A REVIEW OF WHOLE-STICK SUGARCANE TRANSFER SYSTEMS

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ABSTRACT

Delivery components in the sugar industry's have been continuously improving throughout the world. The objective of this study is to review the loading, transloading, transport and off-loading operations of whole-stick sugarcane. These are reviewed at an international level and are collectively referred to as the transfer system. The various types of loading, transport and off-loading processes are presented, followed by a review of the cane properties that influence these operations.

Many techniques for transferring cane, mainly indirect, are employed worldwide. Loading operations are generally carried out by grab-loaders. The transport in-field is normally by tractor–trailer units which are transloaded into Hilo-type vehicles. The chain-spiller off-loading system was found to be very common and is widely used.

The main cane characteristics found to affect loading include the cane density, the length, the diameter and different cane variety characteristics e.g. the degree of lodging. Other factors, such as the preparation method for loading, the harvesting method, and the topography, also have a marked influence. It was deduced that the transfer component of the sugar industry offers opportunities for improvement and that South Africa requires development in this area in order to remain competitive.

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1. INTRODUCTION

Sugar from sugarcane is a commodity which impacts on many economies. The profitability within the sugar industry has for a while been strained internationally by the increasing agricultural input costs, with one of the main factors being expenditure on transport (Gentil and Ripoli, 1978; McWhinney, 1983; Meyer, 2005b; Meyer, 2006; Milan *et al.,* 2006; Lyne, 2007a, Gomez *et al.,* 2010). This component is approximately 20 – 25 % of the total expenditure for the production of sugar, which equates to R 750 million rand per annum (Lyne, 2007; Giles *et al.,* 2008). By expressing the value of cane in terms of litres of diesel, Harris *et al.* (2010) found that within a four-year period this cane value was halved, which justifies the immediate need for improvement.

The sugar industry in South Africa faces many challenges, which need to be addressed in order to remain competitive (Lyne, 2007b). Prior to 1984, cane transport was funded by the sugar industry, which resulted in growers not being interested in reducing transportation expenditure and therefore little improvement was made (Statham, 1990). In 1984, the Rorich Commission adjusted the system and made the growers responsible for the costs of the movement of cane from the field to the mill. This encouraged growers to create more viable transport systems on an economical basis (Statham, 1990). Environmental concerns have also been raised, such as the number of vehicles present on the roads and the change from burnt to green cane harvesting. Countries such as Brazil and Colombia have legislation limiting and/or banning the burning of cane (Meyer 2005a; b). These factors complicate improvement strategies (Abreu *et al.,* 1980).

The transporting system employed is significantly affected by the loading and off-loading processes (Cowling, 2008a). The prime objective of cane transport systems is to convey cane from the field to the mill within a minimum time-frame and at a minimal cost (Meyer *et al.,* 2001; Stutterheim, 2006). There is room for improvement in the loading and off-loading components within the sugar industry (Meyer, 2005; Benningfield, 2010; Phillips, 2010). Steward and Fischer (1983) reported that the insufficient training and supervision of the loader operators result in high production costs. Barnes (1999) found that the largest delays occurred at the transloading zone and at the millyard stockpile.

An understanding of the interactions within the sugarcane transportation system is essential in order to allow for efficient and effective management (Libunao, 1978). In this document factors such as the optimal utilisation of vehicles, maximum payloads, low turn-around times and optimal fuel use will be regarded as efficient. An effective system comprises of high quality operations with regard to safety, successful loading (reduction of roadside losses of cane) and off-loading (reduction of spilling and cleaning requirements). This can be achieved by considering cane properties such as its length, density, and diameter, along with external factors such as the equipment specifications and the field conditions (Lee, 1978; Carter-Brown, 1980; de Beer, 1982; Cowling, 2008a;b).

The transfer system incorporates the movement of sugarcane from the harvested field to the off-loading at the mill. This, therefore, includes the loading, the transport as well as the possible transloading and off-loading processes. According to Cowling (2008a), systems can be direct or indirect, with the direct system involving the in-field loading onto road transport units. The indirect method involves transportation to a loading zone from where the cane is later transferred onto road units. The main method used for cane transfer in South Africa is an indirect system, where loading is done by grab-loaders, in-field transport is done by tractor-trailer units, road transport is done by spiller-type interlinks and off-loading is done by a chain-spiller mechanism at the mill.

An improvement in the transfer system can be achieved through modifying various components within the system. Movement towards the utilisation transport units at full capacity is favoured and can be achieved by technological advances, a management system or a combination (Gentil and Ripoli, 1978; Meyer, 2005b; Meyer, 2006). Load cells on these units offers a means of achieving accurate loads. However, the initial costs and management of this system make it undesirable for farmers (Lagrange *et al.,* 2008). Measuring devices can be mounted onto loading equipment, such as grab-loaders and cranes, to improve the loading process, however the accuracy decreases when used in inclined regions (Lagrange *et al.,* 2008; Giles *et al.,* 2009). The design of transport vehicles can be revised in terms of the materials used for construction, as well as the geometry and size of the units. Systems can be converted from indirect to direct to avoid the cost of transporting cane to the zone and the double-handling i.e. loading in-field and then loading again at the transloading zone. The various modes of transport can be compared to ascertain the optimal criteria for different situations. Robert *et al.* (2009) carried out an economic analysis which compared different road vehicles and found the tri-axle to be the most cost effective option. By creating and setting up machinery in-field for juice extraction, cane transportation can be eliminated. This option involves large expenditure and may result in reduced quality, due to the quantity of soil within the cane and the possible contamination by pesticides.

The training of loader operators results in a more efficient operations in terms of equipment performance and the cane quality, due to better handling (Bentley, 1956; Barlett, 1974; Neethling, 1982; Steward and Fischer, 1983; Meyer *et al.,* 2001; Stutterheim, 2006, Giles *et al.,* 2009). The main problem with sugarcane is the variation of the cane density, which makes it difficult for a loading operator to estimate whether the process is efficient or not. Training will aid in sensitising the operator to estimate the bulk density and hence load more accurately (Lagrange *et al.,* 2008). A set of guidelines and standards for loading can improve the process.

The aim of this document is to establish and weigh up the properties of sugarcane which influence the transfer process. The various methods employed internationally are presented to ascertain the important properties of cane that govern the transfer system. These properties, once established, will be assessed to create relationships with the loading and off-loading processes in order to make the transfer system more efficient and effective.

2. AN OVERVIEW OF SUGARCANE TRANSFER PROCESSES

This chapter contains a review of the various types of loading, transport and off-loading mechanisms employed by sugar industries internationally. The advantages and disadvantages of these systems are presented and discussed.

2.1 Loading Methods

In-field loading depends on whether the transport process used is direct or indirect. The type of haulage vehicle affects the type of loading operation to be used and its efficiency (Hughan, 1998; Cowling, 2008a, Giles *et al.,* 2009). The systems also vary in relation to the distance to the mill, infrastructure and topography, where areas with minimal slopes result in enhanced operation performance (Lee, 1978; Carter-Brown, 1980; de Beer, 1982; Cowling, 2008a).

Barnes (1999) outlined the various types of loading systems in South Africa, namely:

- directly to the mill in bundles (a truckload contains between 6 to 9 t bundles);
- directly to the mill in loose form;
- cane transported to transloading zones in stacks by tractor-trailer units, then transloaded onto Hilo-type vehicles and transported to the mill; and
- cane transported to transloading zones in loose form by bin or basket trailer units, then transloaded onto Hilo-type vehicles and transported to the mill.

Geddes *et al.* (1998) and Meyer (2001a) specify that the factors affecting cane loading include the following:

- the characteristics of the windrows (width, neatness);
- the features of cane (lodged *vs.* straight, variety);
- the type of loader; and
- the harvesting method (burnt or green).

Training for the preparation of cane for loading is pertinent, since it affects the structure of the cane load, in terms of the alignment of the cane (Neethling, 1982; Stutterheim, 2006). De Beer *et al.* (1989) state that unburnt cane results in reduced payloads, which is due to the increased vegetative material resulting in an increase in volume.

Spalding (1992) found that it was advantageous to convert the single cut and stack harvesting operation, into separate processes. The result was a 54 % increase in labour productivity and a 62 % improvement in the self-loading in-field operations due to stack sizes being more consistent.

2.1.1 Manual loading

Up to 1998, 50 % of the global loading operations, were done by manual means (de Beer and Purchase, 1998). Meyer and Fenwick (2003) state that manual loading will be favoured within the South African sugar industry in the future. Cane loaders carry the stalks from the ground up a ramp or a ladder, in order for the cane to be placed into a truck (Libunao, 1978; Neethling, 1982). The various methods of manual loading include carrying the cane on the hips, head, back or shoulders, which could result in spinal injury or musculo-skeletal strain (Nag and Nag, 2004).

In the Philippines, the loaders carry approximately 10 stalks of cane up ramps which are at an angle of up to 45°. Six loaders can load a 12 t truck within three hours (Hughan, 1996). Figure 2.1 illustrates a worker loading cane with the use of a ramp. The transport unit impacts on the loading operation. A favoured method involves containers being placed on the ground, thus making the container more accessible and hence reducing the risks (Hughan, 1998).

Figure 2.1 Worker manually loading cane onto a truck (Photograph courtesy of Lyne)

Manual loading usually results in the cleanest cane, in terms of trash and ash content (Libunao, 1978; Meyer and Worlock, 1979; Neethling, 1982; Meyer *et al.,* 2001; Abdel-Mawla, 2010). Abreu *et al.* (1980) deduced that the quantity of clean cane loaded is influenced by the cane variety, the cultivation conditions (degree of lodging and crop age) and the skills level of the labourers. Manual loading has been carried out in the Philippines, South Africa, Zimbabwe, Jamaica, Swaziland and the United States of America (Lee, 1978; Bredin and Murton, 1991; Richard *et al.,* 1996; Hughan, 1998; Meyer *et al.,* 2001), but has been drastically reduced over recent years. This decrease is due to the increasing labour costs and the large risk of human injury (Bartlett, 1963; Bartlett, 1974; de Beers, 1982; Hughan, 1996).

If labour is readily accessible and inexpensive, manual loading would be economically viable (de Beers, 1982). Hughan (1996) believes that steps should be taken to mechanise this component. This method is being replaced by grab-loaders in many countries such as the United States of America, India, Egypt, South Africa and Puerto Rico (Partridge, 1965; de Beers, 1982; Richard *et al.,* 1996; Nag and Nag, 2004; Ramjutun, 2005; Abdel-Mawla, 2010).

2.1.2 Loading by crane

Cranes are hydraulically-operated machines used to lift large and heavy objects. These are extensively used in the sugarcane industry and are often used at transloading zones (Ashe

1979; Stutterheim, 2006). Types of cranes include gantry or derrick cranes, which can be stationery or mobile (Bentley, 1956; Libunao, 1978; Meyer *et al.,* 2001). A mobile derrick crane is shown in Figure 2.2.

Figure 2.2 Bundled cane being loaded by a mobile derrick crane at a transloading zone (Photograph courtesy of Lyne)

In the Philippines, empty containers are left in the field for loading and once loaded, are lifted by a self-loading hydraulic hook onto the trucks (Hughan, 1996). In South Africa, large bundles of 4 – 5 t, or small units of 250 kg, are secured by chains or created in loose cane form and loaded by mobile cranes onto vehicles (Bentley, 1956; Bartlett, 1974; Boast, 1985; Worrall and Meyer, 1991; Cowling, 2008a). Carter-Brown (1980) and Spalding (1992) argue that the elimination of the chains will allow for an increase in the efficiency and safety of this system.

2.1.3 Grab-loader operations

Grab-loaders are hydraulically-operated, non-slewing machines and are widely used in the sugar industry (Ashe, 1979; Carter-Brown, 1980; Benningfield, 2010; Phillips, 2010). Experiments undertaken by Nour and Allam (1989) and Abdel-Mawla (2010) revealed that this type of loader offers good manoeuvrability and the use of this system, compared to manual loading, resulted in a significant increase in productivity. Ashe (1979) describes the grab-loader as 4 m wide by 3 m high, with a mass of approximately 4 t. This is the most common type used in the United States of America, South Africa, Egypt, Swaziland, Jamaica, the Philippines and Guyana (Abrahamson, 1949; Lee, 1978; Richard *et al.,* 1996; Hughan, 1998; Meyer, *et al.,* 2001; Tshawuka and Ellis, 2001; Davis, *et al.,* 2005; Abdel-Mawla, 2010).

The use of the grab-loader was found to improve the utilisation of transport vehicles (Lagrange *et al.,* 2008). Carter-Brown (1980) found that different types of grab-loaders are used for varying topographies. In the steeper coastal areas, three-wheeled grab-loaders are used, while in the flatter areas, pushpile grab-loaders are used to load cane (Carter-Brown, 1980). These machines replace cranes at loading zones and eliminate the need for chains (Bartlett, 1974; Carter-Brown, 1980). The attachments of a pushpile grab-loader include a pushpile and a boom and grab, where the pushpile is used to compact the cane while the boom and grab is used to lift and load the cane (Carter-Brown, 1980). The loading operation of loose cane is illustrated in Figure 2.3.

Figure 2.3 Three-wheel grab-loader loading cane at transloading zone

The sugarcane is prepared prior to loading through being windrowed or bundled, followed by loading with a grab-loader (Statham, 1990; Meyer *et al.,* 2001). The creation of the windrows impacts on the efficiency of the loading operation, where neater and denser windrows result in increased payloads (Carter-Brown, 1980; Boast, 1985). Gordon (1978) and Carter-Brown (1980) argue that the loading operation is more effective, for bundled cane as compared to the operation of windrowing, since it results in less spillage and the quantity of extraneous matter such as soil particles within the load is reduced.

With the loading of bundled cane, the larger bundles are loaded first and then the smaller bundles are added, with the aim of attaining payload capacity (Cole, 2006; Lagrange *et al.,* 2008). For stability reasons, loading is carried out from the back of the trailer, moving forward until the front of the trailer is reached. The trailer should be half-loaded and then the truck is moved forward to repeat the cycle until the trailer is loaded to capacity (Carter-Brown, 1980). Carter-Brown (2010) states that this is employed to aid the loader with attaining the correct axle loading and to reduce the amount of cane overhang at the back of the trailer. Trott (2010) states that the method of cane loading adopted, varies in relation to circumstance which may include the type of cane, i.e. burnt *vs.* trash, positioning of the truck and the cane and the cane preparation method, i.e. windrows *vs.* unaligned.

The advantages of using a grab-loader include the fact that it replaces manual loading, it is able to pick up loose cane, it has a larger capacity than manual loading and it results in less in-field losses compared to the mechanised systems (Abrahamson, 1949; Bartlett, 1963; Meyer, 2001a). Trailer designs allow for the grab-loaders to compact the loads through slots on the side of the trailer (Statham, 1990). This machine can quickly and easily be transferred to other transloading zones and may be used to load cane directly into road transport units if field conditions are favourable (Bartlett, 1963; 1974). The grab loader does not pick up as much soil, compared to the push-pile loader (Gordon, 1978).

The main disadvantage of the grab-loader is that it is not suitable to very steep areas (Abrahamson, 1949). Newer designs are able to work in varying field conditions (Meyer *et al.,* 2001). Spalding (1992) found that the use of grab-loaders reduced labour requirements by 75 % and increased the payloads. Gordon (1978) found that small changes to the loading operation can result in the system being significantly improved. Operators require training in loading, in order to ensure the maximum payloads and minimal collection of soil (Bartlett, 1974; Neethling, 1982; Stutterheim, 2006).

2.2 Transport Systems

Prior to 1984, cane transport was funded by the sugar industry, which resulted in growers not being interested in reducing transportation expenditure and therefore little improvement was made (Statham, 1990). In 1984, the Rorich Commission adjusted the system and made the growers responsible for the costs of the movement of cane from the field to the mill. This encouraged the growers to create more efficient transport systems based on economic viability (Statham, 1990). An understanding of the interactions within the sugarcane transportation system is essential in order to allow for efficient and effective management (Libunao, 1978). The aim of sugarcane transport is to ensure a constant supply of cane to the mill (Milan *et al.,* 2006).

McWhinney (1983) and Meyer *et al.* (2001) found that there are various methods used internationally, with techniques ranging between animal-drawn vehicles to massive road trucks. In Guyana, cane transport is *via* a canal system by barge (punts) (Davis *et al.,* 2005). The form of transport employed in the Philippines includes bull-carts for in-field transport and trucks for transfer to the mill (Libunao, 1978; Hughan, 1998). Hughan (1998) added that this system was ideal during wet conditions. The initial mode of transport in Puerto Rico was by ox and cart, which was replaced by simple tractor-trailers in the 1940's (Partridge, 1965). In Zimbabwe, cane is transported directly to the mill in tractor/self-loading trailer combinations or through a transloading zone (Meyer *et al.,* 2001). In Cuba, cane is transported in two ways: either directly, with road swing bolsters, or indirectly, through a transloading zone, and then by road vehicles for transfer to rail carriages (Milan *et al.,* 2006). The main methods of cane transport in the United States of America are by rail and large trailers. The main mode of transporting cane in Brazil is by road haulage (Cowling, 2008a). The systems in Australia include rail or articulated self-propelled tractor/trailer combinations and rigid self-propelled units (Geddes *et al.,* 1998).

Before 1993, few advances were made in the designs of haulage units in order to reduce cane losses while the vehicles are in transit (Bezuidenhout, 1993). The cost incurred for cane transport is one of the largest components within many sugar industries, amounting to 11 % in South Africa, as illustrated by Figure 2.6 (Meyer, 2006; Stutterheim, 2006; Lagrange *et al.,* 2008). On average, 80 % of the time of the transfer process is expended on the transportation component (Gentil and Ripoli, 1978).

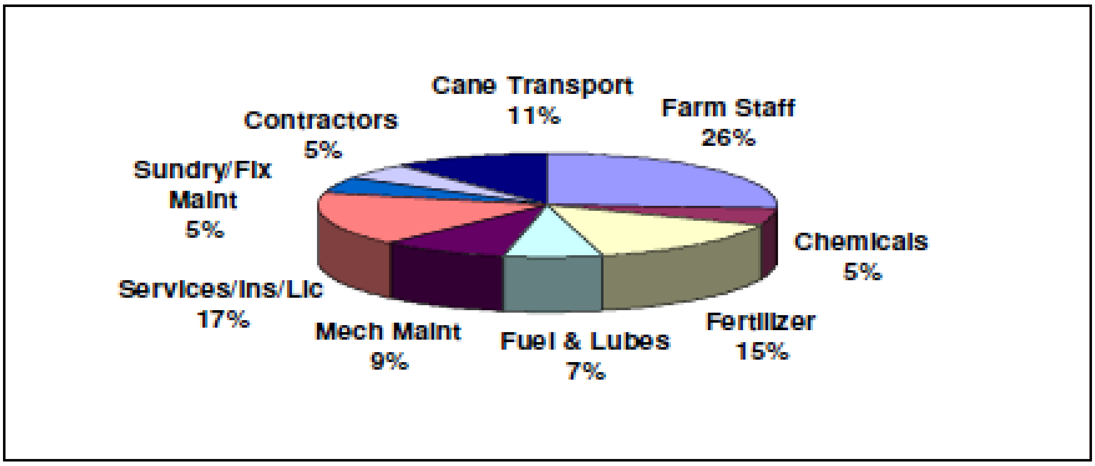

Figure 2.4 Production cost breakdown of sugarcane in the South Africa (from Meyer, 2006)

The transport can be divided into primary and secondary components, where the tractors form the primary components and trucks form the secondary transport (Stutterheim, 2006). There are two main methods of sugarcane transport, namely, rail and road. The various moethods and usage within South Africa are shown in Figure 2.7 (Davis and Archary, 2006; Cowling, 2008a). Often road and rail systems are used in conjunction with each other (Bartlett, 1974). Transport systems are modified in relation to the mill's receiving-facilities (Meyer *et al.,* 2001) and de Beer *et al.* (1993) add that for an efficient transport system, the payload to tare weight ratio should be at least 1.5:1.

Transport type	Quantity (%)
Rail and tram	6.2
Articulated trucks	52
Rigid chassis	21.2
Tractor driven	20.6

Figure 2.5 The percentage variations of different types combinations used for the transport of sugarcane in South Africa (after Davis and Archary, 2006)

2.2.1 Transloading component

Transport systems include direct and indirect systems, with the cane being transported in two different forms, namely, either whole-stick loose or bundled (Meyer, 1997; Meyer *et* *al.,* 2001; Tshawuka and Ellis, 2001; Stutterheim, 2006). Indirect systems include a transloading component and involve the transportation of cane to a loading zone from which the cane is later transferred onto road units. Systems including transloading operations are generally more costly, however certain field conditions such as terrain and soil conditions may inhibit direct transportation (Meyer *et al.,* 2001; Jacquin *et al.,* 1996).

2.2.2 Road systems

There is a shift towards the use of road transportation of cane as it is often found to be the most economical (Hughan, 1998). Tandem basket trailers with 6 t capacity and mesh floors, to allow for the removal of extraneous matter during transit, are used to transport cane to the mills in South Africa (Statham, 1990). Currently 35 % of cane is transported by tractor-trailer combinations and 56 % by interlink and rigid drawbar spiller trailers (Bezuidenhout, 1993; Davis and Archary, 2006; Cowling, 2008a;b; Giles *et al.,* 2008). There is a vast range of transport trailers used in the South African sugar industry, with the main types including the tractor-trailer, the interlink, the rigid drawbar and the tri-axle, which are illustrated in Figure 2.6.

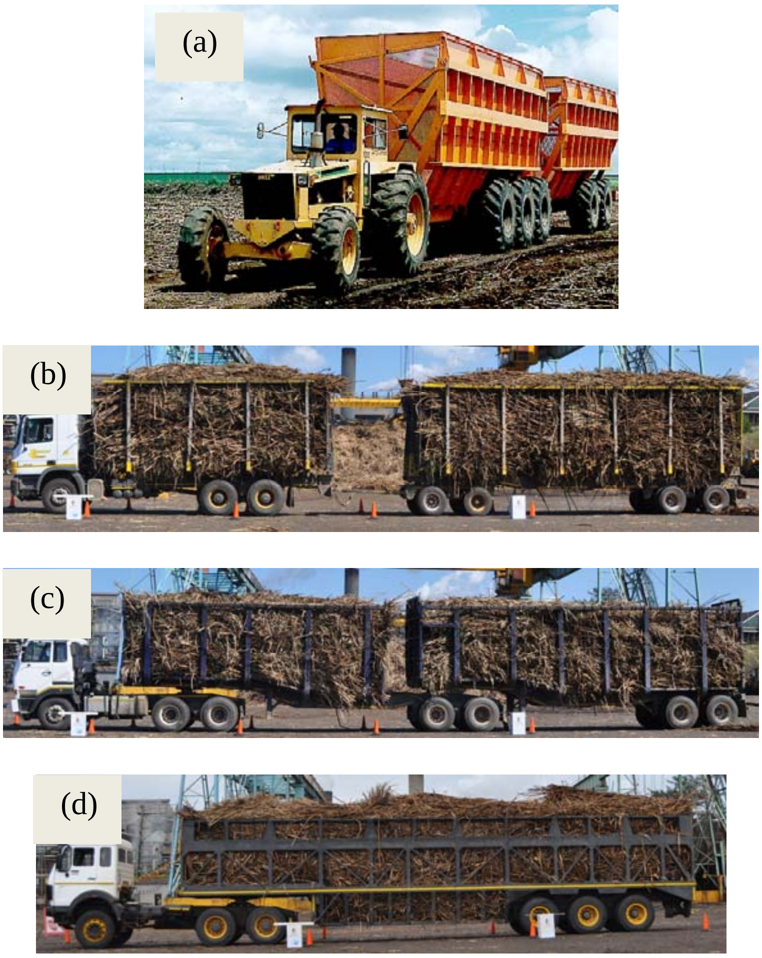

Figure 2.6 (a) Tractor-trailer unit (Lyne, 2010) (b) Rigid drawbar unit (c) Interlink transport units (d) Tri-axle

Road transport is being adopted more widely because it has many advantages, including the fact that less skilled labour is required, minimal supervision is required, no night shift work is required and various types of tractor-trailer combinations are available (Steward, 1955, Giles *et al.,* 2009; Robert *et al.,* 2009). The main disadvantage is the inability to work in adverse weather conditions.

Meyer (2001b) describes a containerised system, which eliminates the need for a transloading operation. This system involves the loading of cane into spiller bar containers which are placed onto a 'roll-on roll-off structure'. This allows for the container to be manually moved onto transport vehicles, as shown in Figure 2.7 (Meyer, 2001b).

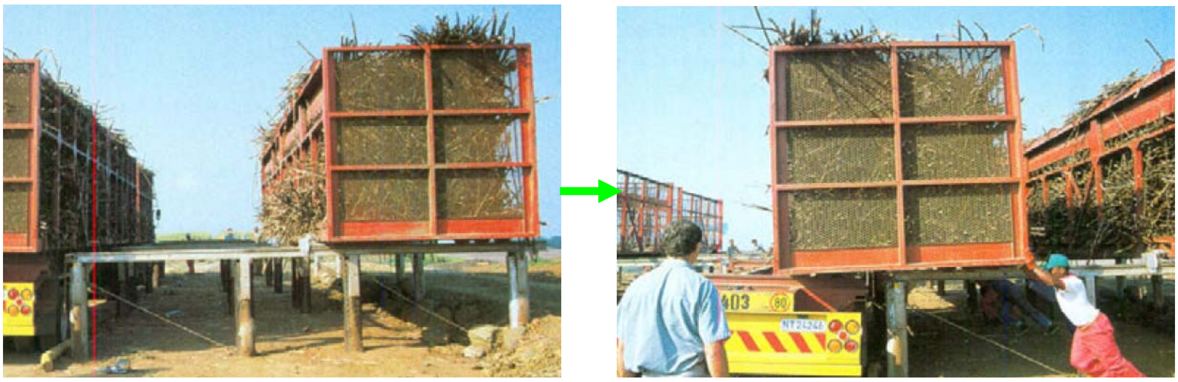

Figure 2.7 Roll-on, roll-off system (Meyer, 2001b)

Interlink units were found to be efficient for low density and lodged cane; however it is also the most expensive combination with respect to the fixed and variable costs (Robert *et al.,* 2009). Geddes *et al.* (1998) formulated a vehicle load index to assess the efficiency of the system, (*cf.* Equation 2.1) which is just an indicator, as there are many factors that affect the transportation cost of cane (Geddes *et al.,* 1998).

$$\beta = \frac{\gamma}{M} \tag{2.1}$$

where: β = vehicle load index,

γ = vehicle payload [kg], and

M = gross mass [kg].

The design of transport vehicles is affected by the off-loading facilities as well as economic factors (McWhinney, 1983; Meyer *et al.,* 2001). New designs for cane trailers should offer a greater capacity for delivery, a lower centre of gravity to increase stability and a reduction in operational costs (Bentley, 1956; McWhinney, 1983; Koppen *et al.,* 1998; Ramjutun, 2005). The material used for the construction of trailer units can be changed to allow for reduced tare mass and hence greater payload capacities (Bezuidenhout, 1993; Geddes *et al.,* 1998; Koppen *et al.,* 1998; O'Reilly, 1999; Cowling, 2008a; Robert *et al.,* 2009).

Bezuidenhout (1993) explored the concept of utilising nylon straps as opposed to chains with the Hilo-type trailer, as this could be advantageous for increased payloads and a reduction in road violations with regard to protruding cane and roadside spillage. A similar system is shown in Figure 2.9 (a) where the chains are replaced by belts with Figure 2.9 (b) illustrating cane hanging from the trailer. The trade-off, however, is the increased ash content within the load (Bezuidenhout, 1993). The implications for replacing the chains were not ascertained, due to complications within the experiments carried out by Bezuidenhout (1993).

Figure 2.8 (a) Cane truck with belts in place of the chains (Lyne, 2010) (b) Overhang of cane from the side of the trailer

Studies done by Cowling (2008a; b), compared two types of transport vehicle trailers, the bolster-type and the frame-type. It was found that the bolster-type trailer requires less effort for off-loading, compared to that of the frame-type. This was as a result of the cane getting stuck in the framework of the frame-type trailer, while the curved shape of the bolster complimented the spilling operation, due to the reduced contact between the trailer and the cane (Cowling, 2008a; Cowling, 2008b). In Figure 2.15 the two types of transport trailers are shown.

Figure 2.9 (a) A frame-type trailer (b) The bolster-type trailer

2.2.3 Rail systems

In South Africa, the transport of cane by rail is limited due to the steep landscape within plantation areas (Cowling, 2008a). In the Philippines, 20 % of the cane is transported by rail cars on trailers that are transferred at a siding onto the rail system, but this is gradually shifting towards road transport (Libunao, 1978; Hughan, 1998). Due to the rising prices of fuel, rail transport is sometimes favoured (Milan *et al.,* 2006). The majority of cane in Australia is transported to the mill by narrow-gauge rail which is slowly being replaced by articulated road vehicles (McWhinney, 1983; Meyer *et al.,* 2001; Higgens *et al.,* 2004; Cowling, 2008a). In Cuba the rail system functions on a 24-hour basis, hence allowing the transport of cane at night, while road transport is halted (Milan *et al.,* 2006). Jacquin *et al.* (1996) found that the incorporation of night transport resulted in a reduction of 31 % of the costs. Rail has not been favoured due to the high initial capital investment cost, high maintenance costs involved, the time required for loading and the greater degree of management required, as many loading operations occur simultaneously (Steward, 1955; Meyer *et al.,* 2001).

2.3 Off-loading Mechanisms

The weighing and off-loading of cane is referred to as the reception component of the transfer system (Gentil and Ripoli, 1978). The type of haulage vehicle used affects the off-loading operations (Cowling, 2008a). According to Cowling (2008a;b) there are various factors that influence the spilling process, these include the method of loading, the type of cane (green *vs.* burnt), and the size of the cane.

The off-loading systems used within the sugar industry include spillers, gantries and mechanised tippers (Kedian, 1979). Cane is spilled onto the floor of the millyard, serving as a buffer, or onto a feeder table for direct entry into the mill (Stutterheim, 2006). Bezuidenhout (1993) found that improvements to aid with spilling efficiency have not yet been explored.

2.3.1 Manual off-loading

Manual off-loading is not practiced on a large scale. It is generally required after a spilling operation, when the spilling operation has not removed all the cane (Bezuidenhout, 1993). The chain-spiller off-loading operation requires the greatest amount of cleaning (Kedian, 1979).

2.3.2 Off-loading by crane

Cranes are used quite extensively in the sugarcane off-loading process (Libunao, 1978; Ashe, 1979; Meyer *et al.,* 2001). Bundled and loose cane may be off-loaded by bridge cranes with a grab attachment or overhead gantries (Bentley, 1956; Kedian, 1979; Meyer *et al.,* 2001; Tshawuka and Ellis, 2001; Watson *et al.,* 2008). In the Philippines, rail cars are carried and moved around by cranes (Hughan, 1998), while in Australia, containers are transferred by a fully-automotive crane-type machine (Koppen *et al.,* 1998). As an alternative, some mills use hysters (Abrahamson, 1949; Bartlett, 1974).

Cranes can be used in association with the chain-spiller system (Kedian, 1979). The off-loading operation is influenced by loading characteristics, shift time and the characteristics of the operator (Libunao, 1978). This system is relatively expensive due to high maintenance and labour requirements, making it a less attractive system.

2.3.3 Off-loading by grab-loader

The introduction of the grab-loader has replaced the manual off-loading operations (Ashe, 1979). Kedian (1979) states that this operation is generally employed in association with another off-loading practice, for example, a chain-spiller and grab. The combined costs of these is equivalent to that of gantries; although this system is less labour-intensive.

2.3.4 Mechanised spilling

Mechanised spilling includes two methods, namely, the off-loading by the chain system and by hydraulic spilling. Gentil and Ripoli (1978) found that the time utilised for off-loading of cane at the mill, which involves queuing at the weighbridge and the spiller, as well as the actual off-loading process, amounts to 20 % of the entire transfer system. Alterations are to be explored in order to decrease the off-loading time so that the transfer system will become more efficient (Koppen *et al.,* 1998). Bredin and Murton (1991) found that off-loading efficiencies can be improved by off-loading two trailers at once. Mechanisation can aid in making this transfer component more efficient (Meyer *et al.,* 2001).

2.3.4.1 Chain-spiller

The chain system requires specialised trailers and can involve Hilo spillers or semi-trailer rigs (Kedian, 1979; Statham, 1990; Stutterheim, 2006; Cowling, 2008a). Trailers are designed around the constraint dimensions of the off-loading equipment (Bredin and Murton, 1991). Generally this method is employed for loose cane (Watson *et al.,* 2008). Hilo-type trailers consist of chains under the cane load attached at each side of the trailer, as shown by A and B in Figure 2.18. The chains form a net within the trailer which aid in the removal of the cane. On the left-hand side (side A) of the trailer a large metal bar is present. This is called a spiller bar and is used for the attachment of a special crane which is raised until the cane is ejected onto the feeder table before transfer to the mill (Bentley, 1956; Bartlett, 1974; Statham, 1990). A schematic illustrating this spilling operation is shown in Figure 2.19.

Figure 2.10 Spilling mechanism at the Sezela mill in South Africa

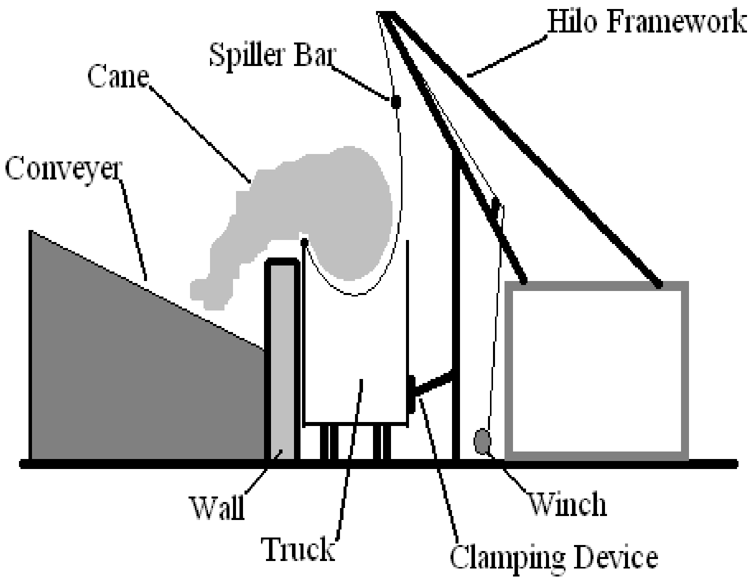

Figure 2.11 Schematic of an off-loading chain-spiller system (from Cowling, 2008a)

Bezuidenhout (1993) argues that the chain system results in losses in revenue since the mass of the chains reduces the allowable payload and sometimes results in inefficient spilling, which, in turn, requires time to be spent on the cleaning processes after off-loading. The spilling mechanism is fixed, which creates difficulties for off-loading by smaller tractor-trailers (Statham, 1990). The chain-spilling system is employed in the United States of America, Cuba, South Africa, the Philippines and Swaziland (Bentley, 1956; Bartlett, 1974; Abreu *et al.,* 1980; Statham, 1990; Hughan, 1998; Meyer *et al.,* 2001;

Tshawuka and Ellis, 2001; Stutterheim, 2006; Cowling, 2008a). The average off-loading time for this system is 2 minutes and 30 seconds (Kedian, 1979).

2.3.4.2 Hydraulic side-tipping

In comparison with the chain-spiller set-up, the hydraulic side tipper is relatively inexpensive and more time-efficient. It takes 90 seconds to off-load and the process can be carried out on a continuous basis (Kedian, 1979; Meyer *et al.,* 2001). There are two types of tippers available in South Africa, which include the tramway and South African Railway (SAR) tippers (Kedian, 1979; Carter-Brown, 1980). A hydraulic side-tipping system employed in Australia is shown in Figure 2.12.

Figure 2.12 Cane being off-loaded by a hydraulic side-tipping trailer in Australia (Lyne, 2010)

Robinson (1983) describes the Rota-Tipper off-loading mechanism employed in Mhlume, in Swaziland, where the off-loading structure attaches to the bin and vertically raises it to empty the contents within 1.5 minutes. Containers are also off-loaded in this manner in Columbia and the Philippines, with designs being customised according to the specifications of the haulage system employed (McWhinney, 1983; Hughan, 1998; Koppen *et al.,* 1998, Gomez *et al.,* 2010). Kedian (1979) argues that hydraulic side-tipping requires less cleaning when compared to the chain-spiller mechanism.

2.3.4.3 Hydraulic rear-tipping

This system is employed in the Philippines, where the truck is positioned on a raised ramp to off-load the cane (Hughan, 1998). Hughan (1998) states that any unit loaded with cane can be easily off-loaded, making the system a viable option (Hughan, 1998). Self-tipping box trailers are off-loaded by the tipping action of the trailer unit (Carter-Brown, 1980). Rear off-loading is adopted in South Africa, Guyana and the Philippines and is shown in Figure 2.13 (Spalding, 1992; Hughan, 1998; Meyer *et al.,* 2001; Davis *et al.,* 2005).

Figure 2.13 Rear-tipping trailer off-loading cane at a transloading zone in South Africa (Photograph courtesy of Lyne)

Payload accuracy is affected by cane alignment and density. Trashed cane results in reduced cane density, which generally has a negative impact on the accuracy of loading. Rear-tipping offers quick off-loading, however the alignment of cane stalks is decreased, which affects loading operation. The most consistent transfer approach in South Africa includes the loading of loose cane by grab-loaders and transporting it to the transloading zone (Meyer and Fenwick, 2003; Stutterheim, 2006).

3. OVERVIEW OF CANE PROPERTIES THAT INFLUENCE THE EFFICIENCY OF THE TRANSFER SYSTEM

This chapter reviews the various properties of cane that have an impact on transfer processes. Other factors such as cane handling and environmental factors, which also influence the system, are presented and discussed.

3.1 Cane Properties

Properties such as the length, the diameter, the density and the fibre content of cane affect payload accuracies (Abreu *et al.,* 1980; Geddes *et al.,* 1998; Meyer, 2001a; Meyer *et al.,* 2001; Tshawuka and Ellis, 2001; Lagrange *et al.,* 2008). Cane possesses a relatively low bulk density and varies between 250 – 450 kg/m^3 (Koppen *et al.,* 1998, Lagrange *et al.,* 2008; Robert *et al.,* 2009). One cane variety, N31, was found to have a significant variation between payloads as it has a fibrous and lodging nature (Lagrange *et al.,* 2008). Lodged cane reduces the payloads because the stalks are curved, which results in a product with a decreased bulk density (Tshawuka and Ellis, 2001; Stutterheim, 2006; Cowling, 2008a; Lagrange *et al.,* 2008).

Clean cane refers to cane which has been trashed *i.e.* the physical separation of the leafy material from the cane stalks (Hughan, 1998; Wynne and van Antwerpen, 2004). It is difficult to estimate the density of trashed cane due to the large quantity of trash. An increase in extraneous matter results in reduced payloads of up to 49 % (De Beer *et al.,* 1989; Wynne and van Antwerpen, 2004; Purchase *et al.,* 2008). Cane placed in stacks or windrows assist with the easier and quicker transfer of cane, compared to unaligned cane. The reason for this is that the bulk density of aligned cane is less than that of unaligned cane.

Abreu *et al.* (1980) established a relationship between mass, density and volume which gives an indication of the amount of cane present within the trailer. This is illustrated by Equation 3.1. The factors influencing the load efficiency include the biological yield, the cane length, the cane diameter and the volumetric weight (Abreu *et al.,* 1980).

$$\alpha = \frac{M}{\rho V_t} \tag{3.1}$$

where:	α	=	fraction of clean cane,
	M	=	vegetation mass [kg],
	ρ	=	density of clean cane [$kg.m^{-3}$], and
	V_t	=	volume of the trailer [m^3].

3.2 Cane Handling Factors

Cane handling factors include the type of harvesting method and the preparation for loading (Lee, 1978; Carter-Brown, 1980; Geddes *et al.,* 1998; Meyer, 2001; Meyer *et al.* 2001; Stutterheim, 2006; Purchase *et al.* 2008). Preparation operations include the stacking or the windrowing, of the cane stalks (Lee, 1978; Carter-Brown, 1980; Meyer and Fenwick, 2003; Stutterheim, 2006).

The loading operation for green cane is more difficult compared to that for burnt cane, because its fibre content is 50 % higher (Wynne and van Antwerpen, 2004; Purchase *et al.,* 2008). Figure 3.1 compares unaligned with well-aligned cane. The loading of unaligned cane is inconsistent, since the amount of cane transferred varies for each action. To allow for efficient loading operations, the cane should be placed in neat bundles or windrows, as shown in Figure 3.1(b) (Meyer *et al.,* 2001). The cut and windrow system was found to be more effective than the cut and stack operation in terms of payload accuracy (Libunao, 1978; Neethling, 1982; Steward and Fischer, 1983; Meyer *et al.,* 2001; Meyer and Fenwick, 2003).

The specifications of the equipment also influence the loading operations (Hughan, 1998; Meyer *et al.,* 2001; Giles *et al.,* 2009). They include the size of the grab and the ability of the loader to compact loads.

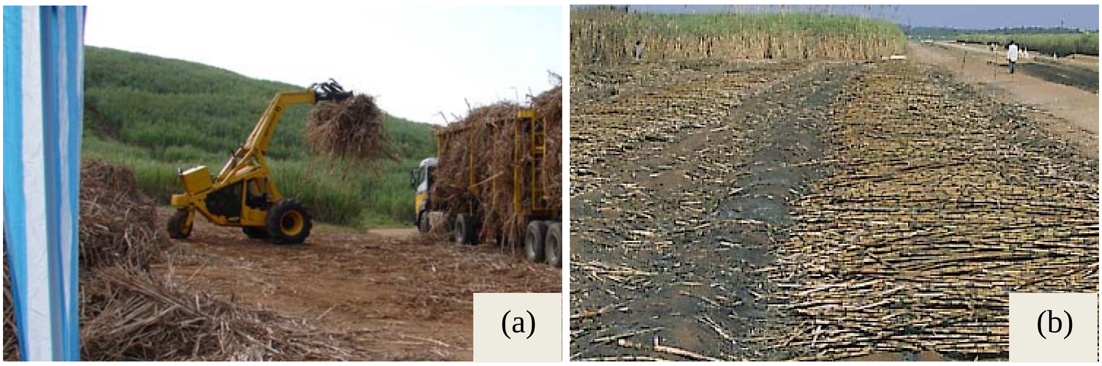

Figure 3.1 (a) Unaligned cane at transloading zone (b) Neat windrows prepared for loading in-field (Lyne, 2010)

3.3 Environmental Factors

The topography influences the loading rates as it affects on the manoeuvrability of the loader (Carter-Brown, 1980; de Beers, 1982; Cowling, 2008a). The climate also affects the transfer system, in that wet conditions increase the amount of soil present and determine the transport system i.e. it can result in a direct transport system being converted into an indirect one (Steward and Fischer, 1983). The change of the seasons offers different amounts of daylight hours, which impacts on the loading process (Robert *et al.,* 2009). The field conditions, such as crop yield and row length, also influence the efficiency of the transfer system (Lee, 1978).

The characteristics of any product affect the payload, loading and off-loading methods and related efficiencies. These factors are divided into cane properties, handling attributes and environmental factors, which are summarised in Table 3.1.

Table 3.1 Factors which have an impact on the efficiency of the sugarcane transfer system

Cane properties	Cane handling	Environmental
Geometry of stalks (diameter and length)	Harvesting method (green *vs.* burnt)	Climate
Density	Equipment specifications	Site conditions
Trash content	Transfer system (direct *vs.* indirect)	Season
Degree of lodging		

4. DISCUSSION AND CONCLUSIONS

This literature reviewed the various components of the sugarcane transfer system. Although this field of study is not well-published in peer-reviewed international journals, it is prevalent in a number of conference proceedings. The review established a list of important cane properties that impact on the efficiency of the transfer system. In South Africa, there are a wide variety of processes and systems which have undergone continuous improvement to ensure that the sugarcane sector remains competitive.

The main approach in South Africa is an indirect system where loading is carried out by grab-loaders, transportation in-field is carried out by tractor–trailer and road transport performed by Hilo-type vehicles. The off-loading is commonly done by a chain-spiller system. Systems are shifting towards loose cane handling, as opposed to bundled cane. This is due to reduced production costs, an increase in the efficiency of operations, as well as safety aspects. Manual loading results in the cleanest cane, however this is being phased out due to the rising costs of labour and high risks. The grab-loader is more widely used and was found to increase productivity significantly.

The important cane properties that affect the transfer function include the sugarcane diameter, its length and its density. Cane handling techniques, such as; the harvesting method, the creation of windrows or cane stacks prior to the loading, as well as topography, have a marked impact. The aim should be to create neat and well-aligned windrows with cane stalks of similar length, since these result in more efficient loading. Neat refers to windrows that are well-aligned with cane stalks of similar length. The harvesting of green cane results in reduced loads between 38 – 50 % due to the increased fibre content, with loss in revenue ranging from 2.9 to 7.3 t/ha compared to 1.3 to 1.4 t/ha for burnt cane.

Training is an essential component to enhance loading operations, however, there are no current standards or guidelines available in one coherent document. Guidelines for loading will aid in addressing high haulage costs and increasing the efficiency of the transfer system.

5. RESEARCH PROPOSAL

5.1 Aim

Standards are a required to ensure efficient operations (Meyer and Worlock, 1979). These are dependent on the local characteristics of the sugarcane. The aim of this study is to compile the necessary standards and guidelines for loading operations in order to improve the sugarcane transfer system of the sugar industry.

5.2 Objectives

- To conduct a literature review of current cane transfer operations and important associated cane properties;
- to collect quantitative and qualitative data surrounding the transport, loading and offloading sugarcane operations and includes digital photography, weighbridge data, spiller data and video footage;
- to conduct a multivariate analysis to establish links between different parts of the system, with respect to payload and off-loading efficiencies; and
- to derive a set of simple standards and guidelines in order to improve the current sugarcane loading operations.

5.3 Proposed Methodology

An empirical approach will be utilized to establish and weigh-up the properties of sugarcane that influence the loading, transport and off-loading operations. Data will be collected in different forms and at various points within the system. Figure 5.1 depicts a summary of the various positions for data collection, with a description of the data to be collected at the different stages. The data collection at the mill will include:

- weighbridge data;
- photographs of consignments;
- data with respect to spilling efficiency and vehicle cleaning requirements; and

- ash/soil content.

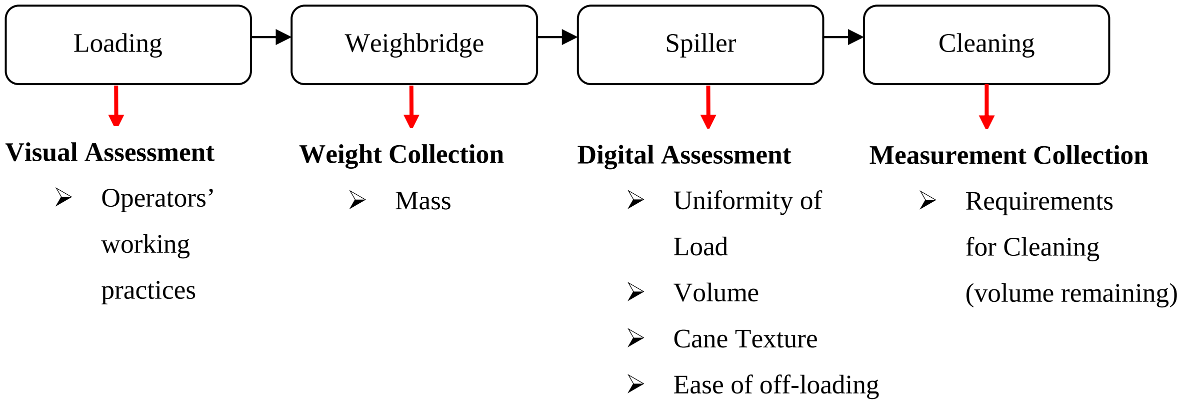

Figure 5.1 Components of the sugarcane transfer process for data collection

Digital photographs will be analysed statistically alongside with weighbridge data. Specific properties which will be explored include: cane density, payload accuracy, degree of alignment and the cane load profile. The effectiveness of the spilling activity will be assessed by an analysis of the energy requirements for the motor of the crane. Activities of cleaning will be monitored to determine a method of measuring the amount of cleaning expected for specific loads.

An analysis of the loading operation will be carried out at transloading zones on farm sites and will include the monitoring of grab-loader operators. Two sets of loader operators will be chosen, using similar loading equipment and loading into similar vehicles. However, there will be distinctive differences in their loading accuracies. The data will be analysed in a multi criteria framework in order to establish standards and guidelines to be used within a management system for the loading of sugarcane.

5.4 Project Plan

The project began with a literature survey of the cane transfer processes. The current problems within this component were determined from the industry itself. A project proposal was handed over to the Sezela Mill which was followed up by a meeting to request permission for the use of the mill and for data records within the study. The expected plan for this project is shown in Figure 5.2 which depicts the tasks to be completed. The project thesis for this project is expected to be submitted by the 15^{th} December 2010.

	Start Date	End Date	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Literature Review	**01/02/10**	**25/06/10**											
Loading, Transport and Off-loading	01/02/10	12/03/10											
Designs and systems	01/02/10	12/03/10											
Cane properties	15/03/10	23/03/10											
First draft submission	**Milestone: 29/03/10**			*									
Corrections	12/04/10	23/04/10											
Final proposal submission	**Milestone: 26/04/10**				*								
Final corrections	26/05/10	11/06/10											
Corrected proposal submission	**Milestone: 11/06/10**						*						
Data Collection													
Mill Visit 1	28/04/10	30/04/10											
In-field (zone) 1	19/05/10	20/05/10											
Analysis of data	**30/04/10**	**20/07/10**											
Digital	30/04/10	30/06/10											
Weighbridge	30/04/10	30/06/10											
Video footage	24/05/10	20/07/10											
Design of management system	**04/06/10**	**03/08/10**											
Implementation	**03/08/10**	**01/11/10**											
Test, evaluate and adjustments	**01/09/10**	**28/10/10**											
Assessment 1	01/09/10	02/09/10											
Adjustments	**03/09/10**	**01/11/10**											
Assessment 2	05/10/10	06/10/10											
Thesis write-up	**01/02/10**	**15/12/10**											
Submission	**Milestone: 15/12/10**												*

Figure 5.1 Project Plan of tasks to be completed

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