AN OVERVIEW OF SUGARCANE SUPPLY CHAIN INCONSISTENCIES

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Submitted in partial fulfilment of the requirements for the degree of PhD

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Pietermaritzburg
March 2013

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ABSTRACT

A supply chain is an integrated network involving people, organizations, information, activities and resources. The parties in supply chains must be able to accommodate fluctuations and uncertainty because these are major factors that affect supply chain performance. In this study, the sugarcane supply chain is defined as a generally inclusive agri-industrial system that aims to grow, harvest, transport and process sugarcane from the field to the mill. This literature study involved a discussion of the factors which cause inconsistencies in sugarcane supply chains and the strategies implemented for improvement.

In the sugarcane supply chain, the pertinent properties that cause quality inconsistencies were found to include seasonality, harvesting techniques, a large number of varieties and the burn-harvest-to-crush delay. Cane flow inconsistencies are caused by weather and harvesting time influences, transport issues and cane bulk density influences. They have a negative impact on mill operations and capacity. Strategies used to improve the sugarcane system include an optimization milling season model, sugar payment systems, stockpiling, a daily rateable delivery system, vehicle scheduling and rearranged harvest schedules. However, these strategies will only be successful through constant communication and trust throughout the system. Also, it is unlikely that one strategy improvement will improve all systems simultaneously.

This document also contains a project proposal, which aims to estimate an appropriate milling season, in each sugarcane region of South Africa. It will be the first appropriate season model for each sugarcane milling season in South Africa. The model will be compared to results from the author’s MSc study at the Eston sugarcane region, in order to test and evaluate the accuracy of the solutions. An economic module will also be developed, in order to quantify the impacts of different solutions. Thereafter, the model, including the economic module, will be utilized in other milling regions in South Africa.
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1. INTRODUCTION

An integrated production network that typically involves people, organizations, activities, information and resources is known as a supply or value chain. The system works together with the aim of acquiring raw materials and converting them into a specific final higher-value product, which is then distributed to the consumer (Beamon, 1998; Pitty et al., 2008). This can be achieved by using processing activities such as transportation, storage and market mediation (Das and Abdel-Malek, 2003). It usually is characterised by a forward flow of materials and a backward flow of information and revenue (Gaucher et al., 2004).

There are inconsistencies which occur in supply chains that make it difficult for the sugarcane industry to be consistent. Optimal resource allocations could be hindered due to the presence of these inefficiencies in the system. Inconsistencies and uncertainties create risk and may erode profitability for the parties involved in supply chains (Le Gal et al., 2008). Inconsistencies in the sugar industry occur due to many logistical, social, economic and physiological linkages across the chain. Many of these factors are inter-connected and difficult to quantify (Higgins and Lerado, 2006). In addition, most of these inefficiencies are due to the various stakeholders having different overall objectives. Each stakeholder aims to fully optimize his/her individual processes, rather than the global operation (Lejars et al., 2008; Le Gal et al., 2008). For example, growers try to maximize revenue by crushing the cane over a short period of time, due to cane quality reduction at the end of the season. Millers and transporters, on the other hand, try to prolong the season to maximize capacity utilization, in order to reduce fixed costs per unit of production (Moor and Wynne, 2001).

Lejars et al. (2008) and Bezuidenhout and Baier (2011) found that large quantities of research in the sugar industry have not been implemented. This is due to many of the proposed solutions excluding issues in the supply chain, such as collaboration, innovation and information sharing. In addition, Higgins et al. (2007) state that there have been limited studies on supply chain solutions for the sugar industry, compared to the manufacturing and automobile sectors. This is mainly because agricultural industries, including sugar, are generally more complex (Higgins et al., 2007; Bezuidenhout et al., 2012). Furthermore, research carried out in seven milling areas in...
South Africa (Boote et al., 2011; Sibomana et al., 2011; Bezuidenhout et al., 2012, Kadwa et al., 2012; Sanjika et al., 2012; Kadwa and Bezuidenhout; 2013; Sibomana and Bezuidenhout, 2013; Bezuidenhout et al., 2013) have all highlighted issues concerning what are perceived to be the appropriate milling season. The sugarcane supply chain, therefore, needs to be researched more holistically than in the past, while considering various issues concurrently, before any significant improvements can be made (Le Gal et al., 2004; Bezuidenhout and Baier, 2011).

AIMS AND OBJECTIVES:

This document has two aims:

1. Firstly, to conduct a brief literature review of (a) an outline of the sugarcane supply chain and its processes, (b) the properties which create inconsistencies, and (c) the strategies which are used to reduce inconsistencies in the sugarcane supply chain. Special attention was given to literature focusing on sugarcane supply chains from the field through to mill processing. Chapter 2 contains this review.

2. Secondly, to propose a PhD research project (Chapter 3), with the emphasis on elaborating on the aim, objectives, methodology, case-study area, resource planning and time-scale of the project. The proposed study involves the development of a model that could be utilized to estimate an appropriate milling season, in each sugarcane region of South Africa. The model will be compared to results from the author’s MSc study at the Eston sugarcane region, in order to test and evaluate the accuracy of the solutions. An economic module will also be developed, in order to quantify the impacts of different solutions. Thereafter, the model, including the economic module, will be utilized in other milling regions in South Africa.
2. A REVIEW OF SUGARCANE SUPPLY CHAIN INCONSISTENCIES

In this study, the sugarcane supply chain is defined as a generally inclusive agri-industrial system that aims to grow, harvest, transport and process sugarcane from the field to the mill (Gigler et al., 2002; Gaucher et al., 2004). The entire sugar supply chain is highly integrated and contains: (a) cane growing, (b) harvesting, (c) cane transport to the mill, (d) mill processing and refining, (e) sugar transported to the port or market, (f) storage, and (g) retailing to customers (Higgins and Muchow, 2003; Higgins et al., 2006). Figure 2.1 illustrates the components of a sugar supply chain.

![Sugar supply chain components](image)

Figure 2.1  The sugar supply chain components (after Higgins et al., 2004)

Inconsistencies in the sugar industry occur due to many logistical, social, economic and physiological linkages across the chain. Most of these factors are inter-connected, such as the harvesting and transporting of cane, whilst many of the social and physiological aspects are difficult to quantify (Higgins and Lerado, 2006). Inconsistencies create risk and may decrease profitability for the parties involved in the supply chain. Therefore, decreasing inconsistencies in the sugarcane supply chain has the potential to increase profitability (Le Gal et al., 2008). The impacts of supply chain inconsistencies can be mitigated by flexible strategies (Tachizawa and Thomsen, 2007; Pitty et al., 2008). However, flexibility is difficult due to the varying involvement of parties in the supply chain, their conflicting objectives, the geographical span of the system, logistical problems, as well as increased costs (Chen and Paulraj, 2004; Tachizawa and Thomsen, 2007)

This Chapter aims to provide a literature overview of: (a) an outline of the sugarcane supply chain and its processes (discussed in Section 2.1), (b) the properties which create inconsistencies (discussed in Section 2.2), and (c) the strategies which are used for the improvement of the
sugarcane supply chain (discussed in Section 2.3). The focus will be on South African sugarcane supply chains in particular, *i.e.* from the field to the production of raw sugar.

### 2.1 An Overview of Sugarcane Supply Chains

The refined product, called sugar, is produced mainly from sugarcane and sugar beet. Worldwide, for every ton of sugar that is derived from sugar beet, about three tons are derived from sugarcane (Higgins *et al*., 2006). Sugarcane products include, amongst others, table sugar, molasses, ethanol and electricity. Sugar is an important fuel for the body, because it is a carbohydrate (Deressa *et al*., 2005). Sugarcane is a tropical plant that is able to grow under various climates throughout the world, from sea level to 1500 metres. However, the ideal climate involves a long, warm growing season and a fairly dry, but frost-free harvest season (Everingham *et al*., 2002). Sugarcane is produced in over 110 countries in the world, with the majority produced in Brazil, Thailand, India, Australia, China, Pakistan, United States and South Africa (Higgins *et al*., 2006).

#### 2.1.1 Sugarcane supply chain

The sugarcane supply chain is highly integrated and involves growing, harvesting, transporting and processing (Gigler *et al*., 2002; Gaucher *et al*., 2004). Climate and the ability to mitigate pests and diseases result in the harvest age of sugarcane ranging from 12 to 24 months. Thereafter, sugarcane is either burnt or cut green prior to harvesting. Burning takes place for a few hours. The cane is then manually or mechanically harvested. In South Africa, manual or conventional harvesting involves employing labourers to cut and stack the cane on the field, before loading onto a vehicle, which will then transport the cane to the mill. Growers either have their own vehicles or contract haulage enterprises to transport the cane. A mechanised harvesting system involves cutting and loading billeted cane onto a trailer. The cane on the trailer is usually transferred to a haulage vehicle, which will transport the cane to the mill. The time taken to transport cane depends on a number of factors, including the quantity of cane, the type of haulage vehicle, weather and road conditions, as well as the distance to the mill. Once at the mill, vehicles are weighed and the cane is offloaded onto a stockpile or directly onto the mill’s spiller.
table. Finally, the cane is processed and refined at the mill, in order to generate sugar and molasses (Gigler et al., 2002; Higgins et al., 2006). The combinations of configurations in growing, harvesting, transport and milling systems are vast and vary from mill to mill.

Collaboration between parties is an important constituent to support more efficient business operations and to lower inconsistencies in supply chains (Cassivi, 2006). In sugar production, the four stakeholder parties who are usually involved are the growers, the harvesters, the hauliers and the miller (Higgins and Muchow, 2003; Higgins et al., 2006). The ownership of mills is an important issue in sugarcane supply chains (Le Gal et al., 2008; Lejars et al., 2008). There are three possible scenarios which are generally used in terms of farm and milling ownership in the industry. These are: (a) the miller owns some farms in the milling region, (b) the miller and growers are independent entities, and (c) the growers own the mill (Lejars et al., 2008). The miller controls the amount of sugar which may be recovered from each ton of cane crushed. The grower aims to reduce the costs of production. The haulier aims to load and transport cane and to sustain a constant supply to the mill at the lowest cost (Higgins et al., 2006). Although each party often operates independently, the supply chain is a single entity. Joint decisions can be made between many supply chain stakeholders, which have the potential to increase profits. These decisions also allow for important tactical planning and strategic problems to be addressed (Le Gal et al., 2008).

As with most agricultural supply chains, parties involved in the sugarcane supply chain compete and aim to minimise costs, in order to maximise net revenue (Lejars et al., 2010). Revenue is obtained from the sale of sugar and other sugarcane by-products, such as bagasse and molasses. An increase in revenue is likely to increase the quantity of cane grown and produced (Lejars et al., 2008). Increased revenue is only likely to be realised through an interconnected relationship between the growers, harvesters, hauliers and millers. In addition, profit maximization can be achieved by controlling three critical factors, namely, (a) throughput, (b) sugar recovery, and (c) quality. These factors are also generally interrelated (Higgins et al., 1998; Purchase and de Boer, 1999). For raw produce, the parties in the agricultural supply chain generally do not use strategies, such as product differentiation, (Archer et al., 2006).
The largest cost component in raw sugar production is logistics. In 2006 it was estimated that the cost of transportation contributes approximately 20% and 25% of the total production costs in the sugarcane industries in South Africa and Australia, respectively (Milan et al., 2006). There is an increased emphasis to improve the integration of the harvesting and transport systems, because they are the more tangible components in the system, which can be quantified (Salassi and Champagne, 1998). Barnes et al. (2000) provide a detailed model of different harvesting and transporting techniques. Other components of the system, including agronomic, social and economic linkages across the chain are difficult to quantify (Higgins and Lerado, 2006).

2.1.2 Sugarcane quality

Sugarcane is made up of different components, such as water, fibre, sucrose and non-sucrose content. The various typical percentages of components in the sugarcane plant are illustrated in Figure 2.2. These components are influenced by the type of soil, the variety of cane, climate, the degree of maturity and the handling practices (Higgins et al., 1998). The most important factors, which contribute to high sugar recovery, are low fibre, low reducing sugars and high sucrose. Excessive fibre is undesirable in the production of raw sugar, because it reduces the volume of sucrose that may be extracted. However, fibre is required in the production of energy for the mill and other by-products such as paper. Other factors that affect the quality of sugar are, amongst others, its colour, ash content, crystal shape and the filterability (Purchase and de Boer, 1999; Higgins, 2006).

Sugarcane is, like many other agricultural products, a seasonal crop, which is influenced by weather and climatic conditions (Hassan and Gbetibouo, 2004). Sucrose yields from cane are at their highest during dry and cool conditions, which makes certain times more ideal for milling compared to others (Higgins et al., 1998; Higgins and Muchow, 2003; Stray et al., 2012). In South Africa, this is usually between July and September (Moor and Wynne, 2001). The subsequent rainy season reduces sucrose yields substantially (Kadwa and Bezuidenhout; 2013), which is undesirable. The rainy season also promotes disruptions and mobility problems in the field. However, transport and mills are capital intensive assets. These resources would, therefore, be underutilized if designed to process the annual crop in a short period of time (Stray et al.,
2012). For over-all economic purposes, this prolongs the milling season over a number of months and into the rainy season. In addition, the weather influences the number of days available for harvesting and is likely to impact on the composition of cane. For example, a long period of rainfall reduces the number of days for harvesting (Boote et al., 2011). Drought, on the other hand, will substantially decrease yields and hence profitability, because it creates fluctuating yield profiles (Higgins et al., 1998; Higgins and Muchow, 2003; Hassan and Gbetibouo, 2004).

The method of harvesting is a key determinant of sugarcane quality (Higgins et al., 1998; Higgins and Muchow, 2003). Sucrose levels are higher when there are minimal delays from the time of harvesting to the crushing of sugarcane. The burn-harvest-to-crush delay (BHTCD) is defined by Higgins (2006) as the “time elapsed between when the cane is burnt and processed by the mill.” The delay varies substantially in the South African industry, due to varying harvesting practices, and it is desirable to minimise the BHTCD (Beamon, 1998; Lionnet, 1998). For example, the burning of cane aims to improve harvest rates and reduce mill trash levels. It may also improve cane quality and hence enhance the short-term profitability throughout the chain. However, burnt cane deteriorates faster and when large fields are burnt at the same time, dead cane could stand for some time before being harvested. Cutting green cane is a method used to reduce the harvest-to-crush delay (Lionnet, 1996; Meyer et al., 2005). Nonetheless, it is important to note that harvested cane is highly perishable (Eggleston et al., 2001; Salassi and Champagne, 1998; Higgins et al., 2004; SASRI, 2000; Eggleston et al., 2008).
2.2 Sources of Sugarcane Supply Chain Inconsistencies

As in other supply chains, there are various factors, each with different impacts, which create uncertainty and inconsistencies in sugarcane supply chains. These factors are inter-connected. The main properties in the supply chain, from the field to the production of raw sugar, where inconsistencies have an impact on the system, are reviewed in this section. The two major properties reviewed are cane quality consistency and cane flow consistency in tons per day. It is not always easy to differentiate these properties and some of these relationships fall beyond the scope of this study. Where possible, connectivity graphs (as in Figures 2.3 and 2.4) are used to depict the inter-connectivity between different factors.

2.2.1 Cane quality consistency

There are various properties which are inter-connected in the sugarcane supply chain and that affect cane quality consistency. These are discussed below and summarized in Figure 2.3.
The milling season and cane variety are important properties that may cause quality inconsistencies. The prolonged milling season, as discussed in Section 2.1.2, causes inconsistencies in cane quality and yield (Higgins et al., 1998; Higgins and Muchow, 2003). Furthermore, Langton (2005) found that when a larger the numbers of cane varieties are grown, the cane quality consistency decreases. However, for several reasons cane variety diversification is required, such as to reduce the impacts of pests and diseases.

The amount of cane deterioration that occurs depends largely on the BHTCD, the prevailing temperature and humidity, as well as exposure of the cane to pests and diseases. Both the grower and the miller would gain significantly if cane could be processed immediately after it is harvested. However, this is seldom possible. In South Africa, there is often a BHTCD of three to four days, or even longer (Barnes et al., 2000; Diaz and Perez, 2000). Rangel et al. (2010) state that there are different distances between fields and the mill, which compromises cane quality consistency. There is likely to be a higher BTHCD for growers who are located further from the mill (Purchase and de Boer, 1999; Rangel et al., 2010). However, Barnes et al. (1998) found that most of the waiting time is in-field and that transportation distances add minutes, compared to hours, in the field. Growers may also use different machines, equipment and methods for harvesting, which can lead to cane quality being inconsistent (Higgins, 2006). Unburnt cane deteriorates more rapidly than burnt cane during the week immediately after harvesting. Thereafter, burnt cane deteriorates more rapidly (Wood et al., 1972; Eggleston et al., 2001; Eggleston et al., 2008). In South Africa, it is generally possible to crush sugarcane within 48 hours, which results in burning cane usually being the preferred harvesting method. The rates of cane deterioration also vary significantly under different post-harvest conditions and according to the season. Sibomana et al. (2011) found that cane qualities were significantly different after weekends, compared to the late-week, at the Felixton milling region in South Africa. In addition, there is greater deterioration in hot-humid summer months and the loss of sucrose value per day can be 2-3% (Lionnet, 1998). During winter, the loss averages one percent per day (Eggleston et al., 2008). The season also influences the prevalence of pests and diseases, which restrict crop growth and also inflict damage to the cane, accelerating deterioration. Therefore, the season has an influence on cane quality consistency (Everingham et al., 2002; Grunow et al., 2007).
Figure 2.3 illustrates a summary of the relationships between the abovementioned sources of cane quality inconsistency in the sugarcane supply chain. The network was developed using the cause-and-effect map network technique utilized by Bezuidenhout et al. (2012).

![Figure 2.3](image)

Figure 2.3  A cause-and-effect network of the properties in the sugarcane supply chain that affect cane quality consistency

### 2.2.2 Cane flow consistency

Sugarcane flow from the fields to the mill usually involves burning, cutting, loading, transporting and unloading at the mill (Diaz and Perez, 2000). There are various factors which affect the consistency (in terms of tons per day) of sugarcane flow through this process. These factors are discussed below and summarized in Figure 2.4.

Weather conditions is a major cause of cane flow inconsistencies, as discussed in Section 2.1.2. The uncertainty of future weather conditions increases the risk associated with the levels of sucrose produced, crop size, the time of harvesting, as well as in-field accessibility (Higgins et al., 1998; Higgins and Muchow, 2003; Hassan and Gbetibouo, 2004; Boote et al., 2011; Kadwa and Bezuidenhout, 2013). For example, in Australia, the supply chain usually allows for expected weather disruptions in the harvest season, however, excessive rainfall occurrences may
have significant impacts and complications across the supply chain (Higgins, 2006; Boote et al., 2011; Kadwa and Bezuidenhout, 2013).

Harvesting inconsistency is another major cause of cane flow fluctuations. The ideal time to burn cane is at dawn. However, Crowe et al. (2009) found that when cane is manually harvested, the constant exposure to the late morning and early afternoon sun may result in decreased labour productivity. Furthermore, the BHTCD can be increased by a further 12 hours, or more, if enough cane is burned to meet two day’s demand (Barnes et al., 2000; SASRI, 2004; Higgins, 2006). Wet weather conditions after the burning of cane is undesirable, because it prevents cutters and hauliers from entering the fields. Kadwa et al. (2012) argue that this may result in an increase in the BTHCD to over 100 hours, with substantially reduced sucrose content. In addition, Kadwa and Bezuidenhout (2013) studied the impacts of increased cutter absenteeism, especially after pay-weekends, at the Eston sugar milling region in South Africa. An estimate of the direct costs, of decreased cane quality and an increase in the length of the milling season (LOMS), associated with cutter absenteeism was found to be approximately R1.3 million per season. Other impacts of increased cutter absenteeism include reduced harvesting efficiency, increased field damage due to a longer LOMS, an increased BHTCD, higher management costs, decreased transport efficiency and more mill breakdowns.

There are various factors that have an impact on mill operations, such as the seasonality of sugarcane, the composition of cane, the soil content in harvested cane, sugarcane trash and lodged cane. Also known as the growing season, mills are usually closed for maintenance and upgrades in the rainy and warmer seasons. The sugarcane supply chain can be regarded as being effectively inactive during this period (Higgins and Muchow, 2003). Variable cane quality hampers different processes in the mill (Bezuidenhout, 2010). For example, fibre in the diffuser will have a negative impact on sugar output and will reduce milling efficiency. It is easier for the miller to process juices that need to be crystallised when the cane quality is high and when there are less impurities in the cane (Higgins, 2006). There are usually an increased number of mill stoppages at the end of the season, mainly due to rainfall, which results in increased ash and soil in the cane (Kadwa and Bezuidenhout; 2013). Soil in harvested cane decreases the mill front end capacity and it increases mill maintenance costs, with respect to the wear on chains and gear
boxes. The quantity of soil in harvested cane is affected by the harvesting technique, the loading methods and weather conditions (Purchase and de Boer, 1999; Rayno and Purchase; 2005; SASRI, 2004). The quantity of soil in cane can be reduced significantly by avoiding harvesting in the rainy season.

Trash levels and lodging have an impact on mill operations, as well as cane bulk density. Lodging occurs when mature sugarcane falls over, usually due to high rainfall, wind, saturated soils or structural weaknesses (Singh et al., 2002). Larger crops, especially over 100 tons per hectare of cane yield, are typically susceptible to lodging during windy and wet weather. Lodged cane is more difficult to harvest, which results in higher losses and costs. In addition, lodging reduces the amount of sugarcane that can be transported, because it reduces the bulk density. Furthermore, lodging increases the milling cost per unit of sugar produced (Singh et al., 2002). Trash is defined as the dry leaves that are left on the field after harvesting (Scott, 1977). Burning sugarcane before harvesting reduces trash by a maximum of about two-thirds, but some trash is still delivered and processed at the mill (Wynne and van Antwerpen, 2004). In Australia, Scott (1977) found that a 1% increase in trash can lead to a 2.75% increase in fibre content, which negatively affects cane bulk density and mill operations, with shutdowns being more likely. Purchase and de Boer (1999) found that crushing sugarcane with trash has the potential of reducing sucrose throughput by 36% per hour.

A major supply chain problem in the sugar industry is that harvesting usually takes place only in daylight hours, whilst the mill operates continuously (Higgins et al., 2006). This problem usually results in times during the day when cane deliveries to the mill exceed the demand, whilst other times of the day the supply to the mill is inadequate. The time of delivery to the mill is also inconsistent over weekends and public holidays (Kadwa et al., 2012; Kadwa and Bezuidenhout, 2013). In addition, the location and number of collection points of harvested sugarcane vary each day (Stutterheim et al. 2008). The time required for loading and off-loading, the length of journeys and the type of vehicles and equipment used may all differ on a daily basis.

Other factors that cause inconsistent deliveries include equipment maintenance, weather conditions, road conditions, accidents and vehicle breakdowns (Diaz and Perez, 2000; Higgins et
There are also logistical and technical delays at the mill that can create queues, such as excess vehicle arrivals, weighing, as well as the inspecting and unloading of sugarcane (Rangel et al., 2010; Sanchez-Rodrigues et al., 2010). Waiting queues create bottlenecks at the mill and usually take place as a result of daylight operations, mill breakdowns, driver shift changes and unscheduled deliveries (Giles et al., 2005; Sanchez-Rodrigues et al., 2008). The above inconsistencies may result in over-sized fleets, low equipment utilization, increased costs, inconsistent throughput and possibly double-handling (Hahn and Ribeiro, 1999; Barnes et al., 2000; Kadwa and Bezuidenhout, 2013). For example, if trucks break down or queue for long periods of time during operations, the return time to the field or the mill will be compromised, hence, it will slow down the overall supply chain (Rangel et al., 2010).

The above factors that affect cane flow consistency are summarized in Figure 2.4, which was developed using the cause-and-effect map network technique, utilized by Bezuidenhout et al. (2012). By carefully analyzing the network, three broadly classified groups that affect cane flow consistency are highlighted, namely, weather and harvesting time influences, transport issues and cane bulk density influences.
2.3 Strategies to Improve Sugarcane Supply Chains

Because of the various inconsistencies, there are different strategies or methods which have been proposed to improve sugarcane supply chains. These strategies have to be flexible to allow for ever-changing uncertainties. They include, amongst others, (a) increasing communication and collaboration between the parties in the supply chain (Moor and Wynne, 2001; Wynne and Groom, 2003; Gaucher et al., 2004) to reduce cane flow inconsistencies, (b) introducing the correct sugar payment system (Todd and Forber, 2005) to improve cane quality consistency, (c) stockpiling (Bezuidenhout, 2010) to enhance mill efficiency, (d) rearranging harvest scheduling (Le Gal et al., 2008; Stray et al., 2010) and, (e) new co-ordinated delivery allocation rules (Higgins et al., 2006) to decrease transport inconsistencies. The following subsections briefly describe each strategy. However, it is unlikely that one specific strategy would improve all sugarcane supply chains (Bezuidenhout, 2012). These strategies may cause new problems in the
supply chain (e.g. Giles et al., 2005). Therefore, each supply chain requires a detailed analysis for improvement strategies to be successfully implemented.

2.3.1 Communication and collaboration

Gaucher et al. (2004) state that communication and trust between the various stakeholders is vital in the sugarcane supply chain, when farms and the mill are owned by independent entities. Increased feedback, communication and more efficient administration reduces product quality variations, deterioration, the bullwhip effect (Wee and Wu, 2009) and hence, cane quality inconsistencies. To minimise conflict between entities in the chain, the stakeholders need to design collective growth strategies rather than to have individual viewpoints. There will need to be increased training and participation between the entities. Outside assistance will be required for management to be changed and for systems development. To encourage stakeholders to match their individual decisions with the collective interest, different economic tools such as contracts, information and the appropriate payment systems need to be implemented (Gaucher et al., 2004; Higgins et al., 2004).

Moor and Wynne (2001) developed an optimal milling season model, by assuming each mill area operates as a single entity. The model was designed to identify the point at which marginal losses due to decreasing cane quality is greater than the benefits of increased capacity utilization. Wynne and Groom (2003) enhanced the milling season model (Moor and Wynne, 2001) by identifying quantifiable parameters that cause season length extensions, such as the adjustment of overall time efficiency, to include the effects of slow and fast mill crush rates. These factors were considered to reduce inefficiencies in the overall system. However, research carried out in seven milling areas in South Africa (Boote et al., 2011; Sibomana et al., 2011; Bezuidenhout et al., 2012, Kadwa et al., 2012; Sanjika et al., 2012; Kadwa and Bezuidenhout; 2013; Sibomana and Bezuidenhout, 2013; Bezuidenhout et al., 2013) have all highlighted issues concerning what are perceived to be an inappropriate milling season.

It is difficult to reduce inefficiencies and to effectively determine the ideal milling season because of many physical and social factors. Wynne and Groom (2003) concluded that
collaboration between growers, transporters and the miller would be required to eliminate the cause of the inefficiency. Further research (Lejars et al., 2008; Bezuidenhout et al., 2012; Bezuidenhout et al., 2013) emphasized this by stating that large quantities of research in the sugar industry are not implemented because the proposed solutions exclude issues in the supply chain, such as collaboration, innovation and information sharing.

2.3.2 Cane payment systems

Cane payment systems are important in providing incentives for growers and millers to improve efficiencies on various fronts. The system incentivizes the improvement of cane yield and quality, as well as enhancing milling performance by increasing collaboration (Wynne, 2001; Todd and Forber, 2005). The sugar industry payment system usually aims at sharing the annual revenue when millers and growers are separate entities. However, similar to most revenue sharing agreements, the type of payment system is usually a contentious issue. The issue is complicated by the development of sugarcane co-products, such as ethanol, electricity, fibre-based products including paper and packaging, as well as lactic acid (Lejars et al., 2010). There are various payment systems in sugarcane supply chains (Todd and Forber, 2005). For example, in South Africa, the growers and millers in the sugar industry receive revenue, based on a relative sugar recoverable value (RV) formula (Wynne, 2001; Murray, 2002; Wynne, 2005).

The RV formula payment system aims for growers to improve quality, in terms of clean and mature cane, with the incentive of obtaining higher revenue (Wynne, 2001; Murray, 2002; Wynne, 2005). The RV formula is estimated, taking into account the sucrose, non-sucrose and fibre components of sugarcane, which all affect milling efficiency. The relative RV system does remove the incentive for growers to all deliver when cane quality is at its highest in the season (Murray, 2002). This is an important consistency regulator. However, the RV payment primarily does not incentivise a consistent cane supply. In contrast, the daily rateable delivery (DRD) system is rule-based with potential penalties in place, in order to identify and correct delivery inefficiencies (Wynne, 2001). However, these penalties are not always enforced. Therefore, a systematic integration is lacking between the DRD and RV payment system, in order to stimulate cane consistency (Murray, 2002; Mac Nicol et al., 2007; Lejars et al., 2008).
2.3.3 Stockpiling

The methods used to allow consistent mill operations include stockpiling at the mill and storage in trailers in the field before transportation to the mill (Higgins et al., 2006). A statistic that quantifies variations in stockpiles may be a key indicator of overall system inefficiency (Bezuidenhout, 2010). Stockpiling occurs when there are increased levels of inventory, which acts as a buffer to enable production to continue, especially when deliveries from suppliers are low (Heng et al., 2005; Germain et al., 2008). Wet weather is a major cause of low cane supply consistency (see Section 2.2.2). Boote et al. (2011) modelled the use of an enlarged cane stockpile outside the Umfolozi mill, in order to allow a consistent flow of cane, even when wet weather prevents further harvesting. The stockpile was estimated to shorten the LOMS and reduce the number of no-cane mill stops and slow crush rates. However, it was found that the stockpile would be a major disadvantage because of cane deterioration (Boote et al., 2011).

Sugarcane supply chain stockpiles can be divided into two groups, namely, (a) deliberate and (b) unexpected (Bezuidenhout, 2010). Bezuidenhout (2010) explains three reasons why deliberate stockpiles are maintained: (a) to mitigate risk, such as building up a stock before approaching rain, (b) synchronization, to reduce inconsistencies, for example, the differences that exist in operating times between harvesting and milling, such as over weekends, when growers are reluctant to deliver cane, and (c) cane maturing, when some growers deliberately allow cane to age to artificially increase its RV percentage. Unexpected stockpiles are due to saturated and unsaturated conditions. Saturated conditions involve capacity bottlenecks. Unsaturated conditions refer to manageable changes in cane flow rates, such as widespread and simultaneous driver shift changes.

Bezuidenhout (2010) tabulates the above groups and the appropriateness of each stockpile to reduce inconsistencies, in order to allow for continuous and consistent mill production. It is not useful to have an in-field stockpile, because (a) it is difficult to predict inventory levels, (b) does not allow for an efficient night transport operation and, (c) is generally vulnerable to wet weather. It is beneficial to have loading zone stockpiles; however, it is also difficult to estimate stock levels. It is not advisable to use a vehicle stockpile because it is highly inefficient, is a major cause of the bullwhip effect and is expensive. It is logical to have a mill yard stockpile;
however, the mill yard may become congested, it can be difficult to maintain the first-in-first-out (FIFO) principle and it could promote under-utilization in the transport fleet (Bezuidenhout, 2010).

2.3.4 Harvest and transport scheduling

In this document, harvest and transport scheduling refers broadly to any harvesting and logistics method that aim to improve efficiency in the sugarcane supply chain. These include a daily rateable delivery system (Higgins et al., 2004), night transportation (Higgins et al., 2006), improvement in vehicle scheduling (Giles et al., 2005; Higgins, 2006) and rearranging harvest scheduling (Le Gal et al., 2008; Stray et al., 2012).

A daily rateable delivery (DRD) system aims for a constant daily supply of sugarcane to the mill. This can improve cane flow consistency; however, it does not have any regard for cane quality consistency (Barnes et al., 2000; Higgins et al., 2004). Bezuidenhout (2010) states that this system can usually only be applied when mill processes run below capacity, due to variability in cane quality that would constrain certain parts of the mill. In addition, Bezuidenhout (2010) states that using the DRD system generally results in deliveries to the mill varying within the day, which negatively affects transport consistency (as discussed in Section 2.2.2).

The transportation of sugarcane to the mill during the night is likely to increase processing consistency. It allows for a more continuous supply of sugarcane to the mill, which probably will decrease the BHTCD and hence improve quality consistency. However, weather patterns, grower operational hours and communication systems can negatively affect the success of night transportation (Higgins et al., 2006).

An improvement in vehicle scheduling, in terms of arrival time at the mill, would result in a shorter queue at the mill, because fewer vehicles would be required (Giles et al., 2005; Higgins et al., 2006). Higgins (2006) states that if there was an equally spaced arrival time of vehicles at the mill, which is aligned with the mill throughput rate, then there would not be any queues. This will minimise the BHTCD and improve profitability. However, weather conditions, as well as
the varying locations of the farms and the mill, can compromise this idea (Hahn and Ribeiro, 1999). The millers may prefer to have a queue of trailers or vehicles in the mill-yard, rather than run the risk of idle time because there is a substantial cost to the miller if the mill has to shut down, or slow down, operations (Higgins et al., 2006). Furthermore, Giles et al. (2005) concluded that due to the sugarcane supply chain being highly integrated, improvements to the transport system may only be effective if several other system properties, such as driver shift changes, contractual agreements, multiple collection points and loading times, are simultaneously adopted.

Le Gal et al. (2008) used the MAGI decision support tool to maximise RV yield, by comparing different supply chain scenarios to increase delivery throughput. The aim is to improve profitability and reduce inconsistencies apparent in the chain. The study included investigations into exploiting geographical and temporal RV production variation opportunities by modifying the cane supply scheduling during a season. Le Gal et al. (2008) concluded that an improvement of the supply chain can occur, by taking advantage of quality differences within the mill supply region. This can be achieved by rearranging harvest scheduling on a different basis, with the effect of changing the cane delivery structure from the fields to the mill. The changes may result in the harvesting season being reduced to maximise cane quality and hence profitability. However, this is dependent on the milling and transportation capacity.

2.4 Discussion and Conclusions

A well-managed supply chain is usually important in raw sugar production. There are various causes and impacts of supply chain inconsistencies, which can clearly be witnessed in the sugarcane supply chain. Even though the growers, hauliers and the miller are parties who operate relatively independently, the sugarcane supply chain can be regarded as a single entity. There is limited peer-reviewed literature on the link between properties in the sugarcane supply chain, from the field to the production of raw sugar, where inconsistencies have an impact on the system. Research has been conducted on various properties which affect harvesting and transport issues in sugarcane supply chains, but the link between flow consistencies requires further research. Sugarcane quality and flow consistency are the two properties developed and reviewed.
as sources of supply chain inconsistencies. These properties significantly decrease consistency across the supply chain, as well as decrease sugar supply.

Cane quality consistency is influenced by the season, harvesting system, deterioration and variety. The date and method of harvesting have an important impact on the composition of cane, its deterioration and therefore the profitability of the industry. Sucrose yields from cane are at their highest during dry and cool conditions, which makes this the ideal time for harvesting. However, due to limited transport and milling capacity in most countries, the harvest season is prolonged over a number of months, which results in increased exposure to seasonal cane quality fluctuations. The amount of cane deterioration that takes place depends largely on the burn-harvest-to-crush delay (BHTCD), as well as the prevailing temperature and humidity. Rainfall events generally lead to significant BHTCDs. In South Africa, the BHTCD is often three to four days, whilst hot and humid conditions result in greater deterioration compared to cooler conditions.

Cane flow consistency impacted by various properties which have been broadly classified into three factors namely, weather and harvesting time influences, transport issues and cane bulk density influences. The uncertainty of weather conditions increases the risk associated with the levels of sucrose produced, crop size, the time of harvesting, as well as in-field accessibility. The time of day, as well as day of week affects harvesting consistency. Cutter productivity decreases during the day, when exposed to extreme heat, as well as after pay-weekends. There are various factors that have an impact on mill operations, such as the seasonality of sugarcane, the composition of cane, the soil content in harvested cane, sugarcane trash and lodged cane. Lodging and trash reduce sugarcane transport and production, by reducing the cane bulk density and the mill capacity, respectively. A major supply chain problem in the sugar industry is that harvesting usually takes place only in daylight hours, whilst the mill operates continuously. This problem usually results in times during the day when cane deliveries to the mill exceed the demand, whilst other times of the day the supply to the mill are inadequate. Other factors that cause inconsistent deliveries include equipment maintenance, weather conditions, road conditions, accidents and vehicle breakdowns.
Many other strategies have been developed to improve the supply chain and mitigate the abovementioned inconsistencies. An optimal milling season model was developed to try to reduce cane quality and flow inconsistencies. The model was designed to identify the point at which marginal losses due to decreasing cane quality is greater than the benefits of increased capacity utilization. However, several studies since have all highlighted issues concerning what are perceived to be the ideal milling season. This is due to the model, as with large quantities of research in the sugar industry, not considering issues in the supply chain, such as collaboration, innovation and information sharing. Sugar payment systems incentivize the improvement of cane yield and quality, as well as enhancing milling performance by increasing collaboration. However, for example, the sugar RV formula used in South Africa does not directly incentivise a consistent cane supply. Consistent mill operations can take place by using a stockpile, however, this causes double handling and further cane deterioration, which substantially reduces profitability. Research has provided emphasis on improving the integration of the harvesting and transport system. A daily rateable delivery system can be implemented to allow for constant daily cane flow rates. On the other hand, it does not consider cane quality, there are fluctuations in delivery times within the day and over weekends and it can only be applied when mill processes run below capacity due to cane qualities constraining different parts in the mill. Vehicle scheduling can reduce the number of vehicles required, although it will only be effective if several systems properties, such as driver shift changes and contractual agreements, are changed simultaneously. Taking advantage of quality fluctuations within the supply region in the harvest system, by rearranging the harvest schedule, has also been researched to improve the supply chain. However, the effectiveness of this strategy is influenced by mill and transportation capacity. These strategies need to be flexible and it is unlikely that one strategy would improve all sugarcane supply chains simultaneously.
3. RESEARCH PROPOSAL

This study proposes the development of a model that could be utilized to estimate an appropriate milling season in each sugar milling area of South Africa. The model will be compared to results from the author’s MSc study at the Eston sugarcane region, in order to test and evaluate the accuracy of the solutions. An economic module will also be developed, in order to quantify the impacts of different solutions. Thereafter, the model, including the economic module, will be utilized in other milling regions in South Africa.

3.1 Rationale

In this research, the ideal milling season is defined as one where maximum sugar is obtained, with consistent rates and production costs are minimised. The milling season has two attributes, the date on which it starts and the length of the season (LOMS). The LOMS is the time window required, per season, to crush all cane produced in a milling region. For example, if a milling area produces 2 million tons of sugarcane per season, with a maximum mill capacity of 10 000 tons per day, in theory the LOMS is estimated to be 200 days long. However, the LOMS is prolonged due to a number of factors, such as reviewed in Chapter 2, which often results in sugar industries experiencing a variable and unpredictable milling season (Moor and Wynne, 2001; Todd and Forber, 2005).

Climate and the associated cane quality, as well as transport and mill capacities, are generally the key factors that dictate the appropriate milling season. Sucrose yields from cane are at their highest during dry and cool conditions, which makes this the ideal time for harvesting. In South Africa, this is usually between July and September. The subsequent rainy season reduces sucrose yields substantially, which is undesirable. However, due to limited milling, harvesting and transport capacities, the harvest season is prolonged over a number of months and into the rainy season (Higgins et al., 1998; Higgins and Muchow, 2003; Hassan and Gbetibouo, 2004; Todd and Forber, 2005). The LOMS in South Africa usually ranges between 34 to 38 weeks, from March until November, in most milling areas, which is regarded to be long compared to other sugar industries worldwide (Moor and Wynne, 2001).
The different milling seasons are due to various attributes, which include, among others, climatic and weather conditions, agronomic practices, logistic capacities, industry structure, mill capacity and political influence. Weather conditions determine the number of days available for harvesting, which is likely to impact on the composition of cane. For example, a long period of rainfall reduces the number of days for harvesting (Higgins and Muchow, 2003; Hassan and Gbetibouo, 2004). Agronomic issues include wet fields, pests and diseases and cane quality. Transport issues could include breakdowns, accidents, underloading, waiting queues at the mill and labour mass action. Milling issues include maintenance stops, no cane stops and breakdowns, as well as capacity constraints due to varying cane quality. Many of these issues are interconnected, for example, low sucrose values at the end of the season, will likely result in more mill breakdowns.

There is difficulty in determining a mutually appropriate or ideal milling season. In most South African milling regions there is limited central control, or ownership. Each stakeholder aims to fully optimize his/her individual processes, rather than the global operation (Lejars et al., 2008; Le Gal et al., 2008). Growers try to maximize revenue by crushing the cane over a short period of time, because of the reduction in cane quality at the end of the season. Millers and transporters, on the other hand, wish to prolong the season to maximize capacity utilization, in order to reduce fixed costs per unit of production (Moor and Wynne, 2001). This results in a complex production system, which presents many challenges to management (Bezuidenhout et al., 2013).

Moor and Wynne (2001) developed an optimal milling season model to overcome the conflict, by optimizing the season length, by assuming each mill area operates as a single entity. The model was designed to identify the point at which marginal losses due to decreasing cane quality is greater than the benefits of increased capacity utilization. Wynne and Groom (2003) enhanced the milling season model (Moor and Wynne, 2001) by identifying quantifiable parameters that cause season length extensions, such as the adjustment of overall time efficiency to include the effects of slow and fast mill crush rates. These factors were considered, in order to reduce inefficiencies in the overall system.
It is, however, difficult to reduce inefficiencies and to effectively determine the optimal milling season, because of many other physical and social factors. Wynne and Groom (2003) concluded that collaboration between growers, transporters and the miller, would be required to eliminate the cause of the inefficiency. This is likely to also reduce uncertainties in the supply of cane to the mill (Lejars et al., 2008). Further research (Lejars et al., 2008; Bezuidenhout et al., 2012; Bezuidenhout et al., 2013) emphasized this by stating that large quantities of research in the sugar industry are not implemented because the proposed solutions exclude issues in the supply chain, such as collaboration, innovation and information sharing. These factors are the likely cause of research, carried out in seven milling areas in South Africa, which have all highlighted issues concerning what are perceived to be the appropriate milling season (Boote et al., 2011; Sibomana et al., 2011; Bezuidenhout et al., 2012, Kadwa et al., 2012; Sanjika et al., 2012; Sibomana and Bezuidenhout, 2013; Bezuidenhout et al., 2013). These issues include cutter absenteeism, stockpiling, cane deterioration, cane supply logistics and milling problems. Although all these factors impact on determining the ideal milling season, the strength of their influence varies between different milling areas.

The sugarcane supply chain, therefore, needs to be researched more holistically than in the past, while considering various issues concurrently, before any significant improvements can be made (Le Gal et al., 2004; Bezuidenhout and Baier, 2011; Bezuidenhout et al., 2013). It has also been argued by Bezuidenhout et al. (2012) that a “one-size-fits-all” approach to optimizing systems is unlikely to be successful among the diverse milling areas in the sugar industry. Each mill is unique because of its history and various biophysical issues on the ground at different times. It is likely that various milling groups have conducted their own internal milling season studies, but for some time there has not been a comprehensive, independent, uniform and transparent research project that has assessed the dynamics of the appropriate or ideal milling season for each region in South Africa. Scope, therefore, exists to create a stochastic modelling approach that includes a wider range of factors and inconsistencies, in order to determine the ideal or appropriate milling season.
3.2 Aims and Objectives

The aim of this research will be to develop relatively simple simulation modules and algorithms that could be selectively combined into a larger simulation framework, to reflect the specific issues at any sugar mill, in order to propose a unique and generic appropriate milling season solution model. The proposed model aims to encompass many agronomic, harvesting, transport and milling issues. Successful implementation of an appropriate season model has the potential to increase efficiency and hence, increase profitability and reduce risk. The solution will also include an economic module, which aims to quantify the impacts of different solutions. It will be the first appropriate season model for each sugarcane milling season in South Africa. Furthermore, the model has the potential to be used in other sugarcane milling regions countries.

The specific objectives of the research are:

(a) To conduct a literature review on the causes, impacts and strategies utilized to mitigate sugarcane supply chain inconsistencies. This literature review was conducted in the author’s MSc study (Kadwa et al., 2012), but will be expanded to include other factors that have an impact on the milling season.

(b) To develop an inventory of factors based on Step (a), which pertain to milling season-related decisions, as well as creating valuable contacts with specialists who have worked in the field, in order to establish a list of issues that may need to be considered during a simulation.

(c) To formulate assumptions, trends and relatively simple algorithms that will be developed to reflect each issue, identified in Step (b), mathematically, within a stochastic simulation framework.

(d) To demonstrate the framework by using the Eston sugarcane milling region as a case-study. The demonstration will utilize data collected and analysed during the author’s MSc study (Kadwa et al., 2012; Bezuidenhout et al., 2013).
(e) Different scenarios will be stochastically simulated over a wide range of seasons. The impacts of the different scenarios will be quantified, by development of a conservative economics module. These results will be compared to the author’s MSc study, in order to test and evaluate the accuracy of the model.

(f) Thereafter, to modify the proposed appropriate milling season model, based on data on future studies, to be conducted in 2014, across all milling regions in South Africa.

(g) The economics module developed in (d) will be utilized for analysing the impacts of different scenarios in each of the milling regions.

3.3 Methodology

The first step to develop the proposed appropriate milling season model will involve identifying the range of main issues that could potentially influence the milling season at any sugar mill. These issues can be identified from literature and specialists in this field. There are many factors that can be found in the literature which affect the milling season. In South Africa, some of these factors have been researched individually, however, they have not previously been included as part of a generic milling season study. Furthermore, there are possibly more factors, which may only be identified when analyzing the milling regions. These issues include, among others:

(a) Stochastic seasonal rainfall generators (Lumsden et al., 2000; Boote et al., 2011),

(b) Harvest productivities under different conditions (e.g. wet fields, humidity, temperature, mechanical harvesting, public holidays and weekends) (Barnes et al., 2000; Langton; 2005; Lyne and Meyer; 2005; Meyer et al., 2005; Stutterheim et al., 2008; Stray et al., 2012; Kadwa and Bezuidenhout, 2013 Sibomana and Bezuidenhout, 2013),
(c) Transport efficiency under different conditions (e.g. lodged cane, short cane, wet cane, haulage distance and road conditions) (Barnes et al., 1998; Barnes et al., 2000; Moor and Wynne, 2001; Wynne and Groom; 2003; Giles et al., 2005; Le Gal et al., 2008; Stutterheim et al., 2008; Stray et al., 2012),

(d) Sugarcane quality and deterioration under different conditions (e.g. under different ERC) (Moor and Wynne, 2001; Wynne and Groom; 2003; Wynne and van Antwerpen, 2004; Lyne and Meyer, 2005; Eggleston et al., 2008; Stutterheim et al., 2008; Sibomana and Bezuidenhout, 2013),

(e) Stockpiling (Bezuidenhout, 2010; Boote et al., 2011),

(f) Crop growth (e.g. conducive growing conditions, lodging and flowering) (Bouman et al., 1996; Singels and Donaldson, 2000; de Lange and Singels, 2003; Bezuidenhout, 2004),

(g) Mill wear and tear (e.g. under different soil % cane scenarios) (Moor, 1994; Purchase and de Boer; 1999; Meyer and van Antwerpen, 2001; Rayno and Purchase; 2005; Rama et al., 2006),

(h) Milling efficiency under different conditions (e.g. diffuser, boiler and back-end efficiency) (Reid, 1995; Moor and Wynne, 2001; Wynne and Groom; 2003; Peacock and Schorn, 2002; Rama et al., 2006; Le Gal et al., 2003; 2004; 2008),

Secondly, interactions between factors, as well as the strength by which they relate to each other, need to be identified and mathematically expressed. This will also be done based on literature, data analyses, as well as from first principles. For example, a mill breakdown will result in waiting queues at the mill yard, unless the mill has a stockpile. Simple algorithms between the interconnected issues will then be introduced. The initial algorithms will be introduced based on previous studies on specific issues. For example, Sanjika et al. (2012) formulated the causal relationships between various issues that affect the sugarcane supply and processing system.
Experts in each area will also be consulted, to calibrate and verify that the correct algorithms are developed. Once all the issues are introduced, with algorithms, the proposed appropriate milling season model needs to be demonstrated by stochastically simulating a wide range of different seasons.

The Eston sugarcane milling region will be used as a case-study to demonstrate the use of a generic stochastic simulation framework, for a certain mill area. This has not previously been developed for the South African sugar industry. Specific algorithms will be identified for the region, based on research conducted during the author's MSc study (Kadwa et al., 2012; Bezuidenhout et al., 2013), which estimated post-weekend cutter absenteeism to prolong the milling season by between six and ten days. The appropriate or ideal milling season model will attempt to validate this conclusion and form the basis for further analysis. For example, in the Eston region, it may be decided that cane diversions, rainfall, temperature, humidity, cutter productivity, pay-weekends, cane quality, queuing at the mill, boiler efficiency and diffuser problems need to be integrated into a single milling season model. Once this model has been configured and resembles the Eston system, several scenarios could be simulated, such as, changes to the mill maintenance schedules, changes to the mill closing date, and a possible upgrade of the boilers. Each scenario will be stochastically simulated, using a wide range of seasons. The estimated impacts of each scenario will be quantified, by applying a conservative economics module. The module will include the quantifiable impacts of the scenarios, including capital budgets, as well as a facility to conduct sensitivity analysis. The module will quantify the estimated impacts of the scenarios and use sensitivity analysis to determine small changes to the scenarios. The results from each scenario will then be interpreted.

Thereafter, the proposed appropriate milling season model will involve ongoing modifications, from each sugarcane region besides Eston. This will be based on studies that are expected to be carried out by a group of MSc students in 2014. The specific algorithms that need calibration for each region will be developed. These algorithms depend on pertinent issues in each milling region. Consultation with experts in each milling region will assist in calibrating these algorithms. Thereafter, different scenarios will be developed and stochastically simulated for a wide range of seasons. The economics module developed in the Eston region, will be utilized for
analysing the impacts of different scenarios, in order to determine a practical solution for each milling region. The quantifiable impacts of the solutions will be calibrated into the module. The different solutions will also include sensitivity analyses to determine the impacts of changes to the system.

While each sugar milling area will be simulated in a unique fashion, the overall research approach will be consistent across all the mills. The specific mill area results that will be generated should provide a sound and independent platform, from where possible changes to the milling season could be negotiated and further facilitated. If correctly designed, the milling community can then use the model to evaluate the impacts of changes to the system. It is believed that due to specialists from the South Africa sugar industry, in each milling region, being involved in the development of the model, the milling community would be comfortable with the results. In addition, the solution could potentially be used for decision making.

3.4 Out of Scope

The exploratory studies that need to be conducted at all milling regions, except Eston, are expected to be carried out by a group of MSc. students in 2014. This is regarded beyond the scope of this research, with only the data being used to develop specific mill area results. The feedback to the specific mill regions are also considered beyond the scope of the research. The specific mill area appropriate milling season will be estimated, but implementation is beyond the scope of this research. This will depend on the Mill Group Board in each area. Changes to the sugar industry, for example, an adjustment to the division of proceeds to the grower and mill, will affect the milling season. The model will, therefore, need to be flexible and be adapted with such changes.

3.5 Study Area

There are a total of 1140 active sugarcane growers in the Eston region. This encompasses approximately 950 small-scale and 190 large-scale growers. However, small-scale growers only contribute an average total sugarcane supply of 1.75% of the annual total crush. Large-scale
growers contribute on average 93.75% of the total sugarcane supply to the mill. The remaining 4.5% of total crush is provided by the Beaumont Sugar Estate, which is owned by the miller. An average of 34 600 hectares of land in the Eston region is utilized for the growing of sugarcane (Lumsden et al., 2000; Department of Transport, 2011; Bezuidenhout et al., 2013).

Sugarcane in the Eston region grows relatively slowly, but yield and especially purity are high once the 24 months growing cycle is completed. Average annual rainfall in the region ranges between 800 mm to 900 mm and the average temperature is about 18-19°C. The cooler temperatures also inhibit and accommodate different pests and diseases, compared to those along the coast (Lumsden et al., 2000; Department of Transport, 2011; Bezuidenhout et al., 2013).

The Eston Mill, which was established in 1994 to replace the old mill at Illovo, is the newest in the KwaZulu-Natal sugar belt. The Eston Mill forms part of the Illovo sugar milling consortium, with the Sezela and Umzimkulu Mills on the south coast and the Noodsberg Mill north of Pietermaritzburg. Both Noodsberg and Sezela have additional processing plants and sugarcane from the Eston region is often diverted at a high cost to these mills in order to optimize overall production (Lumsden et al., 2000; Department of Transport, 2011; Bezuidenhout et al., 2013).

The Eston mill operates 7 days a week, 24 hours a day and is usually open for approximately 34 weeks in the year from March or April until November or December. The area produces an average of about 1.26 million tons of sugarcane annually, which results in approximately 125 000 tons of sugar and 51 000 tons of molasses. All cane deliveries are transported by road, and cane growers are located up to 58 kilometres from the mill. A large amount of cane at Eston is delivered by haulage tractor (Lumsden et al., 2000; Department of Transport, 2011; Bezuidenhout et al., 2013). There have been previous studies conducted in the Eston region (Steindl, 1996; Lumsden et al. 1998; 2000; Lyne et al., 2005; Kadwa et al., 2012; Bezuidenhout et al., 2013). Bezuidenhout et al. (2013) used network analysis approaches, in order to holistically study the complex Eston supply network. Cutter absenteeism was identified as an area for improvement. As previously mentioned, Kadwa et al. (2012) found that post-weekend cutter absenteeism increases the LOMS, which decreases average season cane quality and increases milling costs.
3.6 Resource Planning

The following resources are required for the research to be conducted:

(a) Office space, computing equipment, internet connectivity and stationery,

(b) A telephone,

(c) Transport,

(d) Funding has been secured within a research contract with the South African Sugarcane Research Institute (SASRI),

(e) Ethical clearance has been obtained and further confidentiality agreements may need to be signed.

3.7 Time-scale

Figure 3.1 provides an indication of the proposed work plan, with time-scale and list of deliverables. The research conducted is estimated to take around 18 months. It commences in January 2013 and concludes half-way through 2014.
Figure 3.1   Gantt chart portraying the research work plan

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<th>Deliverables (Jan 2013 - July 2014)</th>
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<td>Research proposal, upgrade literature review</td>
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<tr>
<td>Creating valuable contacts with specialists</td>
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<td>Develop an inventory of milling season related factors</td>
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<td>Model development</td>
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<td>Analysis of different solutions at Eston</td>
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4. REFERENCES


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