Introducing servitization as a means to increase profitability for an irrigation company and its customers

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ABSTRACT

Servitization is a business model innovation that allows a manufacturing company to sell its customers the outcome of their product, rather than the product itself. One of the best examples of servitization is the Rolls Royce business model by which Rolls Royce sells the output of their aeroplane engines as “power-by-the-hour”, instead of selling the engines as a product to aeroplane builders such as Boeing. In this model, the customer buys the power that the engine delivers, while Rolls Royce provides all the service, expertise and technology to ensure the engine continues to deliver the power. This model ensures that there is a closer alignment in the interests of the customer and the interests of the manufacturing company.

Manufacturing companies benefit from servitization as a business model by gaining a competitive advantage, differentiating themselves from their competitors, creating a unique selling proposition and generating an income stream from services on products sold. Customers gain benefits from servitization through the division of labour. The customer can focus on its core business, and leaving maintenance of equipment, for instance, for a company for whom the opportunity cost would be less, to do the maintenance.
Irrigation systems have deteriorating efficiencies throughout their operational life. Eliminating or minimizing these efficiency losses, creates value for a farmer as it increases the farmer’s profits.

The objective of the work presented in this mini-dissertation was to determine whether servitization, as a business model, could be mutually beneficial for both a manufacturing company of irrigation equipment, and its customers.

Conclusions and recommendations were made. The primary and secondary research objectives were assessed, and all of them were achieved.

Keywords: servitization, centre pivot irrigation, irrigation efficiency, coefficient of uniformity (CU), irrigation system efficiency.

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Above all I am grateful to God for the talents and guidance He has given me in my life. I aspire to make the most of the little I have been trusted with.

My sincere appreciation to my wife, Landi. Without your kindness and love, life would be pale. Thank you for painting life with me.

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CHAPTER 1 – NATURE AND SCOPE OF STUDY

1.1 Introduction

The manufacturing industry is an extremely competitive industry with product margins under constant pressure. Emerging economies, increasing their production capacity, adds to the pressure. As more and more products become commoditised, manufacturers are continuously looking for ways to differentiate their products. One way of differentiating, is in the aftermarket through servitization. With servitization, manufacturers offer a holistic solution through products and services in the form of selling a customer the outcome that a product delivers, instead of selling the product itself (Bourne, 2016).

Manufacturers of irrigation equipment are no exception, and must, therefore, innovate to differentiate their product and service offering. On examination of the end-customer of an irrigation equipment manufacturer, key characteristics that make servitization a good fit to create synergy and mutual value for both the manufacturer and the customer can be found. These characteristics are:

1. Irrigation systems that decline in efficiency, causing a reduction in crop yield and increased energy usage that results in lower profitability.
2. Irrigation systems that do not harness new and improved technology such as Variable Speed Drives, improved sprinklers, more efficient pumps and control technology. This causes a reduction in potential efficiency and therefore a reduction in potential profit.
3. Management and maintenance time spent on irrigation systems by the farmer comes at a much higher opportunity cost than would be the case if the manufacturing company handled the maintenance and repair, and the management through technological avenues.

1.1.1 Irrigation Systems as Product for Servitization Model

Irrigation systems experience a reduction in potential optimal operating efficiency over time. The reduction in efficiency drives operating costs higher as energy usage and management time increases. It also reduces crop yield, due to poor water distribution and water losses. Both the increased energy costs and reduced crop yield reduces the profit of the irrigation farmer (Lianhao, 2016).

New technological advancements constantly appear in the irrigation industry. These innovations are focused on reducing system pressures (thus reducing energy costs), distributing water more uniformly and improving ease of management.

If farmers are unaware of these advancements and do not implement them, it reduces the farmer’s potential profit and therefore reduces the competitiveness in the highly competitive industry of producing crop commodities. The reduction in efficiency can be ascribed to several reasons such as wear on system parts, for example, nozzles and pump impellers, improved technology and ill-designed irrigation systems (Rogers, 2016).

The irrigation company used in this study is well positioned to solve the problems that cause reductions in efficiencies on irrigation systems. The company has the product range, technical- and design capacity and geographical footprint in Southern Africa to bring irrigation systems in this region back to their potential optimal functionality, and to keep them functioning optimally.

These characteristics of irrigation systems and the positioning of the irrigation company used in this study, merges well to harness servitization as a business model, to create mutual benefit for crop producers and the irrigation company.

1.1.2 Company Oversight

Irrigation systems are the primary business of the company used in this study, with its main focus on centre pivot irrigation systems in the Southern African market. The company is strongly vertically integrated from manufacturing to sales of irrigation related products. The company has two factories, one in the southern part and one in the northern part of South Africa. A branch network across the country consisting of design teams, installation teams, sales teams and stock items, ensures sales of irrigation equipment throughout South Africa. Sales branches in Zambia makes it possible to service this country effectively, while the rest of Southern Africa is serviced directly from the factory that manufactures the centre pivots.

1.1.3 Product Oversight

Of the various irrigation systems, micro-, drip-, moveable sprinkler-, fixed sprinkler and centre pivot irrigation systems, centre pivot irrigation systems were chosen from the product range of the company, to compile this study. The main reasons being that centre pivot systems are the main business of the company, and centre pivot systems are the most recommendable irrigation systems for Southern Africa due to ease of management for large-scale irrigation developments.

1.1.4 Centre Pivot Irrigation Systems

The main component, of which a centre pivot irrigation systems consists, are:

- Pumps
- Electrical motors
- Water supply pipelines
- Electrical supply
- Electrical control systems
- Centre pivot structures.

Centre pivots consist of steel structures, moving in a circular pattern over a field, to irrigate crops planted. These structures can commonly irrigate areas between 3ha and 200ha, depending on the number of “spans” or “wheelsets” on the structure.

Figure 1.1 shows a structure of this type, referred to as a “centre pivot” in this text. The part of the steel structure between two wheelsets is referred to as a “span” in this text. The length of a span varies between 40 m and 70 m and averages on 60 m.

Figure 1.1 Centre Pivot Structure.

Figure 1.2 shows a diagrammatic view of how a pump, water supply pipe line and centre pivot structure is configured in series. Water is commonly extracted from boreholes, dams and rivers. The pump may either pump directly into the centre pivot, as in the diagram in figure 1.2, or the pump can supply a dam or manifold, from where the water is pumped to the centre pivot.

The water supply pipeline conveys the water from the source (borehole, dam or river) to the centre pivot. The size of the pipeline is crucial as it determines the amount of water, pressure (and therefore energy usage) and flow speed of the water that is moved to the centre pivot.

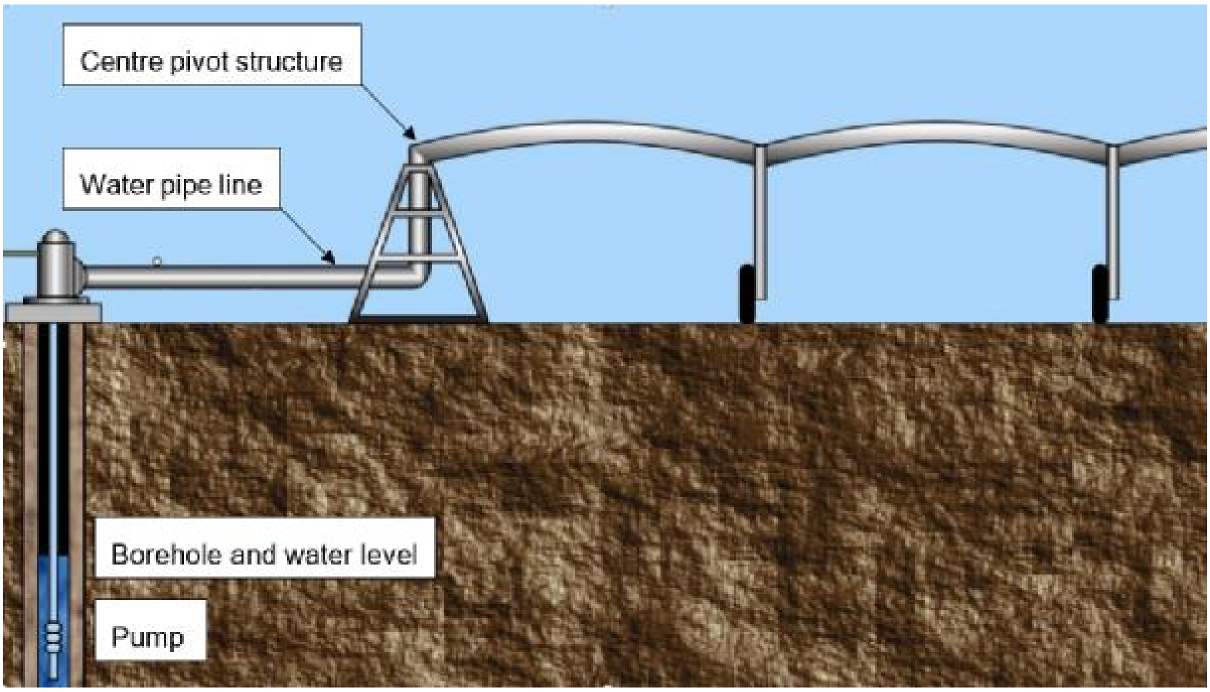

Figure 1.2 Diagram of a Centre Pivot Irrigation System, showing how the pump, pipeline and centre pivot is configured in series.

Centre pivot irrigation systems are of great value and advantage to crop farmers who possess adequate land and water to utilise them. The value for the farmer lies in a crop yield that can be three to four times that of an unirrigated land (also referred to as dry land cropping), a more certain crop that is less affected by timeous rain and ease of irrigation management.

Centre pivots need to be manufactured and installed with high standards of quality to increase their working life. Scheduled maintenance is crucial for optimum operation of these machines. The fast and effective availability of new machines, spare parts, installation teams and technical knowledge, forms the core backbone to unlock value for farmers through these irrigation systems.

The image below shows aerial footage of what the irrigated circles under centre pivot irrigation look like from the sky.

Figure 1.3 Aerial View of Arable Fields Irrigated by Centre Pivots.

1.1.5 Value Chain Oversight

Porter (1985), describes the value chain of a company as the set of activities that an organisation carries out to create value for its customers. The way in which value chain activities are performed affects the operational costs incurred and therefore the profits of the company. The value that a company creates and captures for its customers reflects its profit margin.

This can be expressed with the following equation:

Value Created and Captured – Cost of creating that Value = Margin

The more value a company creates, the more profitable it will be and the bigger it will build its competitive advantage (Amadeo, 2018).

It should be noted that the value for a centre pivot irrigation customer, lies in the efficient operation of the irrigation system, i.e., in delivering the right amount of water, uniformly over the field, at the least amount of electricity or power needed.

Figure 1.4 shows Porter's generic value chain.

Figure 1.4 Porter's Generic Value Chain.

The value chain of a company, as shown above, illustrates that company activities are divided into primary activities, and support activities. Support activities fall outside of the scope of this study.

To provide perspective, the focus of this study will be on the primary activities of the company and more specifically on service and the linkage between service and marketing and sales. This focus aims to create value for the customer, and a competitive advantage for the company, through servitization.

1.1.6 Linkage between Marketing and Sales and other Primary Activities

Currently, the sales team of centre pivot irrigation systems, employed by the company, compete in the southern African market against two to four competitors for every sale. They compete mainly on price and delivery time. Once the order is secured, the salesperson places the order at the factory via a web-based system. The order is then seamlessly received by the factory and processed, manufactured, shipped and installed on the farm.

Once the centre pivot system is operational and signed off to the customer, the centre pivot carries the following warranty:

- **Structure.** The structural strength and quality of manufacturing of the complete structure, as manufactured by the company, carries a 2 year or 2000 hours warranty, whichever expires first.
- **Electrical system.** The electrical control and power supply system and componentry, which powers and controls the centre pivot, carries a 2 year or 2000 hours warranty, whichever expires first.
- **Centre drives.** The electrical motors that convert electrical energy into rotational energy to turn the wheels of the centre pivot is warranted at 4 years or 4000 hours, whichever expires first.
- **Gearboxes.** The gearboxes couples the wheels to the centre pivot structure and provides the torque to turn the wheels and to rotate the centre pivot around the centre. It has a warranty of 4 years or 4000 hours, whichever expires first.

- **“Windsaver” machines that are blown over**. If the customer upgraded the standard tower configuration to a “windsaver”, the structure provides for the two wheels on the same tower, to be further apart, which makes the machine more stable in windy conditions. A 4 years or 4000 hours, whichever expires first, warranty applies.
- **Span pipes that fail as a result of corrosion.** 10-year sliding scale: corroded pipes will be replaced at a price that is equal to the number of months elapsed since delivery multiplied by the list price at the time of replacement, divided by 120.

The customer is issued with a maintenance schedule that outlines how maintenance on the machine, especially the drive train components and electrical parts should be done.

If there are any problems with the functioning of the systems, whether it be componentry, operator’s error or what the case may be, the company would honour their product and send out a technician or technical team to rectify the problem, with no charge to the customer. In more than a year or so, the customer would be charged for fixing any problems that may have occurred. This leaves grey areas as to who is responsible for what, as well as customers or the company feeling that the other party should be obliged to pay for expenses incurred. The company’s value chain therefore pretty much stops after the product has been delivered, installed and signed off.

The reason for this study is to determine if there is value to be created and captured after the irrigation system is installed and operational. Created and captured value can be profited on by both the crop producers and the irrigation company.

To provide perspective, the focus of this study will be on the primary activities of the company and more specifically on services and the linkage between services and marketing and sales. This study aims to determine if value can be created for the customer, and a competitive advantage for the company, through servitization.

1.2 Problem Statement

Declining efficiencies of irrigation systems results in using more water and energy, over the same area of planted crop, with a decrease in crop yield. The decline of efficiencies is preventable through continuous assessment and maintenance of irrigation systems (Koech and Langat, 2018). An irrigation company that is well positioned to do assessments of irrigation systems, will be able to sell the products needed to rectify the irrigation system, through their services of assessment and design. According to Topcu (2005), recent developments in irrigation technology, are helping to improve the irrigation efficiency of irrigation systems. Constrains, however, exist in the form of the lack of economic incentives and the lack of knowledge of the advantages of the adoption of new technologies by the irrigation farmer.

The problem is that no existing model aligns the interests of the crop producer with the interests of the irrigation company, to create mutual benefit, by harnessing declining irrigation efficiencies on irrigation systems, as a mechanism.

A well assessed, redesigned and rectified irrigation system, will, therefore, increase the profits of the farmers, as well as the irrigation company, creating a win-win outcome.

1.2.1 Primary research question

The primary research question is: Can value be created for both irrigation farmers and the irrigation company in this study, in the form of services rendered as a means of servitization?

1.3 Objectives of the Study

1.3.1 Primary objectives

- Determine whether or not the service of an assessment, redesign and upgraded implementation of an existing irrigation system can be profitably performed by an irrigation company.
- Determine whether or not the service of an assessment, redesign and upgraded implementation from an irrigation company, on an existing irrigation system will be profitable for a prudent crop producer if he has to buy the products.

1.3.2 Secondary objective

- Determine whether or not the irrigation company used in the study can expand the value chain to the aftersales market through servitization.
  The irrigation company will be able to expand their value chain, into the aftersales market through servitization, if their products can be sold profitably through the service of assessment and redesign. The crop producer needs to get more value than he/she pays for, to assume that a sales transaction will happen.

1.4 Scope of the Study

The study will focus on the difference in efficiency of the current state irrigation systems and the future state irrigation systems after proper analysis and redesign were done.

The measures for efficiency will be derived from the power consumption and uniformity of the water distribution. The costs of attaining the future state system will then be compared with the increase in crop yield and decrease in power consumption, to determine the increase in profitably for both the farmer and the irrigation company.

1.5 Research Methodology

A case study will be conducted in an empirical manner with quantitative data gathered in the form of empirical measurements, and a qualitative approach where assumptions are made with regards to the decision making process of a prudent business man.
This study will therefore be conducted as a case study consisting of the following four phases:

Phase 1 – Literature review: A literature review on the history, implications, implementation, advantages and possible disadvantages of servitization as a business model will be conducted.
The literature review will also cover how irrigation efficiencies are determined for centre pivot irrigation systems.

Phase 2 – Gathering current state data: A farm was selected at random within a 100 km radius from the factory which produces the centre pivots. Data will be gathered on this specific farm chosen which, is about 48 km away from the factory of the irrigation company participating in the study. The expertise and product range of the participating irrigation company will be used.

Phase 3 – Determining and implementing the future state: The irrigation systems will be assessed thoroughly, redesigned theoretically and new products will be specified to increase the efficiency of the systems. The theoretical efficiencies of the future state will then are determined to be able to compare the efficiencies of the current state and the future state.

Phase 4 – Conclusions and recommendations: The current state- and the future state efficiencies will be compared with each other as well as the cost of attaining the future state vs increase in profit from the increased yields. Conclusions and recommendations will be drawn on these findings.

1.6 Chapter Division

Chapter 1: Introduction.

Chapter 2: Literature review.

Chapter 3: Data gathering and analysis.

Chapter 4: Results.

1.7 Limitations of the Study

Because of the time constraint of waiting for a crop to yield a harvest and the high cost of irrigation products, this study will rely on theoretically determined irrigation system efficiencies and crop yields.

CHAPTER 2 – LITERATURE REVIEW

2.1 Introduction

To understand the concepts needed to conduct this study, a literature review was done on the subjects of *Servitization* and *Irrigation Efficiency*.

To create an understanding of the term ***"Servitization"*** the following concepts were analysed and studied to develop a basis for the business model formation:

- Servitization
- Servitization and customer preference
- Servitization as a competitive advantage

The literature review will also cover the term ***"Irrigation Efficiency"*** to obtain a better understanding of what should be measured and controlled to irrigate efficiently. The following concepts were analysed to create a basis of measuring the efficiency of an irrigation system:

- Irrigation Efficiency
- Irrigation system performance
- Water Conveyance Efficiency (E_c)
- Water Application Efficiency (E_a)
- Irrigation Efficiency (E_i)
- Overall Irrigation Efficiency (E_o)
- Uniformity of water application
- Impact of Irrigation Uniformity on Crop Yield

2.2. Servitization

The term servitization refers to the change in a business model to sell an outcome, rather than selling a product (Neely, 2013).

Xerox was one of the first companies to pioneer this business model where they charged customers for photocopies made, and not for a photocopier machine, sold as a product to the customer. In essence, the customer thus bought what they wanted, and that was photocopies, and not a photocopier machine (Visintin, 2014:23).

A number of factors relating to the photocopier industry make servitization a good fit for the industry. These factors include the high capital cost of big photocopy machines (especially when the technology first came about, and the Japanese haven't entered the market yet with their smaller, basically service-free, cheaper models) as well as the numerous amount of mechanical parts that a photocopier consists of, that is bound to break (Visintin, 2014:25). These machines required a lot of service and maintenance initially, off which the OEMs of copier machines could profit.

In the same way, Alstom, a French company that traditionally is a manufacturer in the transport industry, now offers "TrainLife Services". They undertake to design, manufacture and manage train and signalling systems. Their value offering in the service market includes maintenance, fleet support, managerial and technical support and improved performance for the lifetime of the train (Ampleati, 2015).

Another definition of servitization is the shift to offering services, to complement a company's core product offering. This generates an additional income stream for a company (Kanungo, 2016).

The concept dates back to the 1980s when Van der Merwe and Rada suggested servitization as an alternative way to generate a revenue stream for manufacturing companies through customer base retention differentiating products (Van der Merwe and Rada, 1988).

Because of the complexity and integration of different aspects of business, servitization has benefits on various different levels apart from direct profitability. In a study on Japanese companies, it was revealed that there were significant positive increases on business aspects such as leadership (17.2%), vision (16.3%) and marketing (9.5%) (Ahamed, 2013).

Three key benefits to servitization are suggested by Blood-Rojas (2017) as:

1. More effective solutions
2. Greater financial stability
3. Increased customer retention

By no means should servitiazation be seen as a solution to all problems in a manufacturing firm. A study on UK manufacturing firms that implemented servitization, found that servitization increased overall productivity, but only contributed to company survival after when higher levels of servitization were implemented (Bascavusoglu-Moreau, 2011). This is emphasised by a Chinese study done on servitization, which concludes that servitization levels in China correlates positively with market performance, but correlates negatively with financial performance (Min, 2015).

2.2.1 Servitization and Customer Preference

According to Brooks (2018), customer preferences are shifting from “ownership” to “access”, causing many manufacturers to redefine the way they do business. The manufacturing industry is seeing the shift towards servitization where manufacturers must now focus on selling product up-time, increased performance and many other service-related metrics, instead of physical products (Brooks, 2018).
Customer preference is shifting from *“ownership”* to *“access”* as manufacturing companies are selling *“comfort-as-a-service”*. Servitization is becoming a popular strategy for Original Equipment Manufacturers (OEM) to improve customer satisfaction and grow profits in the manufacturing industry. Customer service is changed dramatically with the shift from break-fix strategies to maximised product uptime through servitization (Bell, 2018).

2.2.2 Servitization as a Competitive Advantage

Firms are increasingly exploring the value of integrating goods and services (Baines and Lightfoot 2013), motivated by anticipated improvements in profit margins and the prospect of locking competitors out of their customer base (Bustinza, Parry, and Vendrell-Herrero 2013). Servitization offers the opportunity to generate a sustainable competitive advantage, since it frees firms from competing on cost alone (Porter and Ketels 2003), allowing for greater differentiation and increased customer satisfaction.

Maheepala (2016), makes it clear that servitization gives manufacturing companies a competitive advantage by increasing its performance and forcing it to stay ahead of the competition.

Kryvinska (2014), argues that one should note that pure services rarely gives a competitive advantage as it is assumed as the industry standard, although it adds significant value for the customer. Such examples are product training, delivery, customer help desks and repairs. This is not servitization, but pure service.

Through servitization, a Taiwanese bicycle company was able to compete with Chinese manufacturers in a highly competitive industry. The Taiwanese manufacturer used aftersales maintenance and repair as well as customization of bicycles to individual needs, as means of servitizaiton (Chuang, 2016).

2.3 Irrigation Efficiency

According to the Certified Irrigation Contractor Workbook (2004), the determining factors of an efficient irrigation system design is one that:

- delivers water uniformly to the crop;
- with the least amount of energy required; and
- economic cost of material to erect and operate the system.

Irrigation efficiency is generally defined by looking at three aspects (Irmak et al., 2011):

- Irrigation system performance;
- Uniformity of water application; and
- Response of the crop to irrigation.

Irrigation system performance and uniformity of water application will be discussed in this literature review as it is of importance in determining irrigation efficiency for comparison purposes for the sake of this study. The response of the crop to irrigation will not be covered as this measures the difference in yield between rainfed crops and irrigated crops.

2.3.1 Irrigation System Performance

Irrigation system performance is a measure of the effectiveness of the chosen irrigation system, as well as operating decisions taken, to deliver water from a source to the crop. The terms that describe irrigation system performance that will be covered in this section of the literature review are:

- Water Conveyance Efficiency (E_c);
- Water Application Efficiency (E_a);
- Irrigation Efficiency (E_i); and
- Overall Irrigation Efficiency (E_o).

2.3.1.1 Water Conveyance Efficiency (E_c)

Irrigation systems normally depend on water that is conveyed from a water source to the field. Water sources include rivers, dams and boreholes. Conveyance systems mainly consist of pipelines and earthen – or lined canals. When the water delivered to the field is less than the water extracted from the water source, transmission losses have occurred. Most common transmission losses are leakages in pipelines, canal seepage, canal evaporation and canal spills (Jacob, 2003).

Water conveyance efficiency is expressed as:

$$E_c = (V_f / V_t) \times 100$$

Where the elements of this formula are given as:
E_c = Water conveyance efficiency (%)
V_f = Volume of irrigation water that reaches the field (mm/ha)
V_t = Volume of water extracted from source (mm/ha)

2.3.1.2 Water Application Efficiency (E_a)

Irrigation system application efficiency is defined as the amount of water that is stored in the root zone of the irrigated crop, that is available to meet transpiration, in relation to the amount of water applied by the irrigation system, to the field (Harms, 2011).
According to Harms (2011), the efficiency of irrigation systems varies due to factors such as:

- Type of system (centre pivot, micro, drip, hand moveable sprinkler etc.);
- Age of the system (efficiency decreases with age);
- Type of nozzles;
- Height of sprinklers above the canopy;
- Degree of maintenance done on the system;
- Technical design of the system; and
- Irrigation management.

System application efficiency losses occur due to the following reasons:

- Evaporation of water before it infiltrates the ground;
- Percolation of irrigated water below the depth on which the plant roots can utilise the water;
- Wind drift blowing the irrigated water away from the target area; and
- Surface runoff due to an instantaneous application rate that is too high.

Due to the number of different factors and the degree of variation within the factors, most irrigation system application efficiencies are displayed as a range, rather than a single number. Table 2.1 below shows the irrigation system application efficiency values for different methods of irrigating (Irmak et al., 2011)

Irrigation System	**Potential Application Efficiency (%)**
Sprinkler Irrigation Systems	
LEPA	80 - 90
Linear move	75 - 85
Center pivot	75 - 85
Travelling gun	65 - 75
Side roll	65 - 85
Hand move	65 - 85
Solid set	70 - 85
Surface Irrigation Systems	
Furrow (conventional)	45 - 65
Furrow (surge)	55 - 75
Furrow (with tailwater reuse)	60 - 80
Basin (with or without furrow)	60 - 75
Basin (paddy)	40 - 60
Precision level basin	65 - 80
Micro Irrigation Systems	
Bubbler (low head)	80 - 90
Microspray	85 - 90
Micro-point source	85 - 90
Micro-line source	85 - 90
Subsurface drip	> 95
Surface drip	85 - 95

Table 2.1 Irrigation System and Application Efficiencies for Various Irrigation Systems.

It should be noted that the efficiency values in table 2.1 are a strong function of how well the system is managed. Because of the complexity of managing any of the micro irrigation systems, the efficiency may well drop to below any of the other systems if not managed well (Irmak et al., 2011).

For the sake of this study, only centre pivot systems will be considered. The table shows that the efficiency range is higher than that of surface irrigation systems.

2.3.1.3 Irrigation Efficiency (E_i)

Irrigation water may in some cases be applied to a field, to achieve other goals than that of fulfilling the evapotranspiration needs of the crop. Reasons for applying water for other reasons may include:

- Reduction of salts through leaching;
- Creating a microclimate for purposes of evaporative cooling during extreme heats or spraying the crops to protect them against frost;
- Preparing a seedbed before planting;
- Germinating seeds;
- Softening of soil crust;
- Irrigating beneficial plants such as windbreaks or cover crops;
- Fertilising; and
- Chemination.

When more water is distributed to the field than is required for evapotranspiration alone of the crop alone, the concept of irrigation efficiency is used to express the ratio between the water that is used by the crop to all the water that is distributed to the field (Sakadevan and Nguyen, 2010). The equation for irrigation efficiency is given as:

$$E_i = (V_b / V_f) \times 100$$

Where the elements of this formula are given as:
E_i = Irrigation efficiency (%)
V_b = Volume of water used by crop (mm/ha)
V_f = Volume of water delivered to the field (mm/ha)

2.3.1.4 Overall Irrigation Efficiency (E_o)

The overall irrigation efficiency describes the efficiency of the system as well as decisions that are made, to get water from the water source to the crop. Overall irrigation efficiency is given by multiplying the efficiencies of water conveyance in 2.2.1.1, and the water application efficiency in 2.2.1.2 with each other (Meyer, 1957).

The formula is thus:

$$E_o = (E_c \times E_a) \times 100$$

Where the elements of this formula are given as:
E_o = Overall water irrigation efficiency (%)
E_c = Water conveyance efficiency (decimal)
E_a = Water application efficiency (decimal)

2.3.2 Uniformity of Water Application

The irrigation efficiencies described above do not directly address the irrigation uniformity or non-uniformity of an irrigation system. Irrigation uniformity impacts the crop yield drastically as it results in overwatered areas as well under-watered areas in the same field, all while the energy costs of the pump would have been the same (or in most cases is higher) for a uniformly distributed water application (Irmak et al., 2011).

Crops experience water stress in areas that are under-irrigated, and oxygen stress in areas that are over-irrigated. In contrast, plants perform optimally when exposed to conditions of uniform water application, where each plant has equal opportunity to utilise the same amount of water, ground and nutrients. A study by Li (1998) confirms that by testing a model on crop yield and irrigation uniformity, crop yield evidently increases as uniformity increases.
According to Kara (2008) the main factors for irrigation uniformity are:

- Sprinkler type;
- Number and size of the nozzle;
- Arrangement of sprinklers;
- Working pressure;
- Wind speed;
- Improper selection of delivery pipes;
- Wear and tear on the system; and
- Nozzle clogging.

These factors can be divided into three categories on basis of their causes:

Design related causes	Maintenance related causes	Natural causes
Sprinkler type	Wear and tear on system	Wind speed
Number and size of nozzle	Nozzle clogging	
Arrangement of sprinklers		
Working pressure		
Improper selection of delivery pipes		

Table 2.2 Factors affecting Irrigation Uniformity, categorized on basis of their root cause.

Most of the causes for poor irrigation uniformity can thus be avoided through well-designed systems and all the causes, except natural causes, can be avoided through a combination of design and management excellence. This is a positive pointer towards servitization as a remedy for improving irrigation uniformity.

Irrigation uniformity can easily be measured practically for centre pivot irrigation systems as explained by Harrison (2013). Figure 2.1 shows a practical setup of how this measurement is conducted. A line of catch cups, of equal size, or rain gauges should be evenly spaced out on a field, in a radial direction from the centre. In figure 2.1, these are the red cups that can be seen, fixed to anchoring rods in the ground. The centre pivot should then run over the line of cups while emitting water. The water from each cup should be measured by throwing it into a rain gauge and recording the amount of millimetres of water emitted into the cup. The water measured in millimetres, should be plotted on the y-axis of a graph, with the number of the catch can from the centre of the pivot, on the x-axis. This graph shows the irrigation uniformity of a centre pivot. Figure 3.2 in chapter 3, shows what such a graph looks like. This irrigation uniformity graph gives a graphical representation of the water distribution over a field where one can easily identify which part of the field receives more water or less water than other parts of the field.

The numeric values gathered in the irrigation uniformity test, can be used to calculate the coefficient of uniformity, which gives a numeric indication of how well water is distributed over the field. This numeric value can also be used to calculate the loss in crop yield, due to irrigation un-uniformity, as will be discussed in chapter 3.

Figure 2.1 Irrigation uniformity test setup for a centre pivot system, where the red cups catches water emitted by the centre pivot, in order to measure and record the amount of water emitted onto each section of land.

2.3.2.1 Uniformity Coefficients

Highly uniform water application in irrigation systems does not necessarily ensure high efficiency of the system since water can be uniformly over- or under applied. Irrigation uniformity, together with an efficient irrigation system, is, however, a prerequisite for optimal crop yields (Pitts, 2001).

There are a number of different coefficients for uniformity on irrigation systems which include the following (Reinders, 1996):

- Coefficient of Uniformity (CU);
- Distribution Uniformity (DU);
- Statistical Uniformity (SU); and
- Emission Uniformity (EU).

In a study done on the impact of Coefficient of uniformity (CU) on crop yield (Reinders, 1996), the following table of data was constructed for maize under irrigation:

Coefficient of Uniformity (CU) (%)	Yield of Maize (tons/ha)
80	6.8
75	6.3
70	6
65	5.15
60	4.2

Table 2.3 Coefficient of Uniformity vs Yield of Maize

Table 2.3 indicates that roughly a 1% decrease in CU effects the yield with a decrease of 2%. This measurement and ratio enables the calculation to see what the crop yield loss (in tons/ha) is, for a given CU measured on a field. Once the loss in tons of crop yield is established, the loss in monetary terms can be calculated. The loss of money can be used by the farmer to make a prudent and informed decision, whether or not it will be a viable option to spend money on the irrigation system to obtain a higher CU, by buying and installing new parts to replace worn out parts, or to buy more efficient technology. The higher CU translates into a higher yield and thus a monetary return on the investment needed to obtain the higher CU.

The coefficient of uniformity (CU) used in Table 2.3 was calculated using Christiansen uniformity equation. The coefficient of uniformity (CU) of 84% is regarded as satisfactory.

The adjusted Christiansen uniformity equation for centre pivots is given as (Test Procedure for Determining the Uniformity of Water Distribution of, 2001):

$$CU = 100\left[1 - \frac{\sum_{i=1}^{n} S_i \left| V_i - \overline{V}_p \right|}{\sum_{i=1}^{n} V_i S_i}\right] \qquad \overline{V}_p = \frac{\sum_{i=1}^{n} V_i S_i}{\sum_{i=1}^{n} S_i}$$

Where the elements of this formula are given as:

CU is the adjusted Christiansen coefficient for centre pivots

n is the number of cups used to collect the water

i is a number used to identify a specific cup, i = 1 being closeted to the centre of the pivot and i = n being the cup furthest away from the centre

V_i is the depth of water in the *i*th cup

S_i is the distance of the cup from the centre

V_p is the weighted average of the water caught

2.3.3 Impact of Irrigation Uniformity on Crop Yield

When table 2.3 is considered, it can be seen that a 1% decrease in CU, translates to a 2% decrease in crop yield. This figure is backed by Reinders (1996) in a study on the performance of irrigation systems and the impact on water use efficiency.

According to research done on plant growth and yields as effected by wet soil conditions due to over-irrigation by Rathje (2008), over-irrigation results in nitrogen leaching and runoff. Continuous conditions of wet soil create an environment favourable to diseases. Crop yield is also compromised when over irrigation effects the following:

- The oxygen balance in the root zone is affected and stresses the plant due to reduces water uptake and drowning.
- The exchange of air between the ground and atmosphere is prohibited, and nutrients are prevented from entering the ground.
- Increased microbial growth causes the formation of sulphides that are toxic to plants.
- Increases potential for root and lower stem diseases.

Too much water on the field can be a result of natural causes such as rapid rain showers or above normal rainfall during the season. Poor irrigation management and poorly designed irrigation systems can be another cause. Fungal and bacterial diseases can cause root rotting which translates into yield reduction (Rathje and Irmak, 2008).

In the same study done by Rathje (2008), data from two previous years, 2006 and 2007 were used to plot graphs that show the negative impact of over-irrigation on crop yields. The data shows the percentage of evapotranspiration that was irrigated on the x-axis and the yield (in bushels per acre) on the y-axis.

Crop yield is a maximum when 100% of the evapotranspiration is irrigated. Figure 2.2 shows that over-irrigation causes a reduction in crop yield (Rathje and Irmak, 2008).

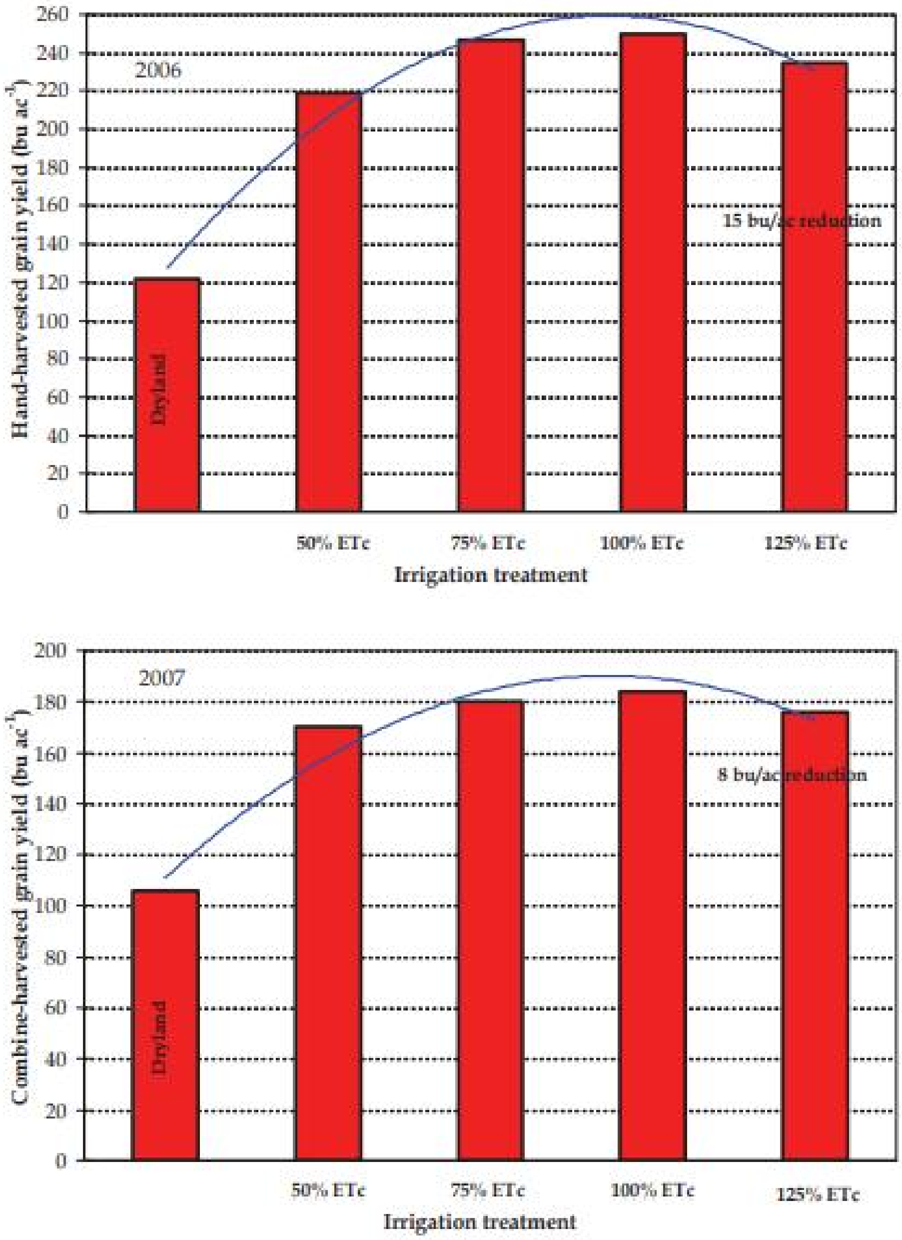

Figure 2.2 Crop yield vs % of ETc

With harvested grain yield on the y-axis and percentage of evapotranspiration irrigated on the x-axis, it can be seen that the yield reduces when more than the required water (125% of ETc) is irrigated. These graphs shows the same trend in result for hand harvested as well as machine harvested crops.

2.4 Summary

Servitization is a business model that works well when skill, knowledge and competency, needs to be applied in order to keep an asset performing at optimal capacity. Irrigation systems are assets which fit this description.

Irrigation efficiencies continuously declines as irrigation systems increase in their lifespans. If these declining efficiencies can be prevented or rectified, advantages for the irrigation farmer exists in the form of increased crop yield as well as reduced energy usage. Irrigation efficiencies, as well as the effect of declining efficiencies, can be measured and calculated. The effect of rectifying the loss in efficiencies can also be theoretically determined.

With the theoretical background of this literature review, the irrigation efficiencies and theoretical crop yields can now be determined through a practical study. This practical study is the essence of the next chapter, Chapter 3.

CHAPTER 3 – DATA GATHERING AND ANALYSIS

3.1 Introduction

To determine whether or not servitization as a business model can create value for the irrigation company as well as it's customers, it needs to be determined whether or not the irrigation company can offer a service to its customers, for which the customers will be satisfied to pay.

Prudent farmers would be satisfied to pay for a service if the service offers more value to them than the cost of the service. The irrigation company would be satisfied to sell products, through rendering service, if the margin on the products it sells are higher than the cost of rendering the service.

To determine whether these conditions can all be met, data was gathered on an irrigation system, followed by a five-phase systematic approach.

3.2 Irrigation System Layout

The irrigation system used for this study was randomly selected in a 100 km radius from the factory of the irrigation company, the main reasons being the ease of access and keeping costs low.

A centre pivot irrigation system consisting of a dam, pump and electric motor, pipeline and centre pivot irrigator was used. The centre pivot irrigates an area of 60 ha where mainly maize and wheat is produced.

Figure 3.1 shows an aerial view of the centre pivot, as well as the location of the dam and pipeline, for the reader to form a better understanding. The pump is located against the dam and pumps water through the pipeline, to the centre of the centre pivot applicator.

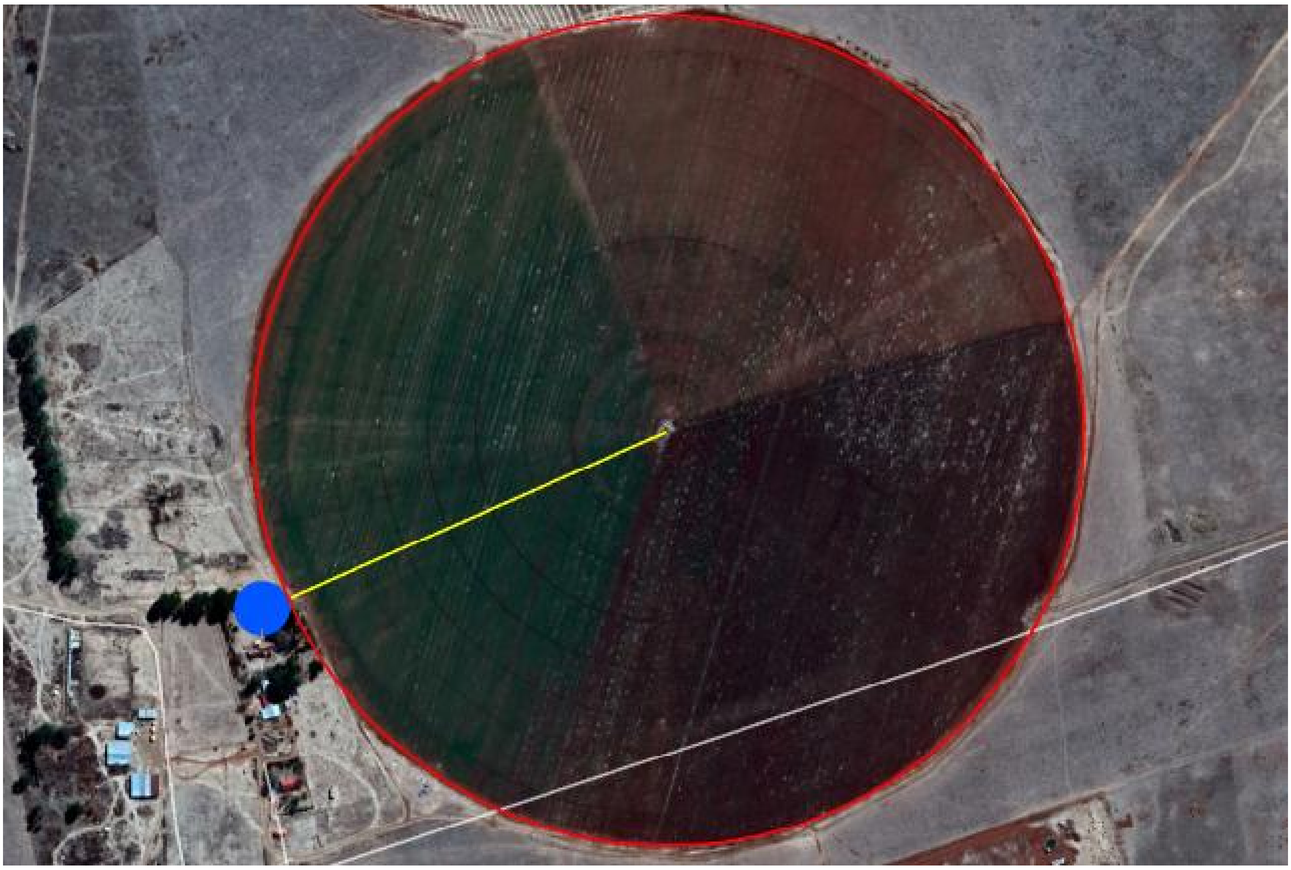

Figure 3.1 Aerial View of the Irrigation System, showing the Dam (Blue), Pipeline (Yellow) and Centre Pivot (Red).

3.3 Five-Phase Systematic Approach

To conduct the practical study, the following five-phase systematic approach was followed. A brief description of every phase is outlined below.

Phase One: Current state analysis:

i. Determine the current state quantity of irrigated water used.
ii. Determine the current state water distribution efficiency.
iii. Determine the current state power used.
iv. Determine the current state pump and motor specifications.
v. Determine the current state pipeline size.
vi. Determine the current state centre pivot configuration for optimal centre pressure.

Phase Two: Future state design:

i. Do an optimal, efficient hydraulic design for the centre pivot irrigation system, based on the available water and land.
ii. Determine the following:
iii. Determine the theoretical water distribution efficiency.
iv. Determine the theoretical power usage.
v. Determine the theoretical optimal pump and motor specifications.
vi. Determine the theoretical optimal pipeline size.
vii. Determine the optimal centre pivot configuration for optimal centre pressure, from the available span sizes.

Phase Three: Cost Calculation:

i. Calculate the costs that will be needed to achieve the future state design, incurred by the crop producer.
ii. Calculate the costs that are incurred by the irrigation company to obtain the data and design for the future state system in phase 2.

Phase Four: Change in Yield Calculation:

Based on the current state analysis obtained in phase 1, and the future state analysis obtained in phase 2, combined with the literature on the subject, calculate the change in crop yield expressed in tons per hectare.

Phase Five: Income and Expenses Calculation:

i. Calculate the profit or loss that the crop producer would achieve if the future state design was implemented.
ii. If a profit arises, calculate the return on investment (ROI) the producer would achieve.
iii. Calculate the profit or loss that the irrigation company would achieve.

3.4 Phase One: The current state analysis

The composition of the irrigation system that was analysed in this study is shown below in table 3.1:

	Centre Pivot
Number of spans	8
Length of the machine (m)	436.9
Irrigated area (ha)	60
Nozzle package size (mm/24h)	8

Table 3.1 Current State Composition of System A and B

3.4.1 Quantity of irrigated water

To determine whether or not a loss of water through the pipeline occurs, the volume flow of the water was measured at the pump, and again at the entry point into the centre pivot. Theses flowrates are shown in table 3.2.

Flow at the pump (m^3/h)	**266**
Flow at centre (m^3/h)	**266**

Table 3.2 Quantity of Irrigated Water

With the flowrates being the same at the pivot centre as well as at the pump, it can be concluded that no water is lost in conveyance in the system.

3.4.2 Water distribution efficiency

A catch cup system was used to determine the irrigation uniformity. The catch cup configuration was described in detail in section 2.3.2. The graph in figure 3.2 was compiled, it shows the water distribution of the centre pivot irrigator.

The graph indicates that the water is distributed in a non-uniform manner to a large extent. The effect of this can be seen in the yield of the crop

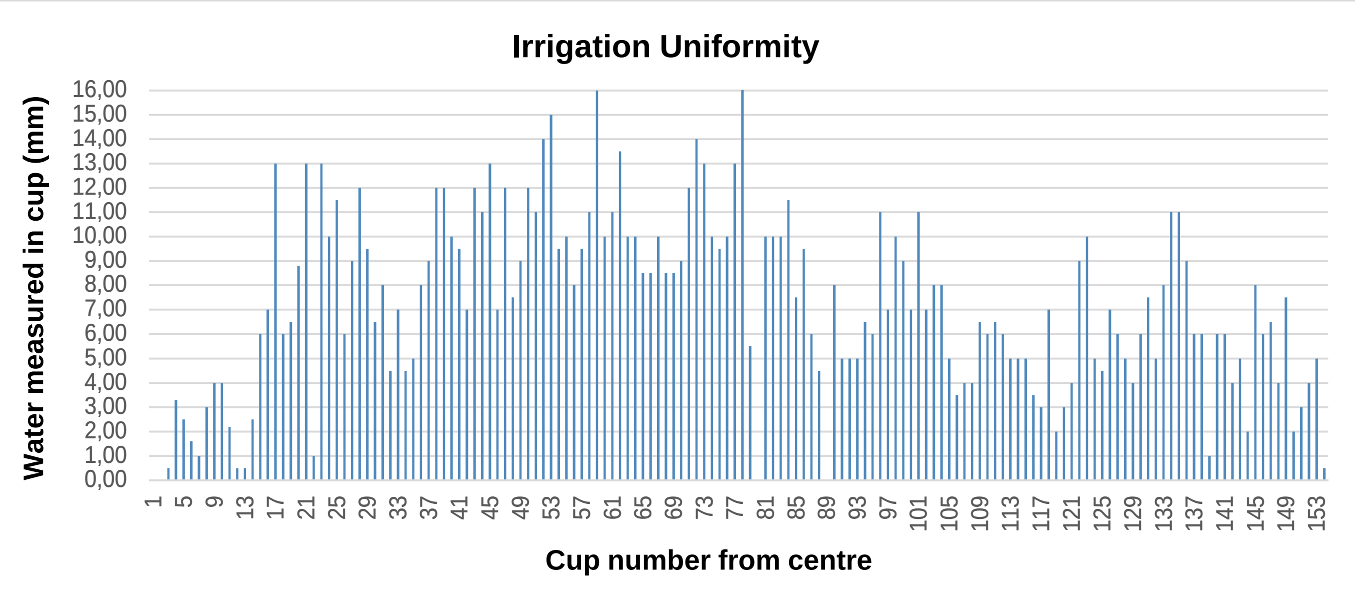

Figure 3.2 Irrigation Uniformity

3.4.3 Irrigation Uniformity

The Coefficient of Uniformity for the centre pivot was calculated, using the results from the catch cups. See Appendix A For calculation of the Coefficient of Uniformity (CU) calculations. Table 3.3 shows the Coefficient of Uniformity (CU).

CU (%)	62

Table 3.3 Coefficient of Uniformity (CU)

3.1.4 Power used

The power used by the motor at the pump was measured using a multimeter. The power usage is displayed in table 3.4.

Power at pump motor (kW)	**49**

Table 3.4 Power used

3.5 Phase Two: The future state design

The future state for the irrigation system was redesigned for optimal performance. The system properties for the future state system are given in table 3.5.

Power used (kW)	34.34
Quantity of water (m³/h)	266
System inlet pressure (kPa)	309
Nozzle package size (mm)	8

Table 3.5 Future State Design

Table 3.6 and table 3.7 shows the design configurations for the current state and future state of the centre pivot structures, respectively. The design configurations for the centre pivot structures includes the span lengths, flow speed of water through the structure, friction losses, total area irrigated and application of water per pass of one one revolution of 360 degrees.

Item	Pipe diameter / Centre selection	Span length	Flow to crop	Friction per unit length	Friction or pressure	Centre drive ratio	Weight on wheels (kg)
Centre:	3-Leg	1,0 m		0,20 kPa/m	0 kPa		1 550 kg
Span 1:	165 mm	47.0 m	0,7 l/s	0,45 kPa/m	21 kPa	40:1	2 700 kg
Span 2:	165 mm	47.0 m	2,0 l/s	0,43 kPa/m	20 kPa	40:1	2 700 kg
Span 3:	165 mm	47.0 m	3,2 l/s	0,39 kPa/m	18 kPa	40:1	2 700 kg
Span 4:	165 mm	47.0 m	4,5 l/s	0,34 kPa/m	16 kPa	40:1	2 530 kg
Span 5:	127 mm	53.7 m	6,7 l/s	1,07 kPa/m	57 kPa	40:1	2 360 kg
Span 6:	127 mm	53.7 m	8,4 l/s	0,75 kPa/m	40 kPa	30:1	2 730 kg
Span 7:	165 mm	53.7 m	10,1 l/s	0,11 kPa/m	6 kPa	30:1	3 275 kg
Span 8:	165 mm	60.5 m	13,3 l/s	0,04 kPa/m	2 kPa	30:1	2 181 kg
Span 9:	None						-
Span 10:	None						-
Span 11:	None						-
Span 12:	None						-
Span 13:	None						-
Span 14:	None						-
Overhang:	101 mm	26.8 m	6,6 l/s	0,06 kPa/m	2 kPa		
R55:	None		-				
P85 Endgun:	None		-				
Area:	60,0 Ha	436,9 m	56,6 l/s	Avg 0,42 kPa/m	183 kPa	Price ex-VAT:	
Circle time (time to run 360˚): at 100 %			12,4 h	Total elevation:	34 kPa	Installation:	
Application per pass at 100 %:			4,1 mm	End pressure:	140 kPa	Eskom est.:	
Current drawn per phase (400 V 3 phase):			8,2 A	Inlet pressure:	358 kPa	Total est.:	

Table 3.6 Centre Pivot Design Span Configuration, Current State

Item	Pipe diameter / Centre selection	Span length	Flow to crop	Friction per unit length	Friction or pressure	Centre drive ratio	Weight on wheels (kg)
Centre:	3-Leg	1,0 m		0,20 kPa/m	0 kPa		1 550 kg
Span 1:	165 mm	47.0 m	0,7 l/s	0,45 kPa/m	21 kPa	40:1	2 700 kg
Span 2:	165 mm	47.0 m	2,0 l/s	0,43 kPa/m	20 kPa	40:1	2 700 kg
Span 3:	165 mm	47.0 m	3,2 l/s	0,39 kPa/m	18 kPa	40:1	2 700 kg
Span 4:	165 mm	47.0 m	4,5 l/s	0,34 kPa/m	16 kPa	40:1	2 900 kg
Span 5:	165 mm	53.7 m	6,7 l/s	0,27 kPa/m	15 kPa	40:1	3 100 kg
Span 6:	165 mm	53.7 m	8,4 l/s	0,19 kPa/m	10 kPa	30:1	2 730 kg
Span 7:	127 mm	53.7 m	10,1 l/s	0,43 kPa/m	23 kPa	30:1	2 520 kg
Span 8:	127 mm	60.5 m	13,3 l/s	0,15 kPa/m	9 kPa	30:1	1 796 kg
Span 9:	None						-
Span 10:	None						-
Span 11:	None						-
Span 12:	None						-
Span 13:	None						-
Span 14:	None						-
Overhang:	101 mm	26.8 m	6,6 l/s	0,06 kPa/m	2 kPa		
R55:	None		-				
P85 Endgun:	None		-				
Area:	60,0 Ha	436,9 m	56,6 l/s	Avg 0,31 kPa/m	134 kPa	Price ex-VAT:	
Circle time (time to run 360°): at 100 %			12,4 h	Total elevation:	34 kPa	Installation:	
Application per pass at 100 %:			4,1 mm	End pressure:	140 kPa	Eskom est.:	
Current drawn per phase (400 V 3 phase):			8,2 A	Inlet pressure:	309 kPa	Total est.:	

Table 3.7 Centre Pivot Design Span Configuration, Future State

3.5.1 Future State Power Usage

Table 3.8 shows the energy costs for the pump in both the current state of the irrigation system, as well as the future state of the irrigation system. The calculations for the data in table 3.8 is attached as Appendix B.

System A	**Current State**	**Future State**
Power used (kW)	49	34.34
Energy cost (R/kW)	1.40	1.40
Pumping cost (R/h)	68.60	48.10
Pumping cost at 2000 hours (R)	137 200	96 152
Total annual saving (R)	**41 048**	

Table 3.8 Power Usage on Pump

3.5 Phase Three: The cost calculation

The costs incurred by the crop producer, are summarised in table 3.9, see Appendix C for the formal quotation on these prices:

Item	**Price (ZAR)**
Pipeline	37 454
Fittings	6 120
Nozzle package	72 000
Pump and Motor	29 560
Installation	8 996
Total	**154 130**

Table 3.9 Cost Incurred by Crop Producer

The costs incurred by the irrigation company are summarized in table 3.10.

Item	**Price (ZAR)**
Labour on system analysis	1 250
Travel	850
Design time	2 100
Total	**4 200**

Table 3.10 Cost Incurred by Irrigation Company

3.6 Phase Four: Change in Yield Calculation

Using the coefficient of uniformity (CU), calculated in section 3.2 as 62%, a theoretical crop yield can be calculated for both the current state of the irrigation system, as well as for the future designed irrigation system. The following assumptions were made:

- A satisfactory CU (see section 2.3.2) is 84%;
- Average yield for irrigated maize in the area is 11.5 tons per ha;
- Average yield for irrigated wheat in the area is 6.5 tons per ha;
- A 1% reduction in CU translates to a 2% reduction in yield (see section 2.3.3);
- The future state theoretical design will bring the CU up to 84% (although in practice this might be higher, the more conservative number of 84% instead of 90% - 100% is used);

- The future state designs gets the yield up to the average yield, where in practice a newly designed system would surpass the average yield; and
- A summer maize crop and winter wheat crop can be planted on the same irrigated field.

Table 3.11 shows the theoretical current state and future state crop yields.

	Current State	**Future State**
CU (%)	62	84
Maize yield (tons/ha)	7.3	11.5
Wheat yield (tons/ha)	3.64	6.5

Table 3.11 Current Sate and Future State Crop Yields

The resulting change in crop yield and income is summarised as in table 3.12, assuming a price for maize of ZAR 2 300/ton and wheat ZAR 3 800/ton.

Increase in maize yield (tons/ha)	4.2
Increase in wheat yield (tons/ha)	2.86
Increase in maize yield over the entire field of 60 ha (tons)	252
Increase in wheat yield over the entire field of 60 ha (tons)	171.6
Increase in income on maize crop (ZAR)	579 600
Increase in income on wheat crop (ZAR)	652 080

Table 3.12 Increase in Crop Yields

3.7 Phase Five: Income and Expenses Calculations

In this phase, the income and expenses for both the irrigation company and the crop producer is summarised. In order to draw a sensible conclusion on whether or not profitability is increased for both the irrigation company and the crop producer, one needs to evaluate the income and expenses for both parties.

The income that the future state irrigation system will generate additionally, and expenses to obtain the future state, of the crop producer are summarised in table 3.13.

	Additional annual Income (ZAR)	Single Expense (ZAR)
Gain in yield of maize and wheat	1 231 680	
Saving in energy cost per year	41 048	
Cost of attaining a future state		154 130
Total	**1 483 028**	**154 130**

Table 3.13 Income and Expense for Crop Producer

The farmer, therefore, realises a profit of R 1 328 898 after year one (1 483 028 – 154 130). This is an attractive profit. The underlying concept is, however, that the irrigation system has lost its efficiency over time and the crop producer has been losing money for several years in the form of reduced yield and increased power costs.

The income and expenses for the irrigation company are shown in table 3.14. An assumption is made that a 25% markup is added to the products sold.

	Profit from sales (ZAR)	Expense (ZAR)
Sales of R 154 130 with 25 % markup	38 533	
Labour on system analysis		1 250
Travel		850
Design time		2 100
Total	**38 533**	**4 200**

Table 3.14 Income and Expenses for Irrigation Company

As the gross profit from sales for the irrigation company of R 38 533 far exceeds the expenses R 4 200, the irrigation company would be satisfied to do the assessment and design for free to realise a nett profit of R 34 333 (38 533 – 4 200).

3.8 Summary

As stated in the previous section (3.7), in order to find whether or not profitability is increased for both the irrigation company and the crop producer, one needs to evaluate the income and expenses for both parties. In this chapter it was found that:

- The crop producer realises a profit of R 1 328 898 after year one.
- The irrigation company realises a profit of R 34 333.

Profitability therefore increases for both the irrigation company and the crop producer, by harnessing the services rendered by the irrigation company.

New irrigation systems are designed and sold by the irrigation company and are economically designed for irrigation efficiency and irrigation uniformity. As irrigation systems grow older, they lose their efficiencies and uniformity. This results in yield loss and higher energy costs, decreasing the crop producer's profit. The irrigation company used in this study has the capacity regarding design capability, technical knowledge, infrastructure, product range and labour capacity to perform assessments on existing irrigation systems, redesign them for optimal efficiency and implement the changes needed.

The results of this practical study can now be used to conclude the primary objectives of this study, namely:

- Determine whether or not the service of an assessment, redesign and upgraded implementation of an existing irrigation system can be profitably performed by an irrigation company.
- Determine whether or not the service of an assessment, redesign and upgraded implementation from an irrigation company, on an existing irrigation system will be profitable for a prudent crop producer if he has to buy the products.

CHAPTER 4 – CONCLUSIONS AND RECOMMENDATIONS

4.1 Introduction

Servitization is a new concept in the irrigation industry. This study aimed to do a cost analysis, to see if servitization can be used as a business model, to increase the profitability for an irrigation company and its customers.

The purpose of the study, as stated in 1.3.1 and 1.3.2 of this study, was to achieve the primary and secondary objectives, namely:

4.1.1 Primary objectives revisited

- Determine whether the service of an assessment, redesign and upgraded implementation of an existing irrigation system can be profitably performed by an irrigation company.
- Determine whether the service of an assessment, redesign and upgraded implementation from an irrigation company, on an existing irrigation system will be profitable for a prudent crop producer if he has to buy the products.

4.1.2 Secondary objective revisited

- Determine whether the irrigation company used in the study can expand the value chain to the aftersales market through servitization.

4.2 Research Results

When the results of the practical study were considered, the following became evident, relating to the primary and secondary research objectives:

4.2.1 Profitable for company to render services

An assessment, redesign and upgraded implementation of an existing irrigation system can be profitably performed by the irrigation company (see table 3.14).

4.2.2 Profitable for farmer to upgrade irrigation system

The service of an assessment, redesign and upgraded implementation from an irrigation company, on an existing irrigation system will be profitable for a prudent crop producer if he has to buy the products (see table 3.13).

4.2.3 Servitization as viable business model

The irrigation company used in this study can expand their value chain to the aftersales market through servitization, as they will be able to sell their products as a service to their customers. The customers will profit from buying this service, and will thus buy the service as it is assumed that they are in business to increase their profits.

4.3 Recommendations

To turn the results of this study into real benefits for both crop producers and the irrigation company, it is of importance that this study is followed up with implementation. The following recommendations are made to implement the results of this study for mutual benefit of the company and the farmer:

4.3.1 Marketing of Services

The free service of assessment, redesign and implementation needs to be marketed by the irrigation company to crop producers. The result of this study can be used as a reference to show potential customers the impact and benefit.

4.3.2 Utilise Customer Contact

The irrigation company should utilise the fact that their employees will see their customers more frequently and should capitalise on this. Direct customer feedback and free delivery of products can give the irrigation company a competitive edge.

4.3.3 Expand Value Chain

The irrigation company should focus on capturing more value through expanding their value chain, by adding services like the services proposed in this document, in the after-sales market. By expanding its involvement in the value chain, it can capture more value.

4.4 Suggestions for further study

1. Monitor the increase in yield of the irrigation system in this study to verify the theoretical assumptions.
2. Study the effect of continuous monitoring and irrigation efficiency improvements on the profits of an irrigation farmer, as well as the irrigation company.

4.5 Conclusion

The occurrence of declining efficiencies of irrigation systems can be harnessed to create value for both irrigation companies and irrigation farmers.

As this study focused on the irrigation efficiency of a system at a single moment in time, it should be noted that irrigation systems lose their efficiencies gradually over time. This phenomenon gives servitization as a business model an advantage over a single service rendered at a single moment in time. Through servitization, continuous monitoring of an irrigation system would ensure that the irrigation efficiency is kept at acceptable levels, ensuring that losses in yield and rising power costs do not compound over time.

An irrigation company can benefit from servitization over a single service rendered. This benefit comes in the form of an additional, fixed income stream, generated through continues monitoring of irrigation systems, rather than sporadic single analysis of complete systems.

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Appendix A – Coefficient of Uniformity (CU)

Cup number	Distance from centre Si (m)	Depth Vi (mm)	Vi x Si	Si x lVi - Vpl	CU = 62%	Vp = 6,95
1	2,84	0,00	-	19,71		
2	5,67	0,00	-	39,43		
3	8,51	0,50	4,26	54,88		
4	11,35	3,30	37,45	41,41		
5	14,19	2,50	35,46	63,10		
6	17,02	1,60	27,24	91,05		
7	19,86	1,00	19,86	118,14		
8	22,70	3,00	68,09	89,62		
9	25,53	4,00	102,13	75,29		
10	28,37	4,00	113,48	83,65		
11	31,21	2,20	68,66	148,19		
12	34,04	0,50	17,02	219,54		
13	36,88	0,50	18,44	237,83		
14	39,72	2,50	99,30	176,69		
15	42,56	6,00	255,33	40,37		
16	45,39	7,00	317,75	2,33		
17	48,23	13,00	626,98	291,85		
18	51,07	6,00	306,40	48,45		
19	53,90	6,50	350,37	24,19		
20	56,74	8,80	499,31	105,04		
21	59,58	13,00	774,50	360,52		
22	62,41	1,00	62,41	371,28		
23	65,25	13,00	848,27	394,86		
24	68,09	10,00	680,88	207,76		
25	70,93	11,50	815,64	322,80		
26	73,76	6,00	442,57	69,98		
27	76,60	9,00	689,39	157,13		
28	79,44	12,00	953,24	401,26		
29	82,27	9,50	781,60	209,91		
30	85,11	6,50	553,22	38,19		
31	87,95	8,00	703,58	92,46		
32	90,78	4,50	408,53	222,30		
33	93,62	7,00	655,35	4,80		
34	96,46	4,50	434,06	236,20		
35	99,30	5,00	496,48	193,50		
36	102,13	8,00	817,06	107,37		
37	104,97	9,00	944,73	215,33		
38	107,81	12,00	1 293,68	544,57		
39	110,64	12,00	1 327,72	558,90		
40	113,48	10,00	1 134,81	346,27		
41	116,32	9,50	1 105,02	296,76		
42	119,15	7,00	834,08	6,11		
43	121,99	12,00	1 463,90	616,22		
44	124,83	11,00	1 373,11	505,72		
45	127,67	13,00	1 659,65	772,55		
46	130,50	7,00	913,52	6,70		
47	133,34	12,00	1 600,08	673,54		
48	136,18	7,50	1 021,32	75,08		
49	139,01	9,00	1 251,12	285,16		
50	141,85	12,00	1 702,21	716,53		
51	144,69	11,00	1 591,56	586,18		
52	147,52	14,00	2 065,35	1040,24		
53	150,36	15,00	2 255,43	1210,61		
54	153,20	9,50	1 455,39	390,86		
55	156,04	10,00	1 560,36	476,11		
56	158,87	8,00	1 270,98	167,03		

57	161,71	9,50	1 536,24	412,57
58	164,55	11,00	1 810,01	666,63
59	167,38	16,00	2 678,14	1515,04
60	170,22	10,00	1 702,21	519,40
61	173,06	11,00	1 903,64	701,11
62	175,89	13,50	2 374,58	1152,34
63	178,73	10,00	1 787,32	545,37
64	181,57	10,00	1 815,69	554,02
65	184,41	8,50	1 567,45	286,07
66	187,24	8,50	1 591,56	290,47
67	190,08	10,00	1 900,80	579,99
68	192,92	8,50	1 639,79	299,28
69	195,75	8,50	1 663,91	303,68
70	198,59	9,00	1 787,32	407,37
71	201,43	12,00	2 417,14	1017,48
72	204,26	14,00	2 859,71	1440,34
73	207,10	13,00	2 692,33	1253,24
74	209,94	10,00	2 099,39	640,59
75	212,78	9,50	2 021,37	542,86
76	215,61	10,00	2 156,13	657,90
77	218,45	13,00	2 839,85	1321,91
78	221,29	16,50	3 651,24	2113,58
79	224,12	5,50	1 232,68	324,68
80	226,96		-	1577,08
81	229,80	10,00	2 297,98	701,19
82	232,64	10,00	2 326,35	709,84
83	235,47	10,00	2 354,72	718,50
84	238,31	11,50	2 740,55	1084,62
85	241,15	7,50	1 808,60	132,95
86	243,98	9,50	2 317,84	622,48
87	246,82	6,00	1 480,92	234,15
88	249,66	4,50	1 123,46	611,33
89	252,49		-	1754,50
90	255,33	8,00	2 042,65	268,43
91	258,17	5,00	1 290,84	503,09
92	261,01	5,00	1 305,03	508,62
93	263,84	5,00	1 319,21	514,14
94	266,68	6,50	1 733,41	119,65
95	269,52	6,00	1 617,10	255,68
96	272,35	11,00	2 995,89	1103,39
97	275,19	7,00	1 926,33	14,12
98	278,03	10,00	2 780,27	848,35
99	280,86	9,00	2 527,78	576,14
100	283,70	7,00	1 985,91	14,56
101	286,54	11,00	3 151,92	1160,86
102	289,38	7,00	2 025,63	14,85
103	292,21	8,00	2 337,70	307,21
104	295,05	8,00	2 360,39	310,19
105	297,89	5,00	1 489,43	580,49
106	300,72	3,50	1 052,53	1037,10
107	303,56	4,00	1 214,24	895,10
108	306,40	4,00	1 225,59	903,47
109	309,23	6,50	2 010,02	138,75
110	312,07	6,00	1 872,43	296,06
111	314,91	6,50	2 046,90	141,29
112	317,75	6,00	1 906,47	301,44
113	320,58	5,00	1 602,91	624,71
114	323,42	5,00	1 617,10	630,24
115	326,26	5,00	1 631,28	635,77
116	329,09	3,50	1 151,83	1134,94

117	331,93	3,00	995,79	1310,69
118	334,77	7,00	2 343,37	17,18
119	337,60	2,00	675,21	1670,70
120	340,44	3,00	1 021,32	1344,29
121	343,28	4,00	1 373,11	1012,22
122	346,12	9,00	3 115,04	709,99
123	348,95	10,00	3 489,53	1064,77
124	351,79	5,00	1 758,95	685,53
125	354,63	4,50	1 595,82	868,37
126	357,46	7,00	2 502,25	18,34
127	360,30	6,00	2 161,80	341,81
128	363,14	5,00	1 815,69	707,64
129	365,97	4,00	1 463,90	1079,14
130	368,81	6,00	2 212,87	349,88
131	371,65	7,50	2 787,37	204,90
132	374,49	5,00	1 872,43	729,75
133	377,32	8,00	3 018,58	396,69
134	380,16	11,00	4 181,76	1540,15
135	383,00	11,00	4 212,96	1551,64
136	385,83	9,00	3 472,50	791,47
137	388,67	6,00	2 332,02	368,72
138	391,51	6,00	2 349,05	371,42
139	394,34	1,00	394,34	2345,83
140	397,18	6,00	2 383,09	376,80
141	400,02	6,00	2 400,11	379,49
142	402,86	4,00	1 611,42	1187,89
143	405,69	5,00	2 028,46	790,57
144	408,53	2,00	817,06	2021,68
145	411,37	8,00	3 290,94	432,48
146	414,20	6,00	2 485,22	392,95
147	417,04	6,50	2 710,77	187,12
148	419,88	4,00	1 679,51	1238,09
149	422,71	7,50	3 170,36	233,05
150	425,55	2,00	851,10	2105,92
151	428,39	3,00	1 285,17	1691,57
152	431,23	4,00	1 724,90	1271,55
153	434,06	5,00	2 170,31	845,85
154	436,90	0,50	218,45	2817,43
Sum	**33 859,75**	**1 111,40**	**235 280,58**	**89 836,32**

Appendix B – Future State System Design

Pivot	Area[ha]	mm	Flow [l/s]	Precepetation [mm/24 hours]	Flow [m^3/hour]	Pivot inlet pressure [kPa]	Highest point on pivot [m]	Pivot centre hight [m]	Pump height [m]	Pressure needed at centre (static height compensated) [kPa]
Pivot 1	60.00	8	85.00	12.00	266	309	1525	1521.00	1522	348.24
Pipeline	Length [m]	Pipe		Note	Pipe ID [m]	Flow	Flow [m^3/s]	Quntity of 6m	Price per	Pressure loss over
Pump1-pipe mid	462	250/6	1	Full Flow	0.238	266.00	0.07	82	1,379.00	48.28

					Pump efficiency [%]	83%			
Height difference between centre and pump [m]	Pressure needed at pump before loss in pipe [kPa]	Pressure difference in pipeline [kPa]	Total pressure needed at pump [kPa]	10% Safety	Netto kW	kW/ha	kW/mm/Ha	Pump hours per year	Tarrif [R/kW.hour]
-1.00	338.43	48.28	386.71	425.38	34.34	0.57	1.14	2000.00	1.40
Cross sectional	Flow speed	Total cost [R]							
0.04	1.67	113,078							

Appendix C – Quotation of to attain Future state

Whs	Item	Description	Quantity	Price ea (excl)	Total (excl)
18P	SAN000000	Whole Goods Item	1.000	29 560.00	29 560.00
	Pump set Complete and on baseplate Pump - 125-100-200, ETA Norm, KSB Motor 37KW, 2900rpm				
18P	999-S1000-01	Design fee	1.000	2 100.00	2 100.00
18P	129-25006	Pipe, uPVC, 250 mm class 6, length 6 m	41.000	913.50	37 453.50
18SE	998-00004	Labour, crane truck, per hour	16.000	556.00	8 896.00
18P	S326-3600	Custom fitting: see serial number on fitting	1.000	6 120.00	6 120.00
	Junction fittings to join pipelines				
				Total excluding VAT	84 129.50
				VAT	12 619.43
				Total including VAT	**96 748.93**

Appendix D – Pump selection

Appendix D – Pump Data Sheet

Operational data

Fluid	Water, pure		Nominal flow	266,00 m³/h
Operating temperature t A	20	°C	Nominal head	39 m
Density at t A	0,998	kg/dm³	Static head	0 m
Vapor pressure	0,0234	bar	Available system NPSH	
Kin. viscosity at t A	1	mm²/s		

Pump

Manufacturer		KSB SA		Flow	Nominal	266,5 m³/h	
Pump name		Etanorm 125-100-200		Head	Nominal	39,2 m	
Impeller Ø		189	mm	Head H(Q=0)		46,1	m
Suction port	Nominal size	125	mm	NPSH 3%		6,35	m
	Nominal pressure	16	bar	Shaft power		34,20	kW
	Standard	EN 1092-2/DIN 2532		Efficiency		83,2	%
Discharge port	Nominal size	100	mm	Speed		2900	1/min
	Nominal pressure	16	bar	No. of stages		1	
	Standard	EN 1092-2/DIN 2532		Weight		76 kg	
Bearing version		Bearing Pedestal					
Bearing lubrication		Oil					
Sand Rotation Brake		Excluding					

Shaft seal

Manufacturer	KSB SA	Material code	Q1Q1X4GG
Type	Etanorm		

Materials

Pump				Shaft seal	
Volute Casing	Cast Iron			Fixed Face	Silicon
Impeller	Cast Iron			Rotating Face	Silicon
Shaft	Carbon Steel			Joint	Nitrile
Shaft Sleeve	316 St Steel			Springs	Cr-Ni-Mo
Wear Ring	Cast Iron			Frame	Cr-Ni-Mo

Motor

* full load

Manufacturer			Rated current*		A
Motor type			Efficiency*		%
Motor name			Power factor*		
Size			Protection		
Frequency		Hz	Design standard		
Power		kW	Insulation class		
Nominal speed		1/min	Weight		
Rated voltage		V			

Coupling

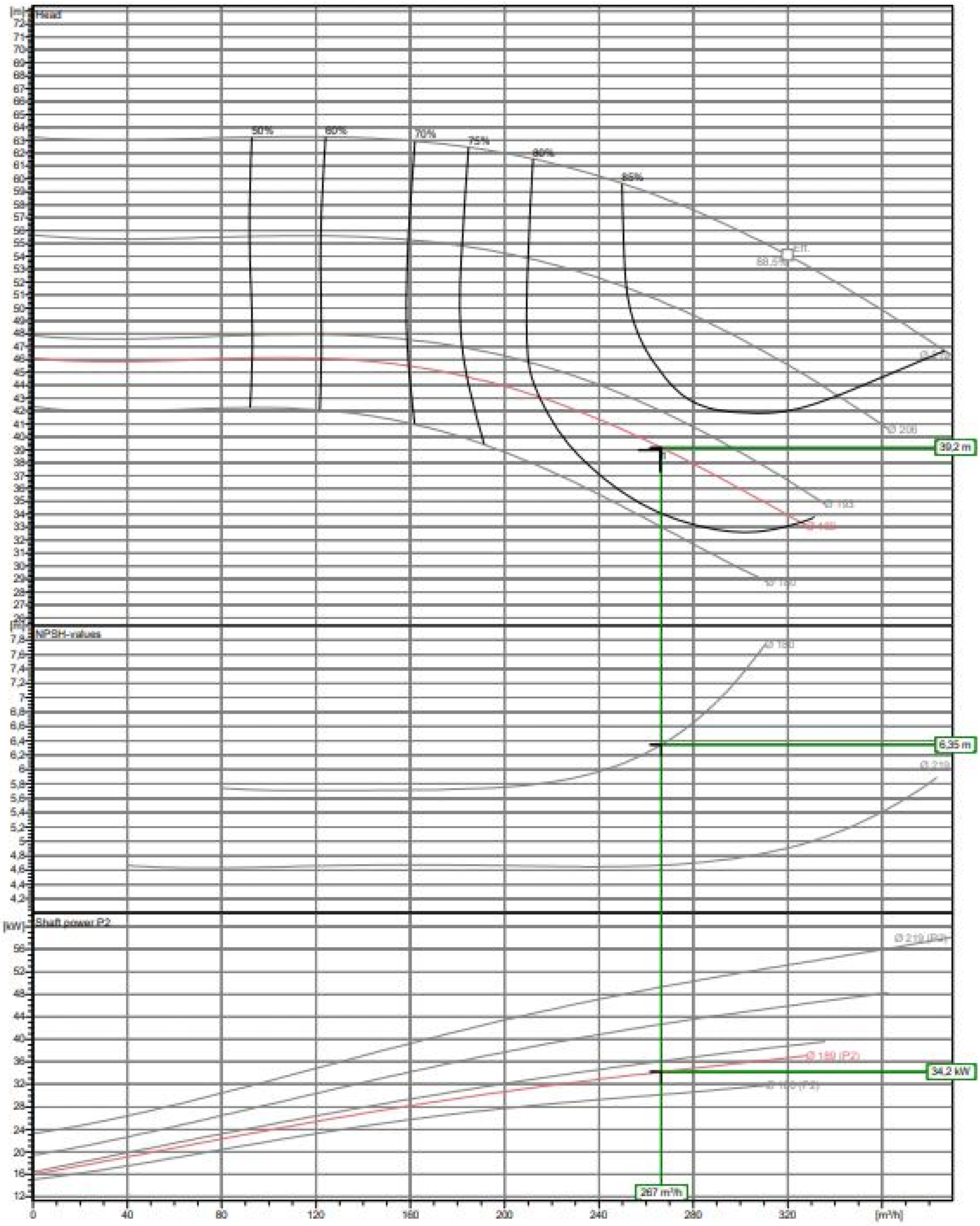
Manufacturer		Spacer length	
Coupling type			
Coupling name			

Baseplate

Type		Size	
Anti Vibration		Weight	

Appendix D – Pump Curve

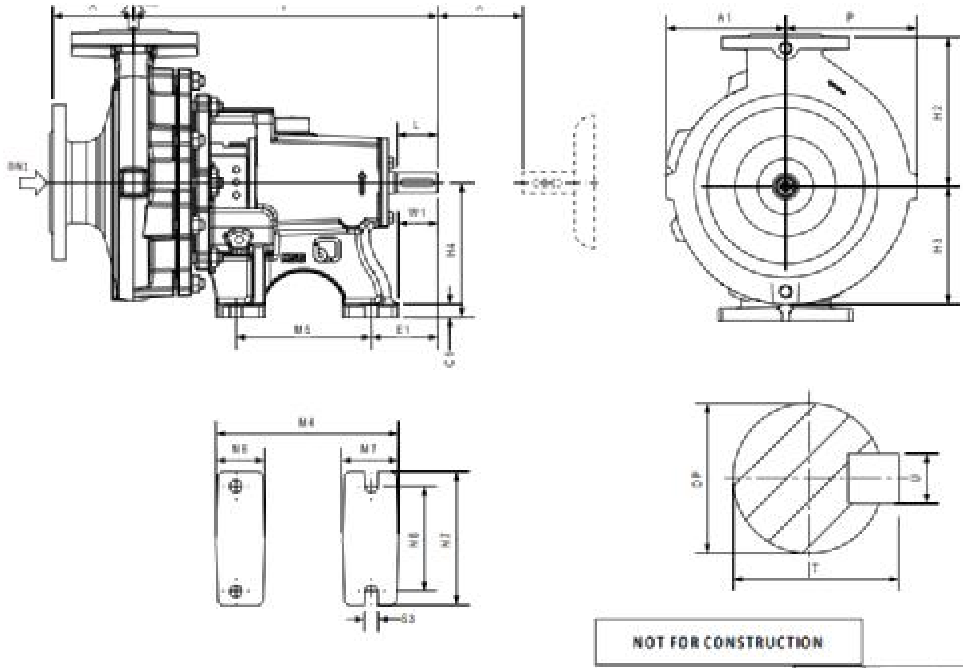
Flow:	266,5 m³/h	Imp Dia:	189 mm	Pumped Fluid:	Water, pure
Head:	39,2 m	Operating Speed:	2900 1/min	Operating temp:	20
NPSHr:	6,3 m	Power Abs:	34,2 kW	Density:	1,00 kg/dm³
Efficiency:	83,2 %	Motor Size:		Stages:	1



Impeller Outlet Width33 mm

K1311.452/46/1

Appendix D – Pump General Arangement



NOT FOR CONSTRUCTION

CAD	SCALE NTS

General Arrangement

Etanorm 125-100-200 GG 10 PO

Only Applicable for Tender

		Dim	(mm)	Dim	(mm)	Dim	(mm)	Dim	(mm)	Dim	(mm)	Dim	(mm)	Dim	(mm)
Pump	Etanorm 125-100-200	A	125	DP	32	H4	200	M6	210	U	10				
Motor		A1	173	E	110	L	80	N6	200	W	70				
Baseplate		C	20	F	430	M3	58	P	212	X	140				
Coupling		DN1	125	H2	280	M4	80	S2	19						
Flange Design	EN 1092-2/DIN 2532 / EN 1092-2/DIN 2532	DN2	100	H3	189	M5	271	T	35,3						

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Tuesday, 13 November 2018

To whom it may concern

Re: Confirmation of language edit, typography and technical precision

The dissertation **Introducing servitization as means to increase profitability for an irrigation company and its customers** by **M Bekker (20249578)** was edited for language, typography and technical precision. The referencing and sources were checked as per NWU referencing guidelines (Harvard Style).

Final, last minute corrections remain the responsibility of the author.

Antoinette Bisschoff

BA Languages (UPE – now NMU); MBA (PU for CHE – now NWU); Translation and Linguistic Studies (NWU)

Officially approved language editor of the NWU since 1998
Member of SA Translators Institute (no. 100181)

Precision … to the last letter