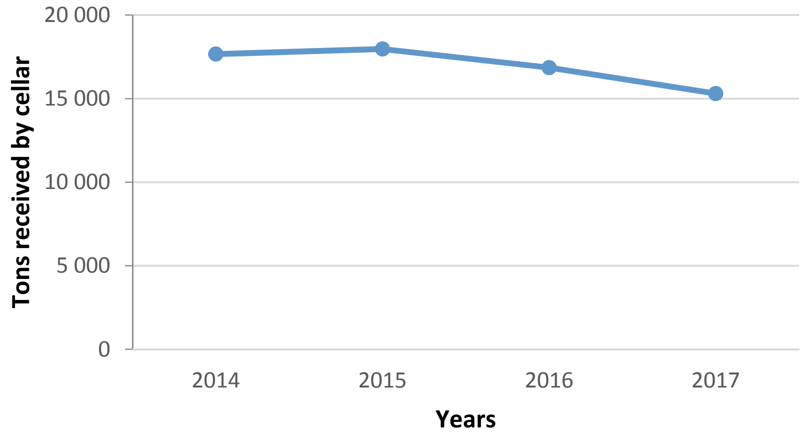

Figure 49: Change in grapes received by Cellar4 for period 2014 to 2017.

Figure 50 is a graphical representation of the change in the amount of grapes received by Cellar5 for the period of 2014 to 2017.

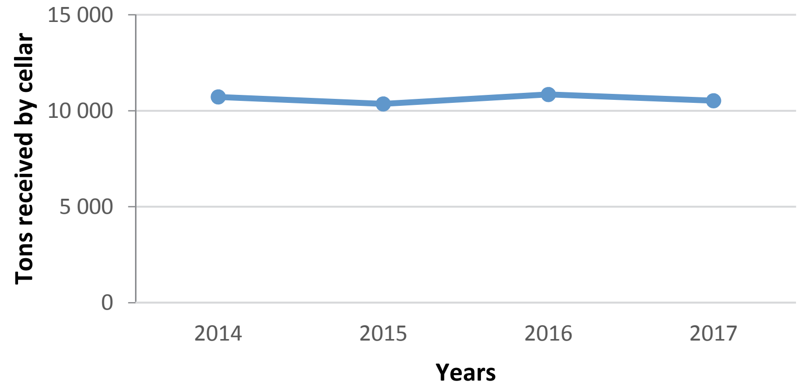

Figure 50: Change in grapes received by Cellar5 for period 2014 to 2017.

Figure 51 represents the change in the amount of grapes received by Cellar6 for the period 2014 to 2017.

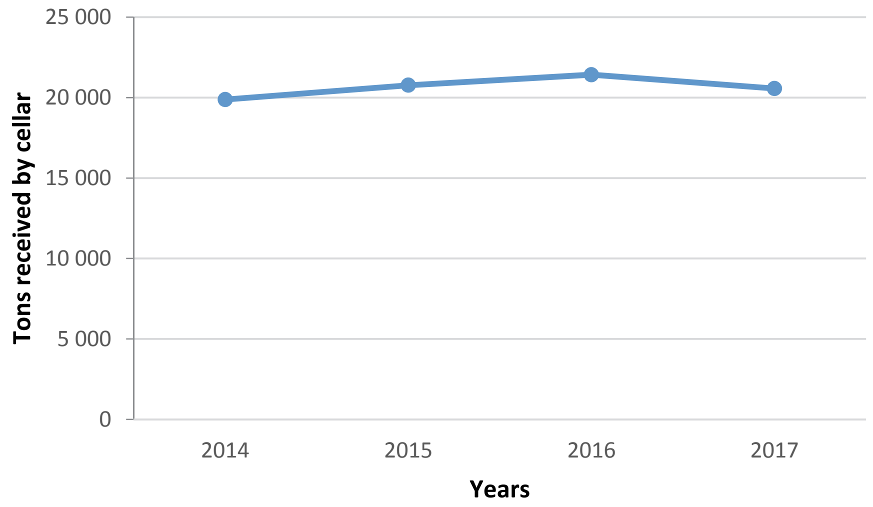

Figure 51: Change in grapes received by Cellar6 for period 2014 to 2017.

Appendix C

Appendix C contains a detailed description of how the Profitability Model, CPLM, Scenario Decision Model and Weighted Decision Matrix work.

C.1 Profitability Model.

For the Profitability Model to work certain inputs needs to be provided. The different inputs per cellar can be seen in the following figures. Figure 52 is a representation of the income input required for the Profitability Model

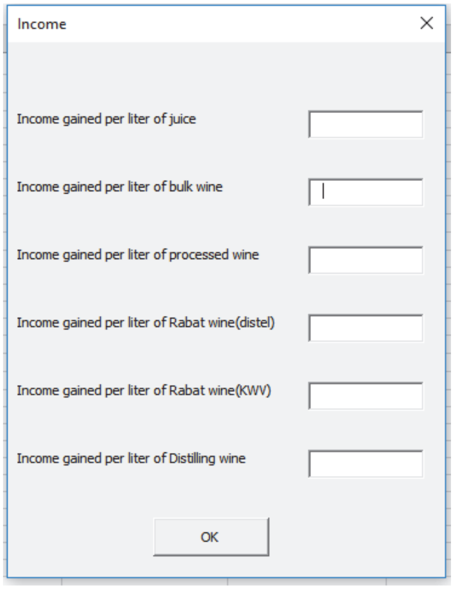

Figure 52: Income input of Profitability Model.

From Figure 53 the cost per litre required to produce the different products can be seen.

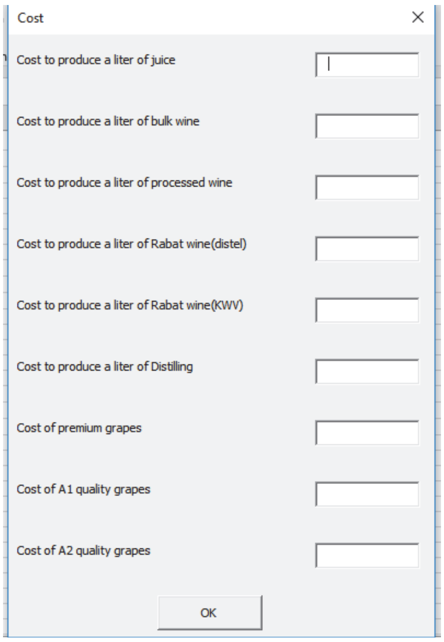

Figure 53: Cost input of Profitability Model.

The next list of input data required is the different volumes of the different products sold by OWK which can be seen in Figure 54.

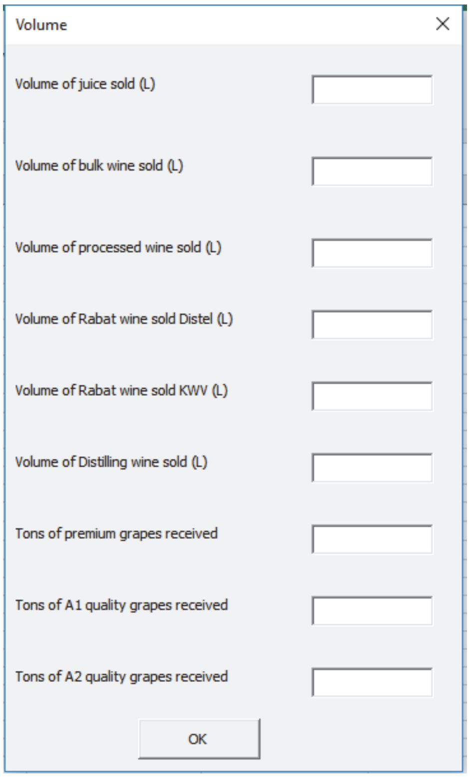

Figure 54: Volume input of Profitability Model.

Figure 55 is a representation of the other costs required for the Profitability Model.

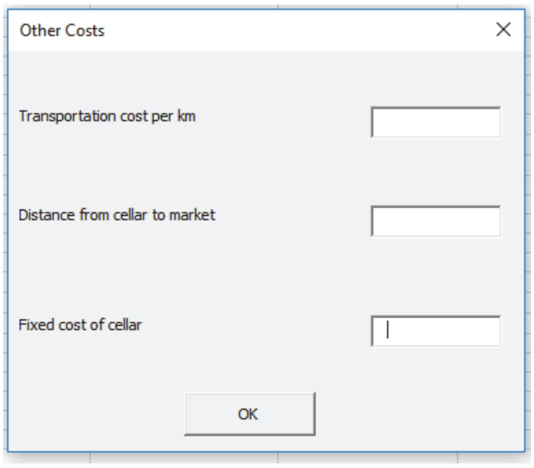

Figure 55: Other cost input of Profitability Model.

The input of the amount of grapes received of the different quality types is displayed in Figure 56.

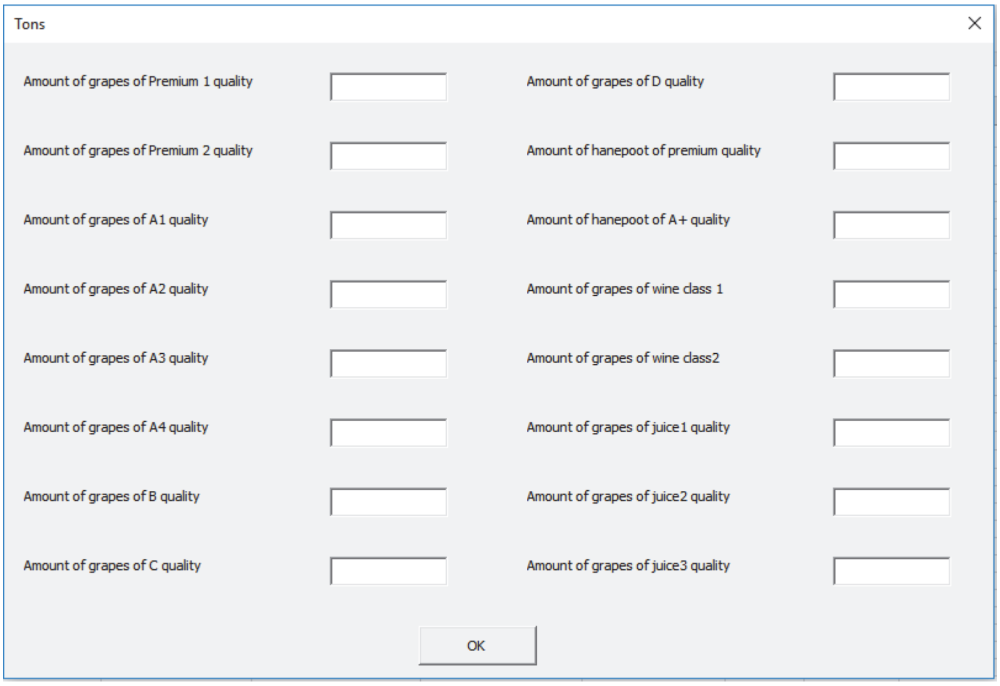

Figure 56: Grapes received input of Profitability Model.

Figure 57 is a representation of the cost of grapes received required for the Profitability Model

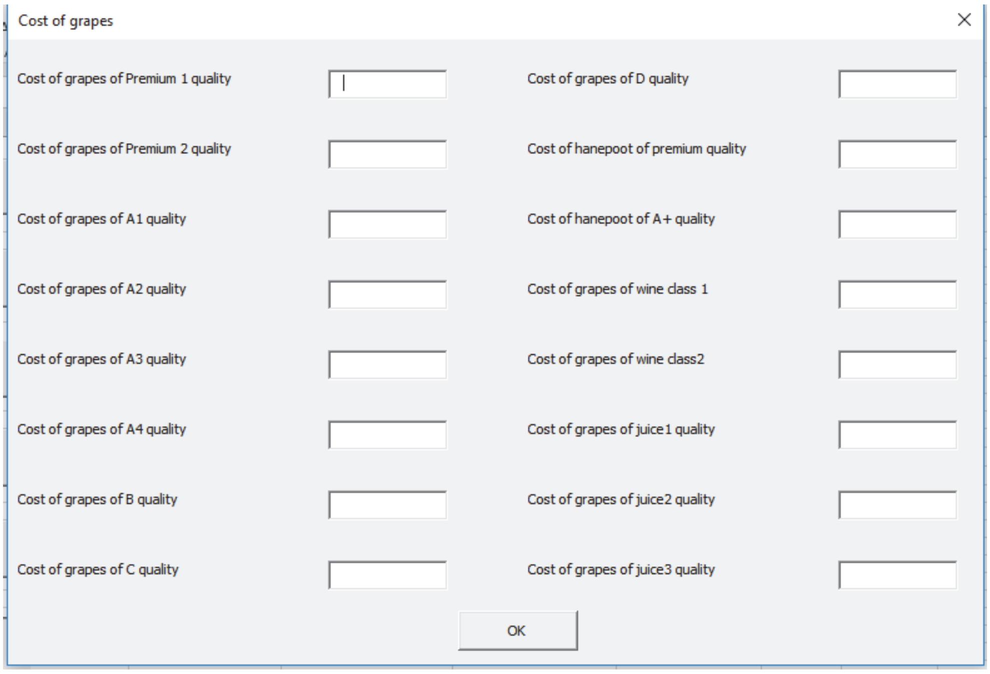

Figure 57: Cost of grapes received input of Profitability Model.

The input data showed in Figure 58 is not financial inputs but are used to measure certain performance aspects of the cellar.

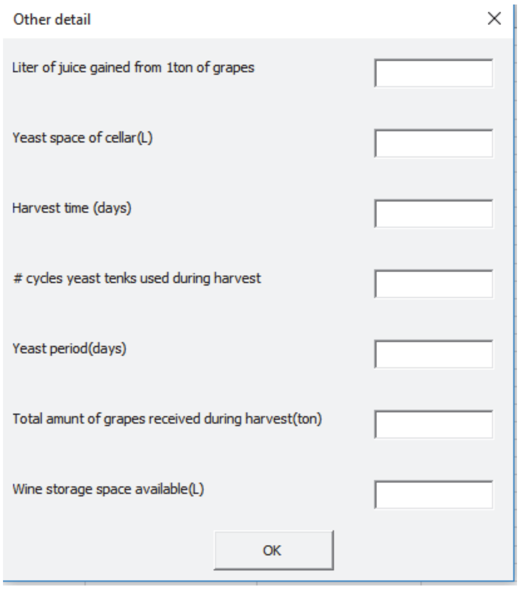

Figure 58: Other detail input of Profitability Model.

After all the different input data is entered into the model the objective function uses it to determine the profitability of the cellar. If the result of the objective function is a positive value it means that the cellar is still profitable and a negative value will means that the cellar is not profitable anymore. If the output of the objective function is a small positive number it means that unless certain changes are made to the cellar it will not be profitable for much longer.

The other input data that is depicted in Figure 58 is used to determine if the performance of the cellar is satisfactory. The data is compared to data that is determined theoretically by using information of the cellar.

If a cellar is not profitable certain sections of the model such as the volume sold and the amount of grapes bought of the different quality types can be investigated to determine what is causing the cellar to not be profitable anymore.

C.2 Weighted Decision Matrix.

The Weighted Decision Matrix was used to determine qualitatively which alternative the company should choose. The different weights are entered into the model and then the model supplies the sum of the weights. Depending on the scale that was the used the alternative with the highest or lowest score would be the most favourable alternative. In the OWK case study the scale was chosen in such a way that the alternative with the highest score was the most favourable alternative. Figure 59 is a representation of the Weighted Decision Matrix that was used in the OWK case study.

	People			Finance	Product		Infrastructure		
Factors:	Supplier	Employee	Community	Network cost	Product range	Product quality	Transport infrastructure	Cellar infrastructure	**Total**
Weights	5	5	4	4	3	3	3	4	
Scenario 1	3	3	3	3	3	3	3	3	93
Scenario 2	1	1	1	3	3	3	3	4	69
Scenario 3	2	2	2	2	3	2	3	4	76
Scenario 4	1	1	1	3	3	2	3	4	66

Figure 59: Depiction of the Weighted Decision Matrix.

Appendix D

Appendix D contains the outputs of the different models that was used as part of the framework that was developed.

D.1 Output of Profitability Model

Figure 60 is an indication of the Profitability Model. This is only the top third of the model seeing that the entire model cannot fit onto one page as it is too large. From this figure it can also be seen that Cellar6 is still feasible from a financial point of view.

Description	year
	2016
Income(R) gained per L of product sold	
Income juice	3,915
Income bulk wine	6,4525
Income processed wine	7,25
Income Rabat wine(distel)	7,0035
Income Rabat wine(KWV)	6,1045
Income distilling wine	2,842
Cost of producing 1L of product	
Cost of juice	0,87
Cost of Bulk wine	1,74
Cost of processed wine	1,74
Cost of Rabat wine (distel)	1,305
Cost of Rabat wine (KWV)	1,305
Cost of Distilling wine	0,87
Cost of buying 1ton pf grapes of quality type:	
Premium 1	6 742,50
Premium 2	5 056,15
A1	2 972,50
A2	2 508,50
A3	2 320,00
A4	2 022,75
B	1 798,00
C	1 460,15
D	1 123,75
Hanepoot Premium	5 056,15
Hanepoot A+	2 697,00
Wineclass 1	4 045,50
WineClass2	3 371,25
Juice 1	1 957,50
Juice 2	1 663,15
Juice 3	1 271,65

Income
Cost
Volume
Other Costs
Tons received
Cost per Ton
Trips
Other detail

Transport capacity	32500	
Objective function		
z =	10 414 269,14	Facility is still feasible

Figure 60: Indication of the top part of the layout of the Profitability Model.

Figure 61 is an representation of the middle part of the Profitability Model as the entire model is too large to fit onto one page.

Volume(L)	
Volume of Juice	6 717 995,00
Volume of Bulk wine	8 799 812,20
Volume of processed wine	4 615 979,30
Volume of Rabat wine(distel)	0,00
Volume of Rabat wine(KWV)	1 244 100,00
Volume of Distilling wine	2 024 635,00
Tons bought of quality type:	
Premium 1	92,16
Premium 2	519,36
A1	3 765,19
A2	10 207,13
A3	11 082,48
A4	1 107,44
B	552,74
C	419,98
D	0,00
Hanepoot Premium	29,96
Hanepoot A+	1 057,85
Wineclass 1	299,57
WineClass2	678,99
Juice 1	0,00
Juice 2	0,00
Juice 3	0,00
Other costs	
Transport cost/ km	134,85
Distance from cellar to Upington cellar	0
Fixed cost of cellar	11422332,95

Figure 61: Representation of the middle part of the layout of the Profitability Model.

Figure 62 is a representation of the bottom part of the Profitability Model.

Trips to move product	
# trips to move juice to Upt cellar	207,35
# trips to move bulk wine to Upt cellar	271,15
# trips to move processed wine to Upt cellar	142,1
# trips to move Rabat wine to Upt cellar (distel)	0
# trips to move Rabat wine to Upt cellar (KWV)	39,15
# trips to move Distilling wine to Upt	62,35
Other	
L juice/ ton grapes	1117,95
Yeast space of cellar (L)	8845000
Harvest time (days)	87
# cycles yeast tenks used in harvest	5,8
Yeast period	21,75
Total amunt of grapes received during harvest	31183,7
Wine storage space available	10295000

Figure 62: Indication of the bottom part of the Profitability Model.

From Figure 63 it can be seen that Cellar5 is not profitable anymore from a financial point of view.

Description	year
	2016
Income(R) gained per L of product sold	
Income juice	3,441532145
Income bulk wine	5,646662001
Income processed wine	6,628135983
Income Rabat wine(distel)	4,767159342
Income Rabat wine(KWV)	5,187791049
Income distilling wine	2,35808684
Cost of producing 1L of product	
Cost of juice	0,764784921
Cost of Bulk wine	1,529569842
Cost of processed wine	1,529569842
Cost of Rabat wine (distel)	1,147177382
Cost of Rabat wine (KWV)	1,147177382
Cost of Distilling wine	0,764784921
Cost of buying 1ton pf grapes of quality type:	
Premium 1	5 927,08
Premium 2	4 444,68
A1	2 613,02
A2	2 205,13
A3	2 039,43
A4	1 778,12
B	1 580,56
C	1 283,56

Income | Cost | Volume | Other Costs | Tons received

Transport capacity	32500	
Objective function		
Z =	-8 787 015,27	Facility is not feasible

Figure 63: Indication of the profitability of Cellar5.

From Figure 64 it can be seen that Cellar4 is slightly non-profitable. Cellar4 can however be made profitable with a small adjustment of the product mix.

Description	year
	2016
Income(R) gained per L of product sold	
Income juice	3,915
Income bulk wine	6,4525
Income processed wine	7,25
Income Rabat wine(distel)	7,0035
Income Rabat wine(KWV)	6,1045
Income distilling wine	2,842
Cost of producing 1L of product	
Cost of juice	0,87
Cost of Bulk wine	1,74
Cost of processed wine	1,74
Cost of Rabat wine (distel)	1,305
Cost of Rabat wine (KWV)	1,305
Cost of Distilling wine	0,87
Cost of buying 1ton pf grapes of quality type:	
Premium 1	6 742,50
Premium 2	5 056,15
A1	2 972,50
A2	2 508,50
A3	2 320,00
A4	2 022,75
B	1 798,00
C	1 460,15
D	1 123,75
Hanepoot Premium	5 056,15
Hanepoot A+	2 697,00
Wineclass 1	4 045,50

Income | Cost | Volume | Other Costs | Tons received | Cost per Ton

Transport capacity	32500	
Objective function		
Z =	-140 344,62	Facility is not feasible anymore

Figure 64: Indication of the profitability of Cellar4.

Figure 65 indicates that Cellar3 is still profitable. From the figure it can be noted that some of the input data is zero values. This is because this cellar only produce juice and the zero values are the input data for if a cellar produces juice and wine. All cost are in South African rand currency.

Description	year
	2016
Income(R) gained per L of product sold	
Income juice	3,915
Income bulk wine	6,4525
Income processed wine	7,25
Income Rabat wine(distel)	7,0035
Income Rabat wine(KWV)	6,1045
Income distilling wine	2,842
Cost of producing 1L of product	
Cost of juice	0,87
Cost of Bulk wine	1,74
Cost of processed wine	1,74
Cost of Rabat wine (distel)	1,305
Cost of Rabat wine (KWV)	1,305
Cost of Distilling wine	0,87
Cost of buying 1ton pf grapes of quality type:	
Premium 1	0,00
Premium 2	0,00
A1	0,00
A2	0,00
A3	0,00
A4	0,00
B	0,00
C	0,00
D	0,00
Hanepoot Premium	0,00
Hanepoot A+	0,00
Wineclass 1	0,00

Income | Cost | Volume | Other Costs | Tons received | Cost per Ton

Transport capacity	32500	
Objective function		
z =	4 311 244,12	Facility is still feasible

Figure 65: Indicates the profitability of Cellar3.

Figure 66 depicts the profitability of Cellar2. From the figure it is clear that Cellar2 is still profitable. All cost are in South African rand currency.

Description	year
	2016
Income(R) gained per L of product sold	
Income juice	3,915
Income bulk wine	6,4525
Income processed wine	7,25
Income Rabat wine(distel)	7,0035
Income Rabat wine(KWV)	6,1045
Income distilling wine	2,842
Cost of producing 1L of product	
Cost of juice	0,87
Cost of Bulk wine	1,74
Cost of processed wine	1,74
Cost of Rabat wine (distel)	1,305
Cost of Rabat wine (KWV)	1,305
Cost of Distilling wine	0,87
Cost of buying 1ton pf grapes of quality type:	
Premium 1	6 742,50
Premium 2	5 056,15
A1	2 972,50
A2	2 508,50
A3	2 320,00
A4	2 022,75
B	1798,00
C	1460,15
D	1123,75
Hanepoot Premium	5 056,15
Hanepoot A+	2 697,00
Wineclass 1	4 045,50

Income | Cost | Volume | Other Costs | Tons received | Cost per Ton

Transport capacity	32500	
Objective function		
z =	12 820 737,07	Facility is still feasible

Figure 66: Representation of the profitability of Cellar2.

D.2 Output of Scenario Decision Model

Figure 67 is a representation of the output of the second alternative. This alternative state that the cellar be closed down and the equipment moved to the other cellar that must accommodate the closed cellars' capacity. All cost are in South African rand currency.

Cellar direct cost			1198 883,20
Admin	69 581,15		
Insurance	69 581,15		
Depreciation	0,00		
Personel	0,00		
Security	456 352,70		
Water and electricity	315 431,55		
Maintenance	357 517,80		
Infrastructure of other cellars accomodating the extra supply			324032,95
Cost of upgrading other cellar that has to accommodate the extra capacity	314309,25		
Expansion(moved closed cellar equipment or buy new equipment)			
Move existing equipment from cellar	1944,74	Buy new equipment	29171,1
Transport cost	4861,85	Transport cost	9723,7
Installation cost	2917,11	Installation cost	2917,11
	9723,7		41811,91
Transport			530395,5
Grapes	530395,5		
Wine/juice	0		
Total cost	2 053 311,65		

Figure 67: Presents the output of the Scenario Decision Model for the second alternative.

Figure 68 presents the output for the third alternative of the Scenario decision Model. In the alternative the cellar will be closed but certain operations such as crushing and pressing will still be performed at the cellar. The “must” will then be transported to the other cellar that must accommodate the capacity of the infeasible cellar. All cost are in South African rand currency.

Cellar direct cost			3 616 549,40
Admin	262 202,05		
Insurance	139 163,75		
Depreciation	123 038,30		
Personel	1577 791,40		
Security	456 352,70		
Water and electricity	525 719,25		
Maintenance	794 484,00		
Infrastructure of other cellars accomodating the extra supply			45615,84
Cost of upgrading other cellar that has to accommodate the extra capacity	38809,25		
Expansion(moved closed cellar equipment or buy new equipment)			
Move existing equipment from cellar	1944,74	Buy new equipment	29171,1
Transport cost	1944,74	Transport cost	9723,7
Installation cost	2917,11	Installation cost	2917,11
	6806,59		41811,91
Transport			1958383,05
Grapes			
Wine/juice	1958383,05		
Total cost	5 620 548,29		

Figure 68: Representation of the third alternative of the Scenario Decision Model.

Figure 69 presents the output of the fourth alternative of the Scenario Decision Model. In this alternative the cellar will be closed down completely and the equipment will be left at the closed cellar. All cost are in South African rand currency.

Cellar direct cost			1198 883,20
Admin	69 581,15		
Insurance	69 581,15		
Depreciation	0,00		
Personel	0,00		
Security	456 352,70		
Water and electricity	315 431,55		
Maintenance	357 517,80		
Infrastructure of other cellars accomodating the extra supply			0
Cost of upgrading other cellar that has to accommodate the extra capacity			
Expansion(moved closed cellar equipment or buy new equipment)			
Move existing equipment from cellar		Buy new equipment	
Transport cost		Transport cost	
Installation cost		Installation cost	
	0		0
Transport			0
Grapes	0		
Wine/juice	0		
Total cost	1198 883,20		

Figure 69: Representation of the fourth alternative of the Scenario Decision Model.

Appendix E

Appendix E contains the future predicted amount of grapes that might be received by the different cellars. Figure 70 is an indication of the future prediction of the supply of grapes to Cellar2 from 2018 to 2022.

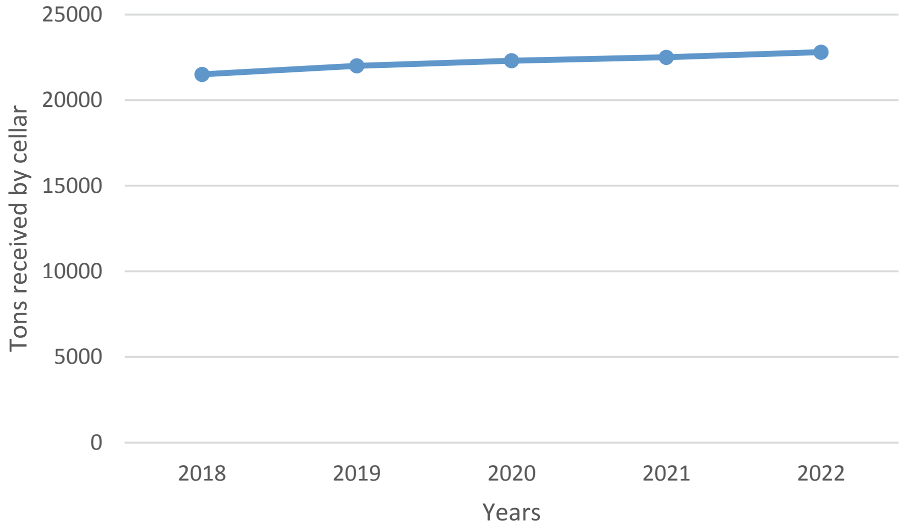

Figure 70: Future capacity prediction of Cellar2.

Figure 71 is an indication of the future prediction of the supply of grapes to Cellar4 from 2018 to 2022.

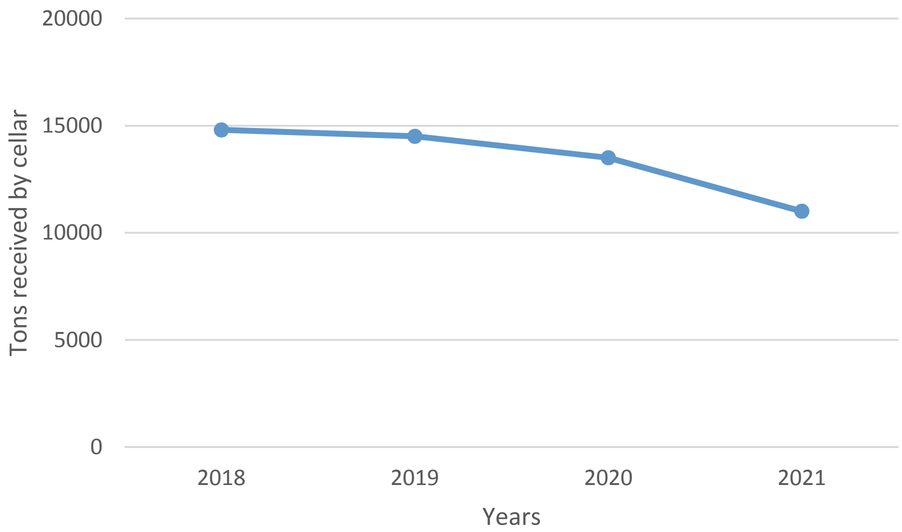

Figure 71: Future capacity prediction of Cellar4.

Figure 72 is an indication of the future prediction of the supply of grapes to Cellar5 from 2018 to 2022.

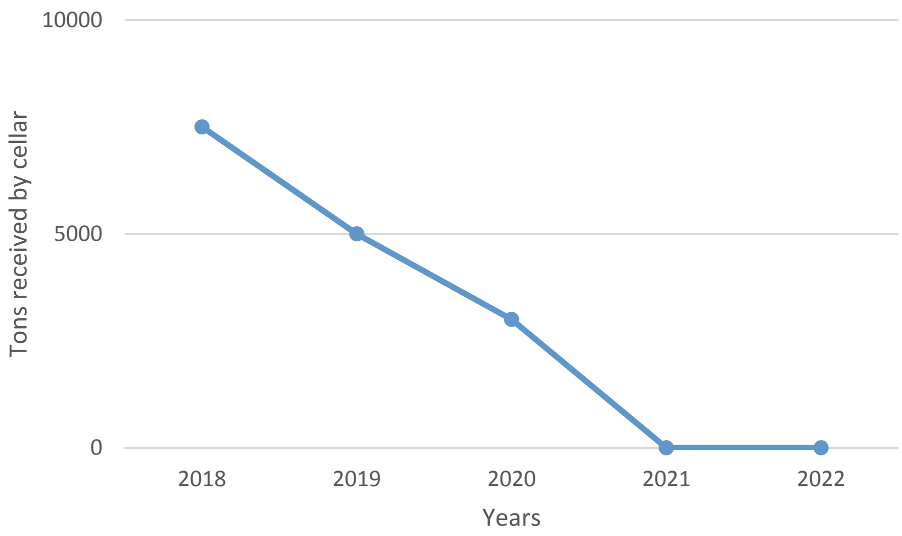

Figure 72: Future capacity prediction of Cellar5.

Figure 73 is an indication of the future prediction of the supply of grapes to Cellar6 from 2018 to 2022.

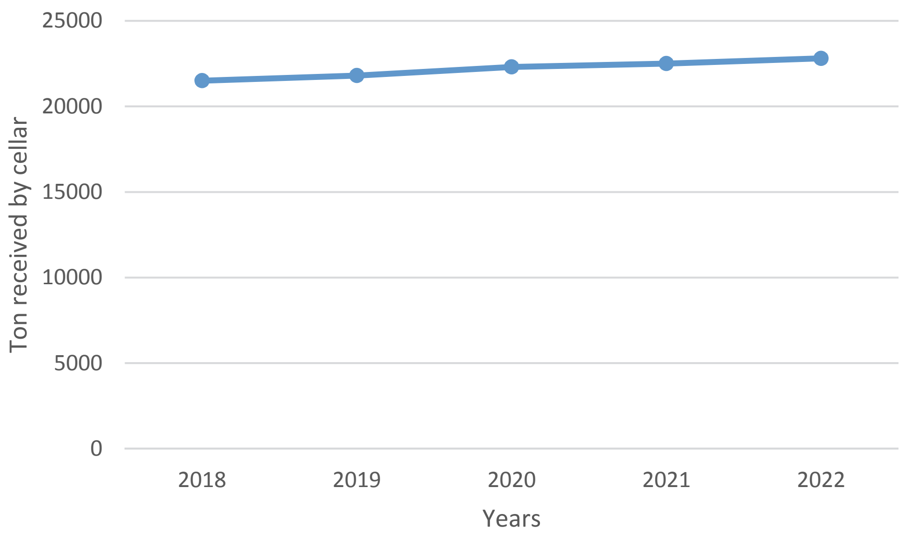

Figure 73: Future capacity prediction of Cellar6.