Designing industrial image processing applications for warehouse management in South Africa

Heinrich Davids

A thesis submitted in partial fulfilment

of the requirements for the degree of **MCom Information Management E-Logistics Stream**

in the **Department of Information Systems**

Economic and Management Sciences

University of the Western Cape

Supervisor: Dr. Johan Breytenbach

October 2021

Abstract

Purpose: With conclusive evidence from multiple research studies it is evident that the lack of real time information flows in Warehouse Management (WM) operations leads to rigid, un-optimised supply chains. Industrial Image Processing (IIP) is a popular new technology that allows for improved information flows in WM processes through the capture and analysis of images in real time. This study aims to investigate the design principles for improving WM processes through IIP implementation.

Methodology/design: The study will present data from a comprehensive questionnaire of middle management to executive level participants, working in the WM domain in South Africa (SA). First, the researcher present a summary from past literature to describe the different areas in which IIP systems can be implemented in South African warehouses. Second, from the collected questionnaire data, a descriptive list of design principles to adhere to when implementing IIP systems to improve WM processes in South African warehouses is presented. Third, using a design science framework as foundation, recommendations are made to improve the fitness-for-use of IIP systems in South African warehouses.

Practical implications: This research aims to have implications for designers of IIP systems in the South African WM domain.

Originality/value: This paper aims to identify key design principles for the design of IIP systems in the WM domain in SA. The originality of our contribution resides on the focus of using IIP technology specifically in WM in SA and in part on the focus of fitness for use as a design principle, and the focus on improving WM efficiency through real time data flows.

Keywords:

Industrial image processing; Warehouse management; Supply chain agility; Information technology; Machine learning; Design Science Research; vision-based technology; Fitness-for-use; South Africa; design principles

Declaration

I declare that *Designing industrial image processing applications for warehouse management in South Africa is* my own work, that it has not been submitted for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

Full name: Heinrich Davids   Date: 31 October 2021

Signed:

Table of contents

1 Introduction and Background to the study

1.1 Background

In this study, design principles for improving Warehouse Management (WM) processes through Industrial Image Processing (IIP) implementation are investigated. With the increase in importance of information collection and flow, and analysis among Supply Chain (SC) functions (Burinskiene, 2018), IIP can be an ideal solution for capturing and processing raw data in image format and converting it into valuable information. Replacing current worker dependent and manual tasks with more accurate and automated machine vision systems are becoming a more attractive solution in WM processes (Golnabi & Asadpour, 2007). Many past researchers have noted improved information flow among SC functions improve the agility of the SC.

Most firms can group their value generating activities into the SC phases of the organisation (Morawakage, 2016). These activities range from procurement, manufacturing, distribution, all the way to delivering the product or service to the customer. According to Porter's value chain theory, the above SC activities are among the primary activities where value should be added to the processes or products to increase competitive advantage (Simatupang, Piboonrungroj & Williams, 2017). Thus industries are continuously trying to improve SC activities to maximise organisational profits. The importance of SC efficiency in organisations makes economic, operational or natural disruptions a big threat for business continuity (Stecke & Kumar, 2009). These disruptions can come in the form of labour strikes, natural disasters or for example, the unexpected COVID-19 global pandemic. SC practitioners need to ensure strategic agility and operational flexibility within their organisations to cope with economic uncertainty and to maximise SC performance (Fayezi, 2017). These attributes are currently in high demand as industries seek to eliminate human interaction and seek substitute products (due to restricted international trade) amid the COVID-19 pandemic. Forty percent (40%) of South Africa's (SAs) global trading deals come from China, Germany, USA and India (Krugel & Viljoen, 2020). With international non-essential trade greatly restricted, SA businesses need to optimise, or completely overhaul, crucial SC functions to ensure ongoing success and viability of their businesses.

Intense competition, rapid market changes, accelerated technological developments and customer awareness are all examples of disruptive trends in industries (Wu, Tseng, Chui & Lim, 2017). Hence an organisations' capability to quickly adapt to the external changes and market conditions are crucial to their competitive positioning and even survival (Christopher & Towill, 2001). In this study SC agility is considered as the speed and flexibility an organisation possesses to rapidly react to market changes to prevent major disruption among the SC (Wu et al, 2017). Organisations that speedily respond to disruptions like the COVID-19 pandemic or labour union threats are commonly the market leaders. To achieve agility among the entire SC, organisations need to ensure upstream and downstream collaboration between all SC partners (Gligor, 2014). The flow of crucial information among SC partners enables organisations to respond to changes in demand and/ or supply whilst ensuring uninterrupted service. To manage information flow among multiple organisations or partners in the SC can be a demanding task, and typically organisations turn to Information Technology (IT) or Systems (IS) to facilitate the flow of information (Dehgani & Navimipour, 2019). Having efficient information flow among SC partners enable better decision making and planning. For example, if a supplier is running late with a delivery or the order is understocked and this information is shared with their customer in a timely manner, the customer can ensure availability at the receiving bay or order substitute products to be delivered. IT that promotes effective information exchange and coordination among SC partners improves SC agility and overall organisational competitiveness (Dehgani & Navimipour, 2019). Real-time information sharing is extremely beneficial with regards to decision support and managing requirement changes from customers within warehouse management operations (Lee, Ho & Choy, 2018).

Warehouse management (WM) consists of numerous tactical daily tasks such as inventory planning, workload planning, transport planning and storage location assignment (Ghiani, Laporte & Musmanno, 2004). There are many forms of warehouses, such as raw materials warehouses, finished goods warehouses, distribution warehouses, direct to customer warehouses and fulfilment warehouses (Subramanya & Rangaswamy, 2012). For the purpose of this research the researcher will refer to a warehouse as a distribution and finished goods warehouse. Warehouse activities usually entails receiving, picking, despatching and put-away of inventory (Tompkins, White, Bozer & Tanchoco, 2010). Throughout the life cycle of inventory entering the warehouse to it leaving the warehouse, a lot can go wrong. Inventory can get damaged, misplaced, incorrectly labelled or incorrectly scanned, which can lead to inaccurate information and consequently inaccurate billing. Due to customer orders becoming increasingly complex, the demand for real-time data is required to ensure synchronization of orders to support WM activities for on-time deliveries and order fulfilment (Lee et al, 2018). Warehouse managers evidently rely on Warehouse Management Systems (WMS) to help with tracking and tracing, stock takes, information registration and picking instructions (Subramanya & Rangaswamy, 2012). Although WMS are hugely beneficial to warehouse managers, they are expensive, limited and even more expensive to customise.

Over the last thirty years, Information and Communication Technology (ICT) has progressed significantly and became part of everyday life, in the public, private and personal spheres (Tjahjono, Esplugues, Ares & Palaez, 2018). Different industries have adopted different technologies. For example, in the WM domain technologies such as Radio-frequency identification (RFID) technology to track and trace stock, and in transportation logistics make use of Machine Learning (ML) and Big Data Analytics (BDA) to reduce transportation times (Tjahjono et al, 2018). ICTs have revolutionised modern SCs through optimising individual functions, integration and invaluable data collection. Key digital transformation trends in SCs are, using real time sensor data to build predictive models through Machine Learning (ML), using global positioning systems (GPS) for Fleet monitoring (Location, Condition and Driver techniques), compliance through block chain technology and improved WMS through the help of video and imaging aids (Tjahjono et al, 2017). One of the most notable technological trends in logistics warehousing is IIP, using affordable cameras to capture images quickly with high frequency and extract data from them (Borstell, 2018). IIP can be used as a cost effective autonomous way to collect data from WM activities to improve vital information sharing among SC partners to ultimately achieve and maintain SC agility.

With the growing pervasiveness of IIP in logistical processes, several business functions and application areas can be identified as feasible for camera-based tasks (Alias, Ozgur & Noche, 2016). Some of the noteworthy WM areas where IIP can add value are, autonomous detection of forklifts to prevent congestion in the warehouse, the counting of cartons in the warehouse for productivity monitoring and the detection of cartons to identify damaged cartons/ barcodes (Alias, Kalkan, Koc & Noche, 2014). This study will aim to present an insight into IIP applications in WM in SA.

1.2 Research Problem

As argued in the preceding contextualisation, the lack of real time information flows in Warehouse Management operations leads to rigid, un-optimised supply chains. Industrial Image Processing (IIP) is a popular new technology that allows for improved information flows in Warehouse Management processes through the capture and analysis of images in real time. The use of IIP for WM process improvement in South Africa is still in its infancy. With a limited understanding of what the important design considerations and success factors of such applications are, there is a need to study the design of such applications and document principles that will lead to IIP applications that will improve supply chain efficiency.

1.3 Research Question

The main research question this research aims to answer can be categorised as an Empirical question, Explorative by nature and can be stated as follows:

What are the industrial image processing system design principles influencing Warehouse Management process efficiency in South Africa?

The secondary research questions are:

- Is there an established business need for designing and implementing IIP systems in the South African retail WM environment?
- Are there established IIP design and implementation guidelines currently in use in WM process improvement in SA?
- Which change management considerations related to IIP impact WM process efficiency most?
- What recommendations can be made from the interpretation of the findings to improve the design of IIP technologies in WM processes in SA?

1.4 Research Objectives

In this study, the primary research objective can be defined as:

To establish industrial image processing system design principles influencing Warehouse Management process efficiency in South Africa.

The following secondary objectives need to be addressed in order to achieve the main objective:

- To identify from existing literature the relevance of designing IIP applications for WM processes in SA.
- To identify from existing literature existing standards of designing IIP applications for WM processes in SA.
- To design a questionnaire based on the Design Science Research Framework, to investigate what WM workers in SA perceive to be factors influencing more efficient WM information flows/processes when implementing IIP in SA.
- To analyse data collected and make recommendations for the improvement of the design and implementation of IIP applications in the SA WM domain.

1.5 Chapter Summary

This chapter introduced the case study of the research. The research problem provides an overview of the lack of real time information flows within Warehouse Management. Derived from the research problem the chapter states the research question and the research objectives. The research will explore the design principles of IIP technology to answer the research question.

2 Literature Review

2.1 Introduction

In this chapter the researcher discuss the different classifications of IIP systems and how they relate to WM processes. The combination of off-the-shelf cameras, existing IIP algorithms and basic engineering efforts makes IIP an attractive cost-benefit-ratio solution to improve information flow in organisations (Alias et al, 2016). Within the WM domain camera-based functions range from detection, counting, tracking, measuring and alerting (Alias et al, 2014). Amongst the benefits of IIP applications are cost reduction, improved accuracy and improved information flow among the WM processes. Image processing is a method of manipulating a digital image, to either to enhance the image or extract useful information from it (Ansari, 2020). The analyses of the information or enhanced images leads to pattern recognition, which in turn enables automation or improved decision making (Rahmatov et al, 2019).

2.2 Defining Key Concepts

2.2.1 Image Processing

As illustrated in figure 1 the image processing pipeline usually starts with an ingestion of images, the input is a frame/ image or a set of images extracted from video. The input are stored on computer disks to be analysed, in some instances the video feeds are ingested live from cameras (Ansari, 2020). Once the images have been ingested, they go through a transformation stage, where the images get standardised. This usually entail pre-processing activities like resizing, cropping, rotation and colour manipulation (Ansari, 2020). Next identifiable features needs to be extracted from the images. This is a crucial part of image processing, as the machine learning model use the features to identify the given object in the image (Ansari, 2020). Machine Algorithms are used in the next stage to predict an outcome (Ansari, 2020), for example, is the object a carton or not. Finally an output is delivered, which can be used for decision making, analysis and other management functions.

Figure 1: Image processing pipeline in computer vision (Source: Ansari, 2020)

2.2.2 *Warehouse Management*

Warehouses typically deal with material handling, which can be referred to as the movement of materials through the receiving, storage and shipping operations (Berg et al, 1999). Thus warehouse management core activities are inventory management and storage assignment (Berg et al, 1999). Warehouse management can be defined as the control and optimisation of distribution and warehouse systems (Hompel & Schmidt, 2008).

The first step of WM is the receiving or acceptance of goods in to the warehouse. Based on the goods ordered on the delivery note, the consignment is compared and the goods are received into the warehouse (Hompel & Schmidt, 2008). This usually follows with the storage of the goods in the warehouse. The storage can be a manual system or in many cases it is managed by a warehouse management system, which makes sure stock are rotated and identify empty storage locations (Hompel & Schmidt, 2008). Typically the next process of material handling in a warehouse is order picking (Hompel & Schmidt, 2008). Order picking can be defined as, the process of retrieving goods from a buffer or storage area, to consolidate a specific customer(s) request (de Koster et al, 2006). Order picking has been identified as the most costly and labour intensive process in a warehouse (de Koster et al, 2006). Once the customer orders has been replenished or picked, the goods need to be shipped/ despatched to the customer (Berg et al 1999). These goods are loaded through shipping docks to a carrier which delivers the order at the customer (Gu et al, 2007). The despatching of goods are closely managed with the order picking process, as the scheduling of the shipping operations highly depend on the batching of customer orders in the picking process (Gu et al, 2007).

Figure 2: Warehouse management processes

2.2.3 *Design Science Research*

Design Science Research is defined as a research paradigm where a researcher responds to relevant human related problems via the design of innovative artifacts (Hevner & Chatterjee, 2010). In doing this the researcher is contributing to the body of scientific knowledge. For the purpose of this research the community of practice will be information systems in the warehouse management domain. DSR in IS is generally about digital innovation, where the DSR project is primary goal is to increase human and organisational capabilities by creating new and innovative socio-technical system artifacts (Hevner & Gregor, 2020).

Hevner's initial three cycle view consists of a rigor, design and relevance cycle, which substantiate the fundamental areas of a DSR project (Drechsler & Hevner, 2016). The design cycle is at the heart of a DSR project (Laumer & Eckhardt, 2012), and comprises of research activities of the actual design/ redesign and the evaluation of the artifact (Drechsler & Hevner, 2016). The rigor cycle covers past experiences, expertise and overall knowledge of the DSR project (Drechsler & Hevner, 2016). This will deliver a high level of innovation, and the appropriateness of the IT artifact. The relevance cycle identifies the research problem/ opportunity and the requirements of the artifact/ solution as inputs, and also establishes the acceptance criteria of the artifact within the desired domain (Hevner, 2007). In 2016 Drechsler and Hevner proposed another cycle to take into consideration the impact of the artifact exceeding the artifact's immediate application/ domain context. The cycle is coined the Change and Impact (CI) cycle, which covers the wider organisational and societal impact of the artifact (Drechsler & Hevner, 2016). The CI cycle deals closely with the overall adoption of new technology in the socio-technical system and the adoption impact or factors that's related to the artifact.

IS research needs a conceptual process and a mental model for representing and evaluating the outputs (Peffers et al, 2006). In 2004 Hevner et al explains, DSR "... creates and evaluates IT artifacts intended to solve identified organisational problems". Peffers et al (2007) built on the DSR framework to design a commonly accepted methodology for carrying out research based on DSR principles. A process model comprising of six activities has been formulated that DSR should address to so solve important and relevant problems (Peffers et al, 2007).

The first activity is to identify and motivate the organisational problem. Define the research problem and motivate the value of the proposed solution, as the problem definition will be used to develop the artifact to solve the problem (Peffers et al, 2007).

The second activity is to clearly define the objectives for the solution and resources required. The objectives of the solution should be deduced from the problem definition, and the knowledge of the problem with regards to feasibility and practicality (Peffers et al, 2007).

These objectives can be qualitative of nature, where a description of how the artifact will solve the problem, or quantitative where the artifact can be illustrated to be better than the current process or system (Peffers et al, 2007).

The next and third activity is the design and development of the artifact. The artifact can be defined as a model, construct, instantiation or methods (Hevner et al, 2004). This activity involves deciding on the artifact functionality, architecture and the actual creation of the artifact (Peffers et al, 2007).

The fourth activity is the demonstration of the use of the artifact to solve the problem defined in the first activity (Peffers et al, 2007). The demonstration can range from simulation, experimentation, proof of concept, a case study or any other appropriate way to demonstrate the efficacy of the artifact (Peffers et al, 2006).

Evaluating or measuring the effectiveness of how well the artifact supports the solution to the problem is the next activity (Peffers et al, 2007). This activity requires knowledge of relevant criteria and analysis techniques on how well the artifact's functionality compare to the objectives set out in activity two (Peffers et al, 2007).

The last activity is communication. In this activity the problem, the significance of the problem, the artifact, the rigor of the artifact design and its effectiveness should be communicated to researchers, practising professionals and any other relevant audiences (Peffers et al, 2007). To efficiently do this communication, the researcher should be familiar with the disciplinary culture (Peffers et al, 2007).

2.3 Warehouse Management Technologies in South Africa

To manage a warehouse efficiently, teams needs to be aware of their current stock holding, being able to have accurate visibility of the stock quantities available, which products exist within inventory, and the warehouse location of this stock (Connolly, 2008). IT adds additional value to warehouse operations by improving internal and external coordination, and is crucial to decreasing costs and increasing competitive advantage (Mathaba et al, 2011).

2.3.1 Barcode scanning/ scanners

One of the most popular technologies used in SA warehouses are hand-held barcode scanners (Mathaba et al, 2011). Hand-held barcode scanners interact with a WMS to acknowledge receiving, picking and to manage and control stock movements in the warehouse (Connolly, 2008). Examples of barcode scanners are, fixed scanners which are connected by USB to a computer; Bluetooth scanners, which are connected to a computer via Bluetooth, usually these scanners are operated manually; wireless handheld scanners, these scanners are connected via a wireless network to a server or computer (Garg, 2012). Fixed and Bluetooth scanners are typically used at receiving and despatching stations to scan 2D barcodes, and wireless scanners are most commonly used at order picking and put-away/ storage functions where more options or functionality is required.

2.3.2 Warehouse Management Systems

WMS is the use of technological systems in order to manage warehouse activities like, receiving, storage and shipping of goods (Muhalia et al, 2021). WMS is a crucial part in any warehouse to reduce costs and increase productivity (Kučera, 2017). A vital function of a WMS is to integrate information from various devices such as scanners, printers and even cellphones into one central system, where managers can use the information to make better decisions (Shashidharan, 2021). The main tasks of a WMS are, recording goods received, managing of storage areas, the control of the order picking system, reorganising of storage area availability, recording outgoing goods and stocktaking (Gleissner & Femerling, 2013).

2.3.3 RFID tags

Radio Frequency Identification (RFID) became popular in the early 1990's among companies in the retail sector, mostly for the promising benefits of greater supply chain visibility, reduced labour costs and increased speed of operations (Esau & Seymour, 2019). RFID is an automated data collection device that can read thousands of digits without a direct line of sight and from far distances (Brown & Russel, 2007), and can store the information on a small microchip (Connolly, 2008). Some of the advantages of RFID technology are, reusability, durability, high data volume storage capability, no direct visual contact needed and they add a level of automation to processes (Gleissner & Femerling, 2013). These so-called transponders can be attached to goods like cartons to improve tracking and identification of goods (Want, 2004).

2.4 Overview of Image Processing

IIP is the process of manipulating and enhancing video or imagery to extract purposeful information from it (Olmedo, De La Calleja, Benitez & Medina, 2012). Digital video technology advances has allowed organisations to collect data on a large scale, without someone actually watching the video (Bazhenov & Korzun, 2018). Organisations can use every day mobile, network, security or more advanced forms of cameras to collect data to improve their overall efficiency. IIP has become widely known when ML algorithms were more commonly used (Rahmatov, Paul, Saeed, Hong, Seo & Kim, 2019). ML is a subset of AI techniques that allows computer programs or systems to learn from previously introduced data or previous experiences (Nguyen, Dlugolinsky, Bobak, Tran, Lopez Garcia, Heredia, Mlaik & Hluchy, 2019). ML has been primarily applied in IIP for industrial applications for inspection, measurement and automated recognition (Wang & Weyrich, 2014). This is the same technology used for facial recognition, registration number reading in the traffic industry and sentiment analysis. ML algorithms have shown object classification accuracy of up to 92% and higher (Rahmatov et al, 2019), and has become the accustomed component in IIP (Wang & Weyrich, 2014).

A typical setup of an IIP system involves the following, a sensor which is a camera, computers to execute the ML model and communication, which typically is an internet connectivity to receive and upload video feed and data to a cloud server or database (Rahmatov et al, 2019). The cameras can be placed to have a clear view of a production line, conveyor or any other area of interest. The video feed is run through a ML model which can detect, measure or inspect an object and give an output depending on how the model has been trained. In the case of an inspection model, the model will give an output if the object is defective or not. Common ML techniques used in IIP are Support Vector Machines (SVM), decision trees, regression and neural networks (Nguyen et al, 2019). Image processing can be categorized into low, intermediate and high level (Saxena, Sharma & Sharma, 2016) and the ML technique used is dependent on the level of image processing the task at hand requires. Low level image processing usually deals with converting images into image data, for example, Noise reduction and filter transformation. Intermediate level image processing is a bit more complex and deals with pixel abstractions for object tracking, where high level image processing is the process of interpretation of images, for example pattern recognition and object classification.

In 2018 Mark Williamson wrote an online article, stating a 5Gbp/s internet connection via a CAT 6A cable would offer users an increased data throughput optimal for IIP technologies. According to the Basler website, a company specialising in industrial cameras, Line scan cameras are best suited for industrial/ warehouse related image processing. These cameras boast high definition capability for clear video capture and processing. Williamson (2018) noted there are no clearly accepted qualification indicators for machine vision systems, but should be defined in the specification process of the application by evaluating the application in question.

2.5 Image Processing in Warehouse Management

2.5.1 Fire detection

Fires cause cataclysmic damage to human lives and the environment and usually occurs without a warning (Khan, Uddin, Corraya & Kim, 2018). Fires can cause millions of rand in damage to warehouses, in terms of structural damage and loss of inventory in the warehouse. Typically organisations put precautions in place like heat and smoke detection systems, but most often those precautions are inadequate. Disadvantages of conventional fire detection systems are among, the sensors cover a small area, the sensors do not provide any additional information on how the fire started and the amount of heat and smoke to trigger the alarm needs to be substantial which in many times are when the fire is already out of control (Khan et al, 2018). A vision-based system can eliminate the aforementioned drawbacks of conventional fire detection systems, by providing higher detection accuracy (Zhou, Yang & Bu, 2015). These vision based systems are easy to incorporate using existing Closed Circuit Television (CCTV) cameras, eliminating the need for costly additional hardware (Khan et al, 2018). Fires consist of many features like, heat, light and smoke, which are detectable by various sensors. To train a ML model one need fire data, essentially this will be smoke and fire images to build a dataset for the ML model (Saeed et al, 2020). These images can be obtained from the internet or one can even generate your own images. RGB labelled images are then being used to detect if fire are present or not in the training dataset (Foggia, Saggese & Vento, 2015). By making use of Convolutional Neural Network modelling techniques the ML model can be trained to detect fires. The CCTV camera acts as the sensor for the input to the ML model and the output is 1 for the presence of a fire and 0 for no fire. By using CCTV cameras the cause and exact location of the fire can also be identified and analysed for future prevention.

2.5.2 3D Object detection

Object detection is an image processing and computer vision technology that detects and defines objects such as people, vehicles, animals and other domain related objects (Vahab et al, 2019). The technology has been around for years, but it has recently picked up momentum over a range of industries (Ren et al, 2016).

Object detection with the use of deep learning and IIP with video files input can be used to identify different kinds of objects (Vahab et al, 2019). These vision-based systems can be used for object inspection and detection (Weyrich, Laurowski, Klein & Wang, 2011) within a warehouses. Object tracking is a method of locating moving objects using video camera streams, with the objective to classify objects within consecutive video frames (Vahab et al, 2019). Object classification and detection is the preceding steps of object tracking within vision-based computer system (Vahab et al, 2019).

This makes a possible use case for warehouse managers to employ such technology in the warehouse, for example, to detect damaged cartons on a moving conveyor, identify bottlenecks caused by forklift traffic or detect damaged pallets. Object detection and identification technologies are also used for security detection, unmanned forklift driving, facial recognition and improved industrial robotic operations (Li, Huang & Huang, 2019). These techniques can also be applied to identify available storage space in the warehouse by calculating the space availability in the storage racks. Increased competition and high need for agility in supply chains makes vision-based object detection an ideal solution for increased productivity and efficiency. ML models have shown to have an accuracy of 92% and more in industrial detection and inspection (Li et al, 2019).

2.5.3 Inventory Management

Inventory management (IM) is one of the most important activities in a distribution and finished goods warehouse and can consist of the following, asset management, inventory forecasting and demand forecasting (Singh & Verma, 2018). The extensive use of barcodes has significantly improved accuracy and efficiency of IM in warehouse management, however the limitations of barcodes are the manual use of handheld scanners to capture information (Xu, Kamat & Menassa, 2018). An automated way of barcode scanning in IM is using vision-based technology and drones to scan barcodes in the warehouse (Xu et al, 2018). In a white paper by Pons (2014), drones can scan barcodes 119 times faster than a person using a barcode scanner.

Unmanned drones can vastly improve IM efficiency and because of the protected and controlled environment, warehouses obviate all the governmental regulations surrounding drone operations (Companik et al, 2018). Cameras can be attached to drones to scan barcodes which can aid in cycle counts and stock takes in the warehouse to improve operational efficiency and protect workers from accidents when scanning barcodes at high altitude. In 2016 Wal-Mart reported they decreased a warehouse inventory count from 30 days (manual count) to just one day with an unmanned drone (Bose, 2016). Essentially the camera on the drone will act as the input data source of video stream to the ML model which will identify barcodes, RFID tags or QR codes, then store the information in a WMS or some other form of storage which can later be uploaded to the WMS for stock take calculations.

2.5.4 Process Control

Video-based systems can help warehouse managers with better analysis, tracking and control of inventory and overall more effective process control (Golnabi & Asadpour, 2007). The counting of cartons on a pick line can identify overall productivity. Using CCTV video stream to count cartons on the picking line can give managers an indication of the amount of outgoing stock. The identification of people and forklift traffic to enhancing situational awareness to eliminate bottlenecks. This will eliminate the possibility forklift accidents and delays when stock are being moved around. Facial recognition can aid in an increase in security measures against theft. Dashboards and frequent reporting can help warehouse managers better plan activities in the warehouse and operate in a more efficient manner.

2.6 Fitness for Use

In the context of designing new artifacts, the aim is to ensure the artifact can evolve under changing circumstances and environments (Gill & Hevner, 2013). This should also be the case when designing IIP applications to improve WM processes, for example if the speed of the dispatch conveyor changes, the IIP application should be able to adapt and still deliver a high level of accurate data. Another important factor in the design and adoption of new technology is that the correct reasons for adoption should be identified to get the best value, and not just adopt technology for the sake of it (Grant & Meadows, 2016). Adopting complex ML technology might not always be the ideal solution. In the instance of using IIP technology to scan barcodes on cartons might be a more expensive or inaccurate solution than using basic infra-red barcode scanners. The above factors contribute to the fitness of use of IIP technology in WM, and the process of design science the fitness of use component is vital to comprehend.

2.7 Overview of Theoretical Framework

IS professionals are commonly interested in the design and implementation of technological components with the aim to improve the overall performance of business processes (March & Storey, 2008). In recent years Hevner's three cycle Design Science Research (DSR) has become an established area of research in the IS field (Drechsler & Hevner, 2016). THE DSR models focus is to identify an IT artifact of high priority of relevance in a specific application domain, which in the case of this paper the artifact is an IIP application and the domain the WM.

This study aims to use the four cycle DSR model to identify the design factors of an IIP application within WM. The above mentioned constructs will aid the study in terms of understanding the underlying factors in the design of IIP applications in WM. The DSR model was selected over other well established frameworks like the technology-organization-environment (TOE) framework (DePietro et al, 1990), and the Technology Acceptance Model (TAM; Davis, 1989) as the aforementioned framework and model deal with the acceptance of new technology instead of the design of new technology/ artifacts.

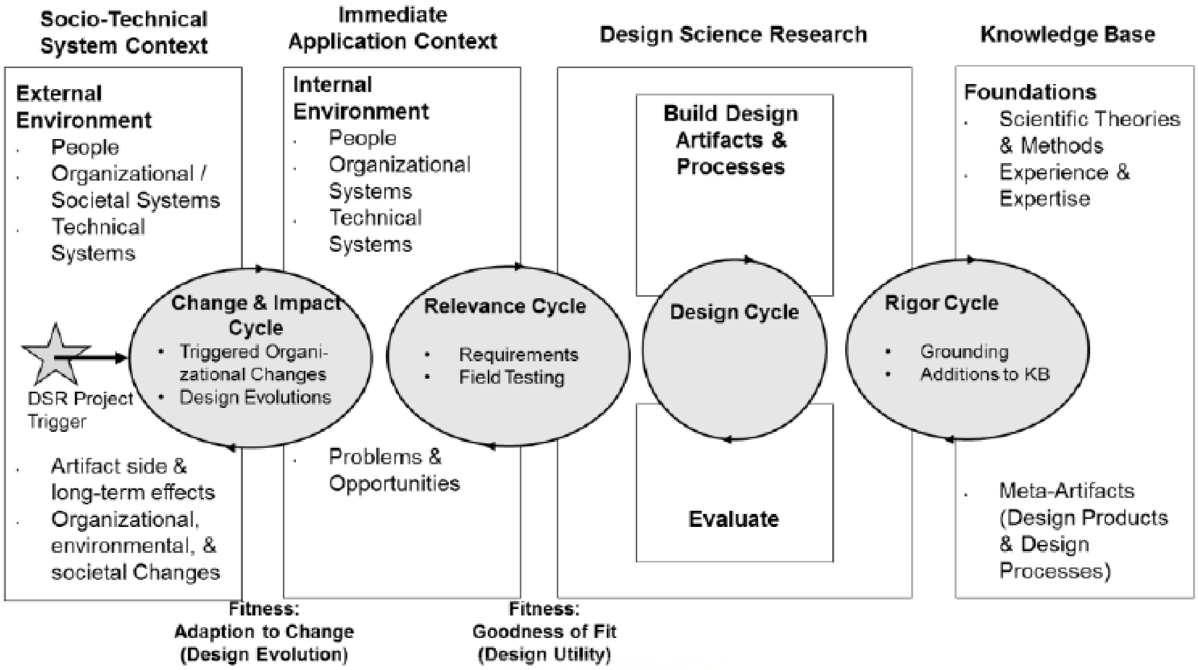

Figure 3: A Four Cycle View of Design Science Research (Source: Drechsler & Hevner, 2016)

2.7.1 Relevance Cycle

The DSR framework is motivated by the need to improve an environment by introducing new and innovative technologies and processes by building artifacts (Simon, 1996). The purpose of the relevance cycle is to identify if there is a business problem area where IIP technology can be useful in the identified unit of analysis. This cycle initiates the artifact requirements as input, and also defines the acceptance criteria for the artifact within the WM domain. By utilising the relevance cycle principles the researcher aim to answer secondary research question three, through an electronic questionnaire.

2.7.2 Rigor Cycle

The rigor cycle ensures a high level of innovation by providing extensive past knowledge to the research project (Hevner, 2007). There are two types of knowledge bases this research are interested in; the expertise and experiences of IIP technology in WM and the knowledge of existing IIP technology and processes in the WM domain. By asking respondents questions relating to the rigor cycle, the researcher can uncover knowledge about IIP technology in WM not known before (Hevner & Gregor, 2020). By utilising the rigor cycle principles the researcher aim to answer secondary research question two, through an electronic questionnaire.

2.7.3 Design Cycle

The internal design cycle is the central part of the design science research project (Hevner, 2007). This cycle can be described as the, generation and evaluation of artifact alternatives until a satisfactory design is achieved that address the business problem (Simon, 1996). In WM there are several application areas and business functions where IIP technology can be employed (Alias et al, 2014). If the business problem area has been identified, this cycle will provide the researcher with design requirements and ways to evaluate the artifact. By utilising the design cycle principles through an electronic questionnaire the researcher aim to answer secondary research question one.

2.7.4 Change and Impact (CI)

The CI cycle deals closely with the overall adoption of IIP technology in the WM domain. The adoption of new technology usually has an impact on the overall socio-technical system (Drechsler & Hevner, 2016), for instance what impact will IIP technology in WM have if the technology replaces a previously manual process. This may cause job insecurity for some workers and relief for others. Thus the newly added cycle by Hevner and Drechsler in 2016 is vital in managing change in the workplace.

2.8 Chapter Summary

In chapter 2 the researcher covered the key concepts, the four main themes and an overview of the theoretical framework of the research paper. In this chapter the researcher highlighted the most prominent technologies used in South African warehouses, the capabilities of IIP technologies within the WM domain, and the importance of fitness for use when designing or adopting new technology. The chapter are concluded with the suitability of the DSR model 's adoption to conduct the research. The following chapter will detail the research methodology.

3 Design and Methodology

3.1 Introduction

The purpose of this research is to establish the information systems design principles that has an influence on IIP implementation success in the WM domain. In the previous chapter the researcher gave an overview of WM processes in South Africa and application areas of IIP technology as per most recent academic literature.

This chapter outlines the research methodology adopted to answer the formulated research questions with the aim to address the research problem identified. To provide a solution to the research problem, the Research Onion (Saunders et al, 2003) was selected to identify the steps in the research process.

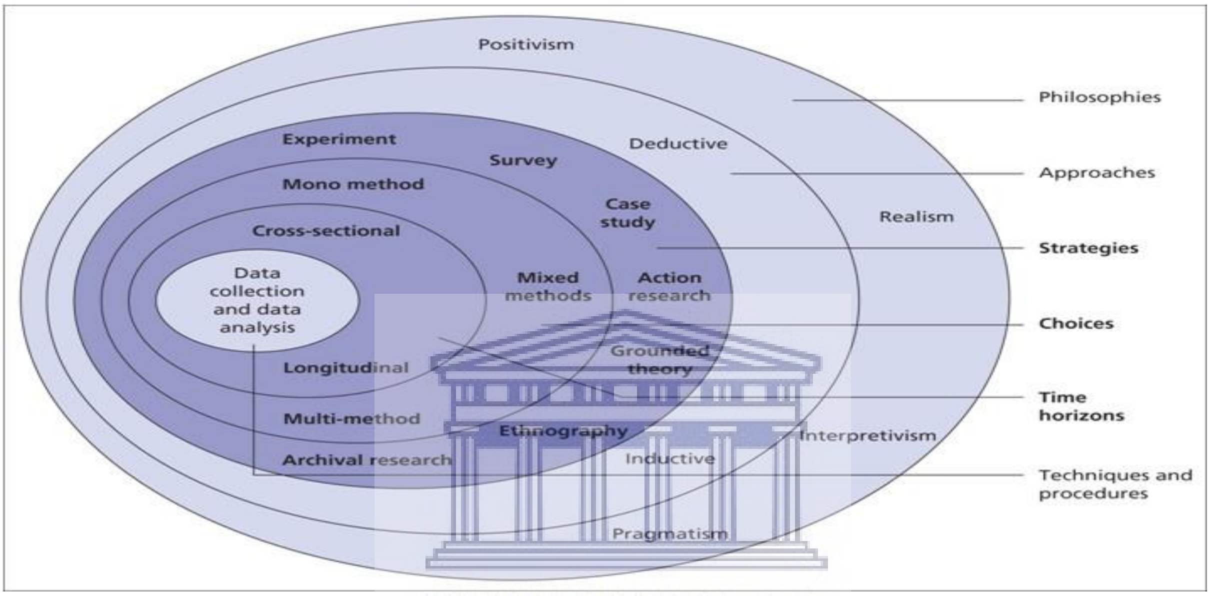

Figure 4: Research Process Onion (Saunders et al, 2003)

3.2 Research Philosophy

The research philosophy underpins the research strategy and which research methods are being chosen (Saunders et al, 2009). The researcher selects a philosophy by based on practical considerations, such as the relationship between knowledge and the process by which it is developed (Saunders et al, 2009). The four main research philosophies are interpretivism, pragmatism, positivism and realism (Saunders et al, 2009).

The research philosophy adopted for this study is interpretivism. The principle of Philosophy of interpretivism is when the researcher interprets and analyses responses from different participants using his/her own subjective perspective (Bhattacherjee, 2012). Interpretivism is best suited when the research study is qualitative of nature when the sample size is small and the study is concerned with generalised theories (Glesne & Peshkin, 1992). This philosophy is most suited as the data collection techniques used deals with a small sample size with in depth qualitative investigations.

3.3 Research Approach

The purpose of this design will be to explore the design principles for implementing IIP technology with the WM domain. The deductive approach is when the researcher draws conclusions of behaviour or a phenomenon based on logical or theoretical reasoning with an initial set of premise, whereas the inductive approach is where the researcher draw conclusions based on evidence or facts (Bhattacherjee, 2012). This study used an inductive approach, following a bottom up approach (Daff, 2011). Firstly the information was identified then the generalised findings derived from the results was identified. This approach is best suited as the researcher draw conclusions based on the primary data collected from an electronic questionnaire. Although the inductive approach is the dominant approach used, with certain rigid information such as demographic information about the respondents deduction is used.

3.4 Research Strategy

The third layer of the research onion address the adoption of the research strategy (Saunders et al, 2009). The research strategy demonstrates how the researcher will capture data to answer the research question(s) to fundamentally meet the research objective(s) (Saunders et al, 2009). The selection of the research strategy are also guided by the degree of existing knowledge on the topic and the amount of time and resources the researcher have available (Saunders et al, 2009). The research strategy selected for this study is the Survey strategy.

The survey strategy has numerous benefits compared to other strategies, for example, it is suitable for remote data collection, when data are being collected over a large geographic area and it is an unobtrusive manner of collection data as the participants can respond at their own convenience (Bhattacherjee, 2012). Surveys works best when the questions are standardised and all respondents should interpret the questions in the same way (Robson, 2002). First-hand data was collected with regards to challenges, experiences, opinions and frustrations from the unit of analysis regarding IIP technology designs and implementations. These methods were selected as it may promote the researcher to uncover topics not previously deliberated, (Saunders, Lewis & Thornhill, 2007). The Design Science Research Framework was employed to answer the research question and sub-questions, thus no hypothesis has been formulated.

3.5 Choices

The next layer of the research onion involves the choices with regards to selecting either a combination or single research method (Saunders et al, 2009). Research is commonly classified into either qualitative or quantitative by nature (Basias & Pollalis, 2018). The research instrument consists of descriptive quantitative and open ended text-based questions. Quantitative research aims for objective outcomes thus the descriptive quantitative collected data are analysed using descriptive statistics. Descriptive analysis refers to statistically presenting, aggregating and describing associations or concepts of interest (Bhattacherjee, 2012).

Qualitative data analysis techniques allows the researcher to develop theory from the data (Saunders et al, 2009). For qualitative data analysis a creative and investigative mindset is required with an ethically enlightened attitude (Bhattacherjee, 2012). The open ended text based data will be analysed using thematic analysis. A Grounded Theory technique are applied to discover emerging patterns in the data. Grounded Theory is an inductive technique for analysing recorded text data about a social phenomenon to establish theories about the phenomenon (Bhattacherjee, 2012). This technique will help the researcher identify meanings, definitions and interpretations made by the subjects of the study (De Burca & McLoughlin, 1996). "ATLAS.ti" qualitative data analysis software was used to analyse, annotate and code unstructured data to uncover patterns and new insights. Data coding makes it easier to understand dense text data based on the themes identified to answer the research question (Creswell, 2015).

For this study the researcher used a mixed method approach. A mixed method approach uses a single dataset, using a qualitative and quantitative approach (Saunders et al, 2009).

3.6 Data Collection

The unit of analysis can be defined as the population with the characteristics one wishes to study (Bhattacherjee, 2012). It can be a person, group, organisation, object, country or any other entity that you want to draw scientific conclusions about (Bhattacherjee, 2012).

Various individuals at managerial and executive level from one organisation in the WM domain participated in an electronic questionnaire. These individuals range from SC Business Analysts, Hub Managers and supervisors, Distribution Centre Managers and supervisors and

SC IT executives. All participants have extensive experience in tactical and strategic operations in managing warehouses and have a vested interest in the improvement of WM processes.

The participants were selected according to the following criteria:

- They play a role in the efficiency of the warehouse operations
- They have an input when selecting new ICT innovations
- They operate in the WM domain
- They operate in either a distribution or finished goods warehouse
- They are familiar with the current ICT in the warehouse

3.7 Research Instrument

The research instrument used within this study, was an electronic questionnaire distributed via email. Main attributes of electronic questionnaires is that the unit of analysis are computer literate; response time is between two to six weeks; consists of close-ended questions predominantly and the likelihood of the correct person responding is high (Dillman et al, 2014). The four cycle view of the Design Science Research (DSR) Framework were used to design the questionnaire employed to answer the research questions. The DSR Framework consists of four cycles namely, relevance, rigor, design and the additional change and impact cycle (Drechsler & Hevner, 2016).

The questionnaire was categorised into the four cycles as below:

3.7.1 Relevance Cycle

- This section deals with the business need or problem
- Requirement and acceptance criteria are also covered in this cycle

3.7.2 Rigor Cycle

- To determine if the participants have had any past experiences or expertise of IIP implementations
- This section also covers any regulations and standards related to IIP implementations

3.7.3 Design Cycle

- This section consisted of questions based on the actual design/ redesign of the IIP system/ implementations
- This section also questions the level of understanding of IIP from participants

3.7.4 Change and Impact Cycle

- This section uncovers the wider organisational and societal impact of the of IIP implementations
- Deals closely with the overall adoption of new technology in the socio-technical system
- Uncovers any change management concerns that might arise from IIP technology adoption

3.8 Data Sources

The organisation where the data were collected, is a corporate fashion retail company in SA. The respondents are in senior to executive roles within the SC of the organisation, with extensive experience in WM. These individuals' involvement in the SC range from managing operations to strategic level input at the organisation's warehouses across the country. This allowed the researcher to obtain a holistic view from the interview feedback.

3.9 Sampling strategies and techniques

Sampling techniques enables the researcher to reduce the amount of data that needs to be collected by only taking data into account from a sub-group rather than all possible cases or elements (Saunders et al, 2009). Sampling save time and increase the accuracy of data collected (Henry, 1990).

For this study a non-probability sampling strategy is adopted, as the sample does represent the views of all the retail warehouses in SA (Babbie, 1998). The sample is selected on the basis of the industry knowledge of the individuals and their contribution they can make to the research objective. This type of sampling is referred to as purposive sampling technique (Babbie, 1998). The advantage of this sampling technique is that industry experts are more familiar with the subject at hand and their opinions are more credible (Bhattacherjee, 2012) and they provide the researcher with invaluable insight. This sampling strategy is best suited when the researcher wants to explore a specific area and the participants suit the specific area interest (Etikan et al, 2016).

3.10 Location of the study

The study was conducted among senior members of the SC of a fashion retail company throughout SA. The organisation has multiple warehouses across the country and many of these warehouse or hub managers partook in the survey from their respective provinces. The executive level individuals in are based in Cape Town.

3.11 Assumptions and Limitations

A notable assumption worth mentioning is that the operational managers the researcher has collected data from, are reasonably familiar with the concept of IIP and vision-based technology, often collectively referred to as image recognition systems. If participants were not familiar with concepts related to IIP technology it will be a finding worth researching about the SC partners in an SA organisation. The impact of the COVID-19 pandemic may have a limiting impact on the study, for example, it might impact the availability of the participants and/ or their appetite for engaging in debate regarding new technologies such as IIP.

The time frame the research was conducted in limited the number of organisations that took part in the study to only one. Another limitation to note is the research was conducted during the COVID-19 pandemic in South Africa, which restricted movement and availability of the researcher and participants.

3.12 Ethical considerations

All participants have given their permission to partake in this research study via a consent form to ensure transparency while collecting primary data. The use of pseudonyms will be used throughout the article and nowhere will the true identity be used in an attempt to protect the autonomy of the participants. The study is not in any way financially supported by any external parties that may have an impact on the outcome and advancement of the study. All data collected will be stored on a password protected device in the possession of the researcher only.

3.13 Chapter Summary

This chapter outlined the research design and options that were favoured to answer the research questions. The research design approach was motivated by the Research onion (Saunders et al, 2009). The study is qualitative of nature, analysing data collected through an electronic questionnaire using an inductive approach.

4 Data Presentation and Analysis

4.1 Introduction

This chapter covers the analysis of the data collected via the electronic questionnaire from senior members (middle and senior managers) of the SC of a fashion retail company in South Africa. As discussed in previous chapters, the aim of the study is to establish the design principles influencing a successful IIP implementation in warehouses.

Miles and Huberman (1994) thematic analysis approach was adopted to analyse open ended textual data supported by Atlas.ti 9 analysis software. Open ended textual data was coded to ensure reliability of the data and to facilitate the analysis process. The descriptive quantitative data was summarised in the form of percentages using descriptive statistics. Descriptive statistics is a good technique to summarise single variable data for plotting or in the form of means or percentages (Kaliyadan & Kulkarni, 2019).

4.2 Profile of Respondents

There were a total of 43 responses from senior members (middle and senior managers) of the SC of a fashion retail company. A total of 18 respondents are in middle management, 19 in senior management, 6 from the IT supply chain team. The 43 respondents worked in various departments in the warehouse, including Receiving, Despatching, Picking and Inventory, with many overseeing all the operations in the warehouse either from an IT or operations approach. Sixty percent of the respondents have more than 10 years experience in WM, whereas 22, 5% have between 5 and 10 years experience, with 17, 5% having less than 5 years experience. The study was done nationwide with respondents from Cape Town, Durban, Johannesburg, East London and Harrismith.

Figure 5: Job Titles of respondents

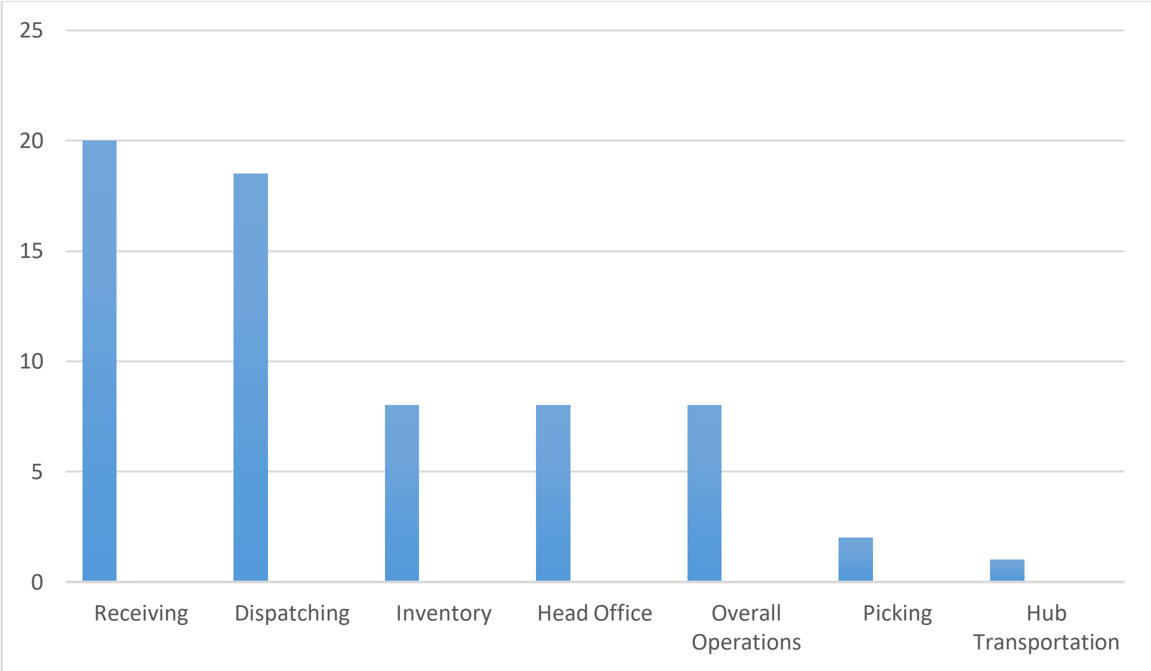

Figure 6: Operational Area of respondents

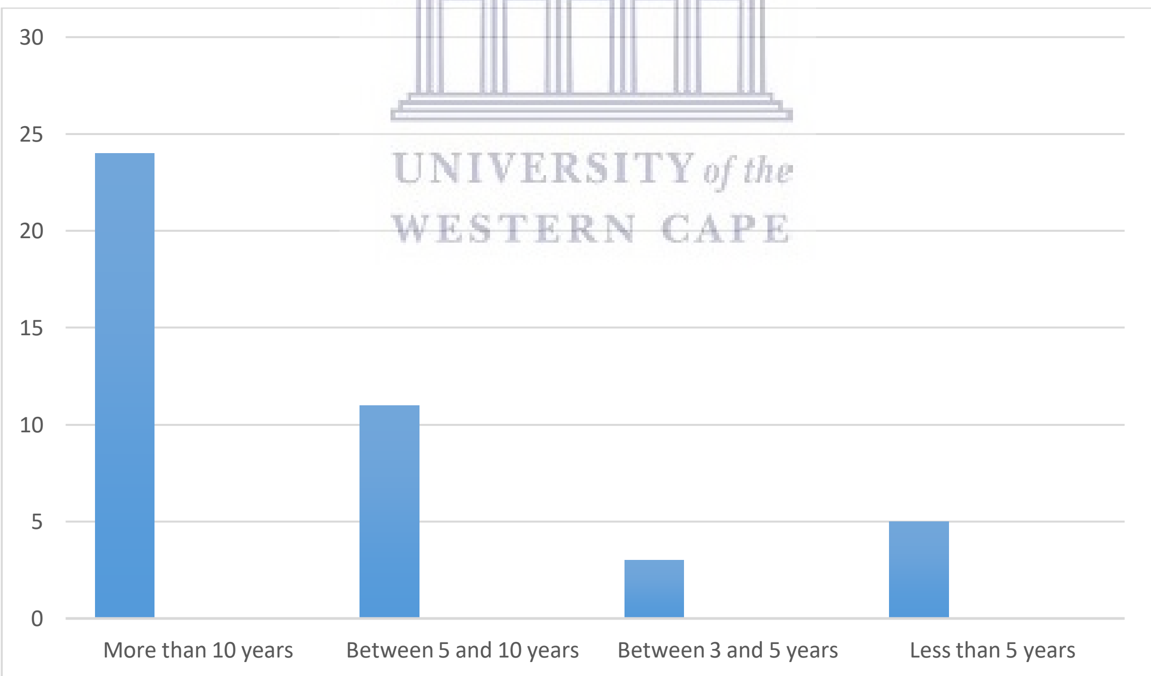

Figure 7: Years Experience in Warehouse Management of respondents

4.3 Relevance Cycle

DSR is motivated by the demand to improve organisational processes by introducing new and innovative artifacts (Simon, 1996). Promising DSR usually starts with the identification of problems in an application environment and presenting opportunities to solve the problem (Hevner, 2014). Thus the relevance cycle starts of the DSR with a problem in the application context as inputs, and also defines the acceptance criteria for the evaluation of the artifact (Hevner, 2014). Improved information flow among SC functions are vital to achieve an agile SC. From the data collected via the questionnaire from the 43 respondents, it was evident that lack of information flow and automation in the warehouses presents a business need or problem. Below the researcher identify the main themes the data identified as the business need or problem.

4.3.1 Automated tracking and tracing of cartons

Within the warehouse process, cartons comes into the warehouse through a receiving process, then goes into a storage area which follows by a picking process, and eventually leaves the warehouse through a despatching process. The duration a carton stays in the warehouse varies, and typically depends on the type of stock that is in the carton. Throughout this complicated process there are many challenges. Common problems the warehouses have to deal with are, miss-scans of cartons, cartons getting damaged, misplaced cartons and human errors. These problems often leads to loss of stock due to misplaced cartons, low productivity due to human errors and longer lead times due to outdated tracking processes.

Respondent 3 on which problem area IIP technology can improve:

"A digital package that will allow the counting, receiving and dispatching of parcels, and also monitor parcel quality"

4.3.2 Stock counting process

Often, many warehouses are required to do biannual full warehouse stock take as well as regular cycle counts. Full warehouse stock takes are when all the goods in the warehouse are counted as well as checking the condition of the stock. Cycle counts must be done regularly of smaller portions of the warehouse to ensure good stock control. These process are done manually by personnel with handheld scanners, where they scan each carton, this information is then uploaded to the WMS where reports can be generated about the results. Depending on the size of the warehouse, this process typically takes one to two days. During full warehouse stock takes, the warehouse is usually taken out of commission and no stock comes in or goes out. This have a huge negative impact on overall productivity for the organisation, and can result in stores running out of stock.

Respondent 41 on which problem area IIP technology can improve:

"Stock Counts / Cycle Counts is a good place to start. This could save time, capture damages on cartons/pallets and 'red flag' possible integrity issues for manual investigations. You could even do cycle count after every Inventory movement."

4.3.3 Manual carton scanning

Carton scanning in the warehouse is essential. By scanning the labels or barcodes on the cartons enables the warehouse to accept the cartons into the warehouse, obtain information of the contents and location of the carton and to distribute the carton out of the warehouse. This is a manual process done by personnel using Bluetooth or Wi-Fi enabled handheld scanners. At the time of writing this article there were more than two hundred thousand cartons between one of the Hubs and Distribution centres. Cartons are usually scanned multiple times throughout it's time at the warehouse. Having to scan all these cartons manually is an error prone and slow process.

Respondent 32 on which problem area IIP technology can improve:

"CCTV cameras that can scan 100%"

4.3.4 Information flow of carton activity

Having accurate, visible and live information on carton activity is vital to Inventory management. Information about cartons can be found on the WMS at the distribution centres and the Distribution Transaction System (DTS) at the Hubs via static reports. These reports are gives a snapshot of the carton activity at specific time, and must be regenerated once the carton have moved. There is a big need for dynamic live dashboards showing carton activity in the warehouses. This will allow for real time visibility of cartons.

Respondent 28 on which problem area IIP technology can improve:

"The Process flow chart digitalization within the warehouse in order for throughput and output visual management can be visible on daily basis in order for dynamos to understand the methodology of processes across board through VISUAL MANAGEMENT."

4.3.5 Design Principles derived from the Relevance Cycle

There is a big need for automation in the warehouses, which IIP technology can offer. The first design principle derived from the relevance cycle is, the application should autonomous. The warehouses need an IIP application that has the ability to track and trace cartons in the warehouse. For example, if the carton move from the receiving floor to the racks the cameras should detect the carton and track it, whilst updating the location of the carton in the WMS. The second design principle is the output of the IIP application are expected to be operational reports, BI dashboards as well as live video feed for adequate carton activity monitoring and visibility.

4.4 Rigor Cycle

The rigor cycle present past experiences and knowledge to the project to ensure its pertinence and level of innovation (Hevner, 2014). When designing new artifacts it is important to determine the extent to which the design is grounded in relevant knowledge bases. It is common in IS projects where organisations adopt new technology with high expectations without understanding the full capabilities or lack of the technology. Thus it is important to uncover and analyse data related to the rigor cycle from the questionnaire that has not been published before. Below are the main themes related to the respondents experience and expertise related to IIP technology.

4.4.1 Level of awareness of capability and standards of the technology

There is a lack of understanding among the warehouse management about the capability of the technology. They are interested in the technology and have a good understanding of the benefits what the technology can offer, but do not understand certain standards to produce a quality application. When asked questions about pixel density and bandwidth speeds standards or guidelines needed for the IIP application, 80% of respondents did not know. They also unaware of any ISO27001 information security protocols needed to protect the data.

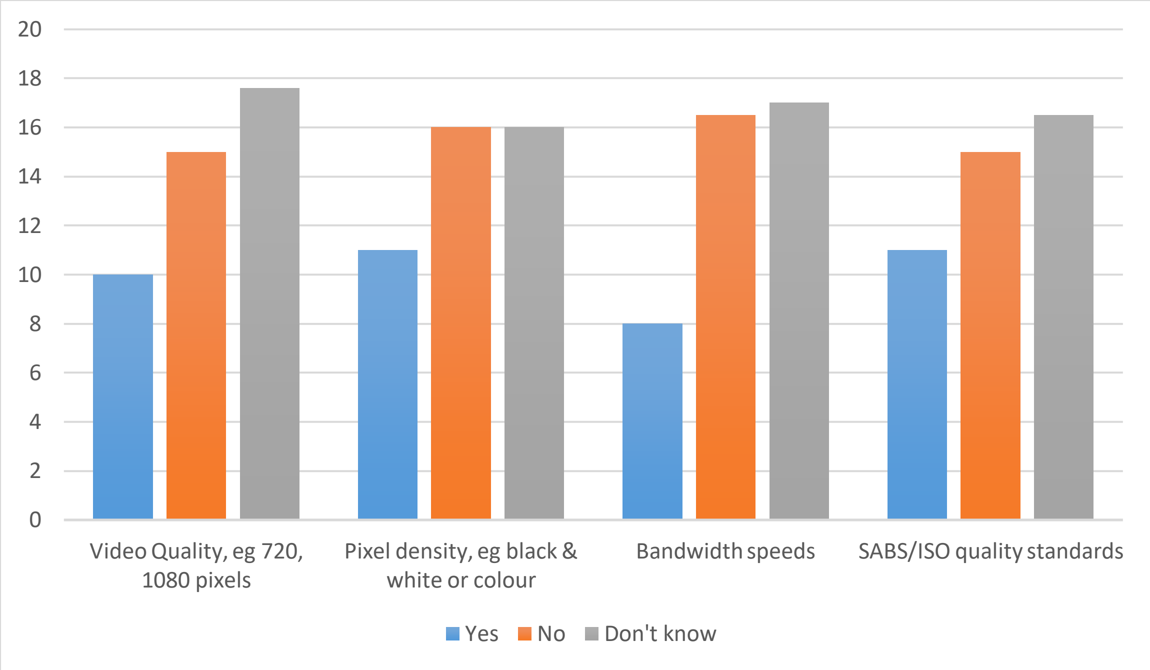

Figure 8: Respondents responses when asked if they know the Bandwidth speed, Pixel density, Video quality and data security requirements

4.4.2 Accuracy level from IIP application

A high percentage of the respondents expected the application to have an above 80% accuracy level when detecting, counting or scanning cartons. This is expected as the majority of the respondents opted for the IIP application to replace current systems or processes.

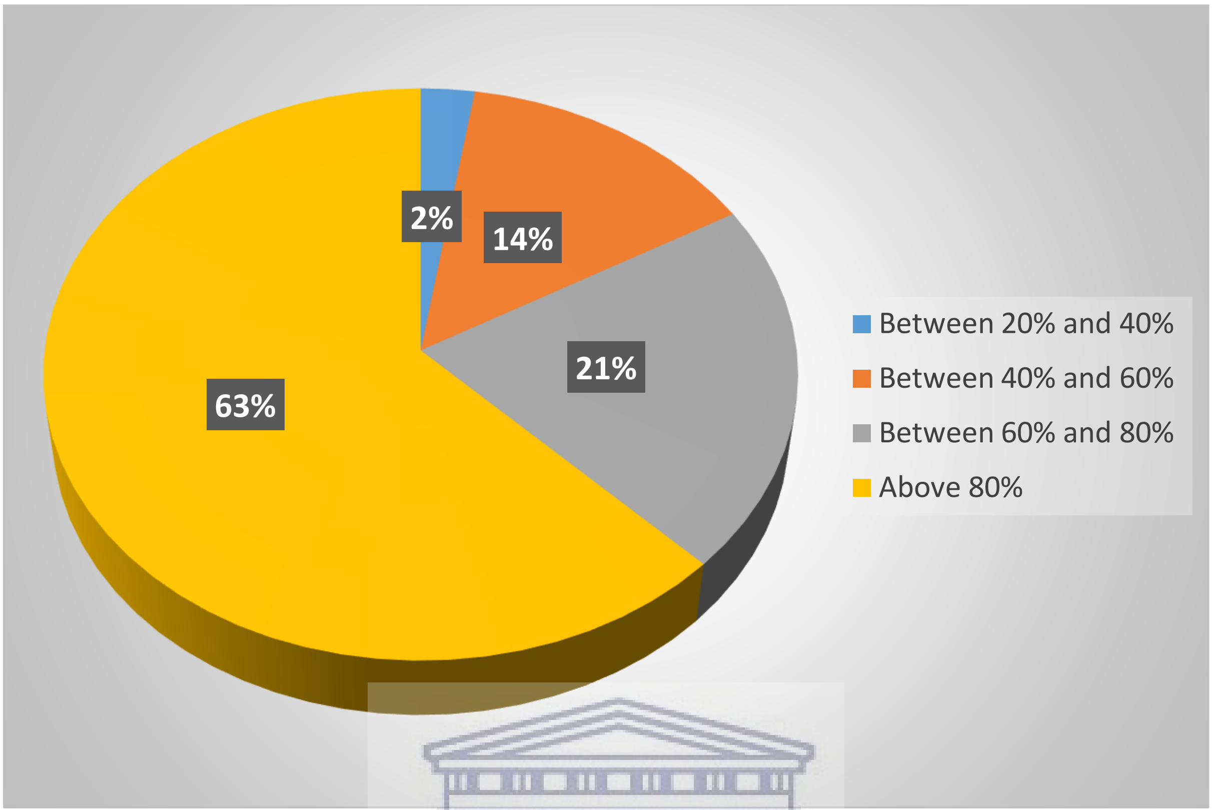

Figure 9: Respondents response when asked which level of accuracy the IIP application should produce

4.4.3 Compliance with governmental/ legal and organisational data policies

Respondents have an expectation the data derived from the IIP application should comply with the Protection of Personal Information Act (POPIA). The assumption can be derived that the respondents feel even if the data collected from the IIP application are not of staff/ people and their movements, but they might be in the frame and the organisation should protect and not misuse the data. The following POPIA principles which was emphasised the most:

4.4.3.1 Accountability

The organisation should appoint an Information Officer (IO) whose responsibility it is for the protection of the data. The information protection principles should comply with the POPIA controls.

4.4.3.2 Information Quality

The IO should ensure that the data collected are complete, up-to-date and accurate. The purpose of the data should determine the expected quality of the data. It is a well-known fact that poor data can lead to poor decision making.

4.4.3.3 *Security Safeguards*

The IO should ensure the integrity of the data and guarantee organisational data security policies are enforced. Although the majority of the respondents are not aware of the organisational security policies and policies regarding accessing the data, they expect it to be enforced.

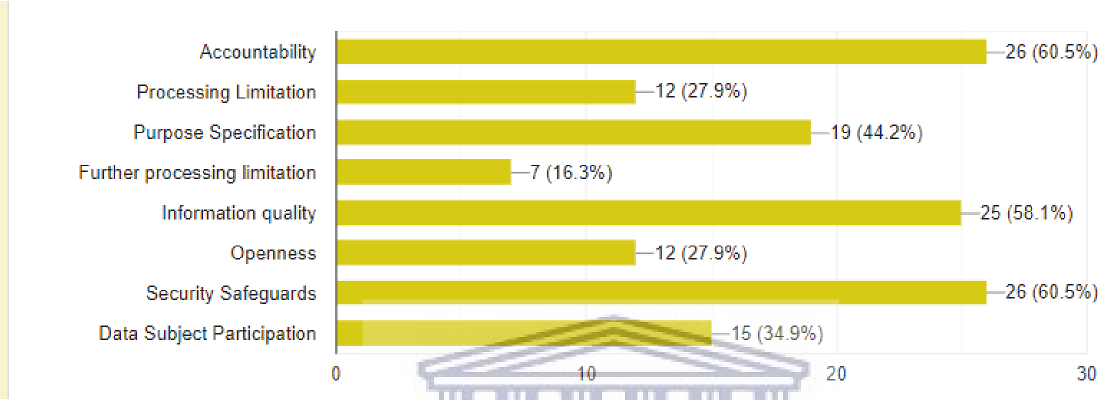

Figure 10: Respondents response when asked which of the 8 POPIA principles are applicable to the IIP application data storage

4.4.4 *Design Principles derived from the Rigor Cycle*

The third design principle is that the storage of the data should comply with organisational policies as well as any local, provincial and national legislature, for example the POPIA. The warehouse management understand the sensitivity of data storage and expects the organisation should enforce the necessary controls. The fourth design principle relates to the expected accuracy of the IIP application. An above 80% accuracy level is required, which relates to the training of the ML model. Thus the fourth design principles can be defined as; A large enough training dataset should be used to train the ML model to ensure high detection accuracy of the IIP application.

4.5 Design Cycle

The design cycle as the name suggests supports the design and redesign aspects of the IIP application (Hevner, 2014). The involvement of management in the design of any new system/ application is vital to the success of an IS project. The operational input is vital, as they are the people that is going to work on the system and eventually evaluate the success of the system. Below are the main themes derived from the design cycle data.

4.5.1 Hardware requirements

There is a clear need for new/ extra cameras to be installed in the warehouses for the IIP application to deliver the desired output. The majority of the respondents feel the existing CCTV cameras are not sufficient for the IIP application to detect carton movement throughout the warehouse. Specific shortcomings are the video quality of the cameras, the lack of cameras in areas of interest as well as the positioning of the cameras.

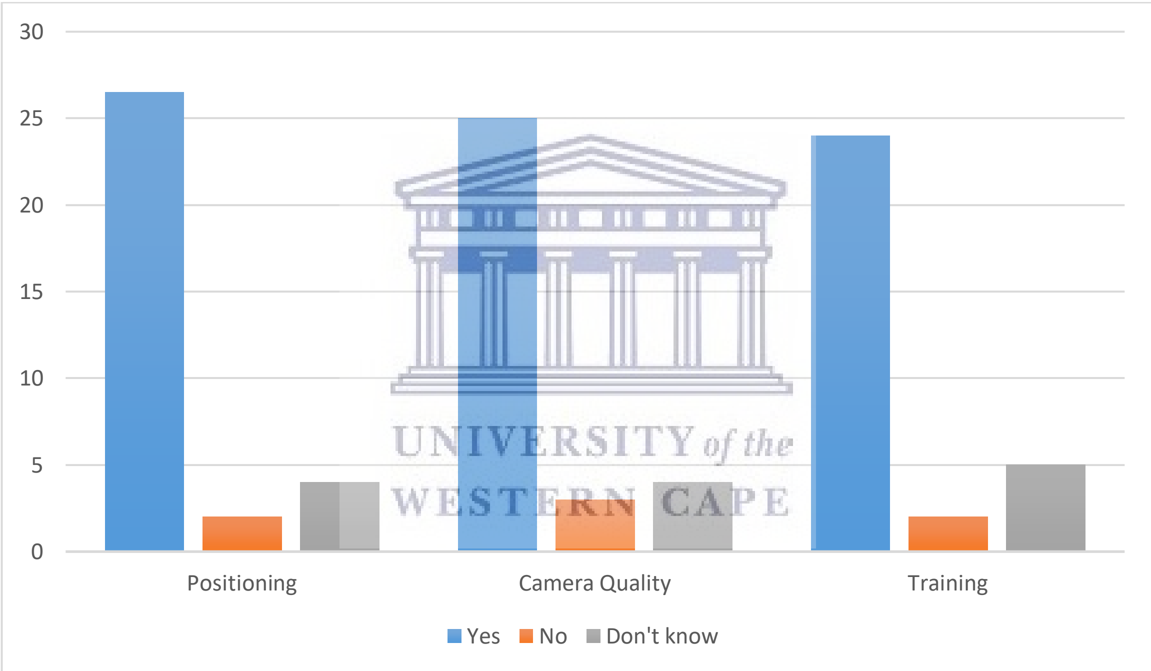

Figure 11: Responses when asked if any improvements should be made to the positioning, camera quality output and training of personnel for IIP implementation

4.5.2 Data accessibility

The respondents require the data that need to be stored from the IIP application is the video feed (71, 4%), images (57, 1%) and text (19%). This data will not only be used for real time reporting, but also for investigations of past occurrences. For example, if a truck makes a delivery at the stores, and there are cartons missing, management want to access the recorded data to investigate what happened. To do such an investigation, textual data, images or video feed can be very beneficial.

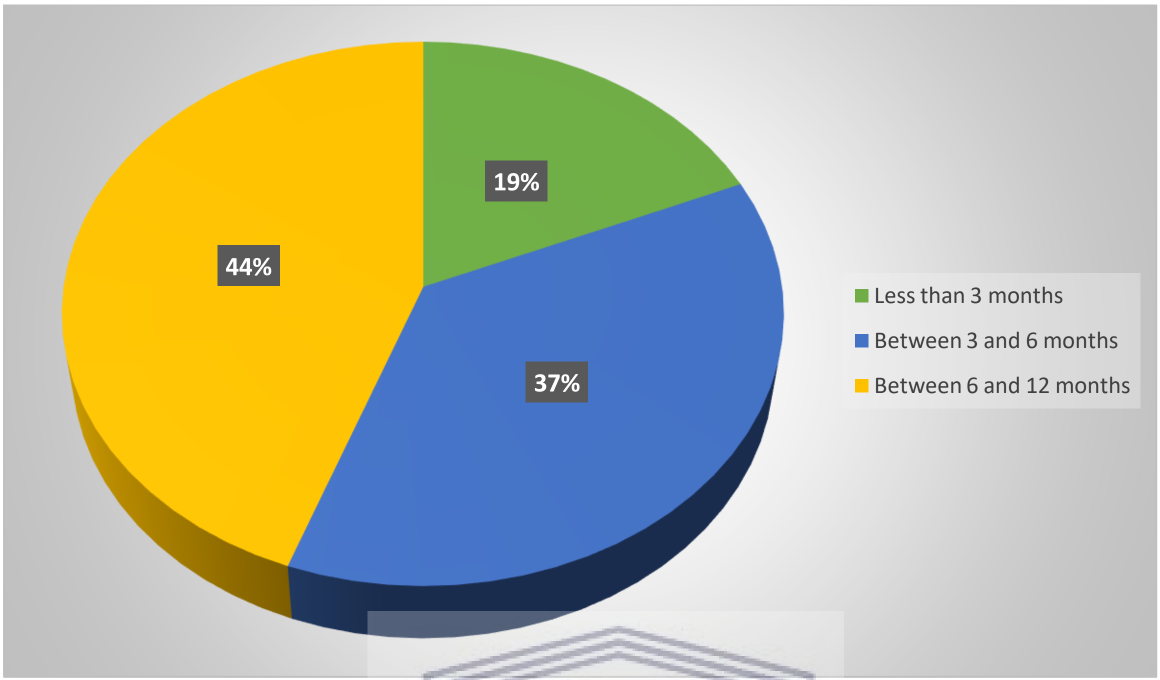

Figure 12: Responses on duration of data storage

4.5.3 Systems Integration

SC integration is well known to have a positive impact on the performance of the overall SC (Vanpoucke et al, 2017). SC integration ensures well-coordinated information flows to facilitate a smooth flow of materials (Vanpoucke et al, 2017). This is a notion that is very popular among the respondents, as all the respondents said yes for integration with one or more systems. Integration with the WMS was most popular, with the DTS and third party systems following.

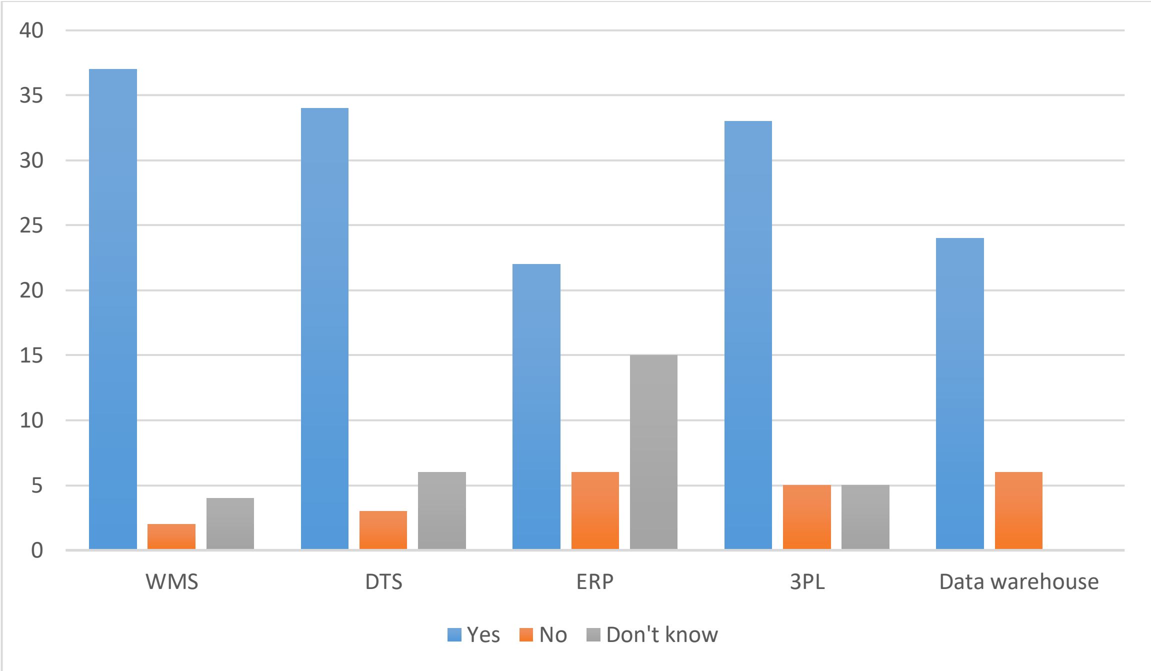

Figure 13: Responses on the need if the IIP application should integrate with various systems

4.5.4 Perceived benefits

Organisations have different preferences when implementing new technology, some organisations prefer a phased approach where new systems in conjunction with other systems, and some opt for a big bang approach where the new system completely replaces the other/ older system. Both approaches have their advantages and disadvantages. The data presents that 57, 1% of the respondents want the IIP application to totally replace manual processes. This illustrate either that they have confidence in IIP technology or the problem the manual processes impose are very big. Replacing the existing manual processes can be very risky, but the IIP application could lower cost, increase productivity and produce higher accuracy levels.

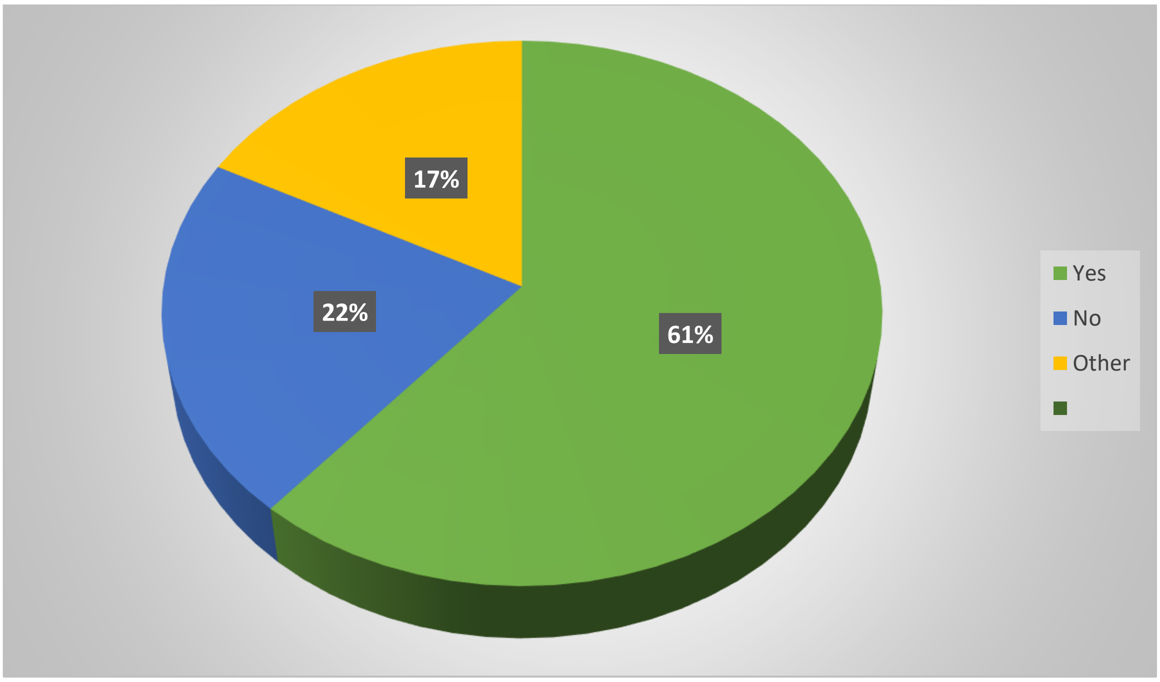

Figure 14: Respondents response when asked if IIP application should completely replace current manual processes

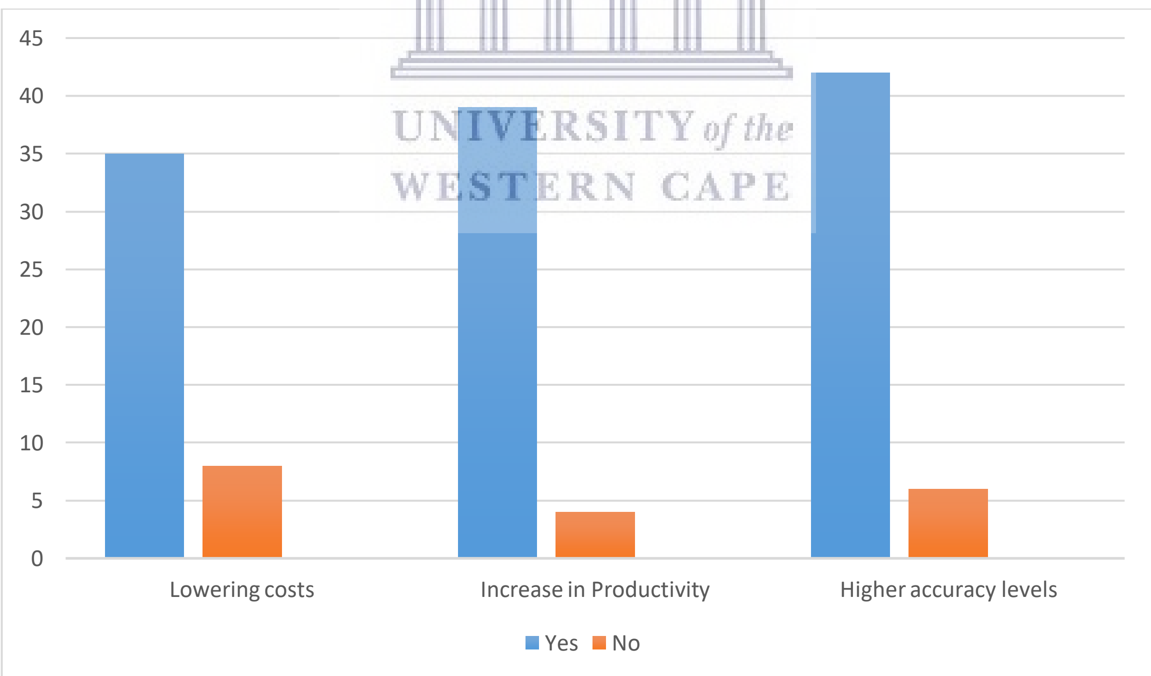

Figure 15: Responses on perceived benefits of implementing an IIP application at the warehouse

4.5.5 Design Principles derived from the Design Cycle

Considering the need to implement carton detection throughout the warehouse, the fifth design principle can be defined as installing additional sufficiently capable cameras in all areas of interest to ensure accurate detection of cartons from different angles. The output data of the IIP application will also be used for investigative purposes, thus the sixth design principle is that ample storage and processing capacity should be available to store and process, video, images and text. Integration from the IIP application to multiple other systems was evident among respondents, thus the seventh design principle isto design a rigorous integration layer capable of integrating with multiple other existing systems. If the IIP application are going to replace existing manual processes, the quality of detection must be accurate. The eight design principle is to do thorough testing to ensure high reliability of the IIP system.

4.6 Change and Impact Cycle

The CI cycle was introduced by Hevner in 2016 to uncover the wider second-order impact the artifact will have on the organisation. Th CI section of the questionnaire aimed to identify how the personnel would feel about the IIP application in the organisational and societal context. Below are the main themes derived from the CI cycle.

4.6.1 Acceptance level of technology

It is prevalent from the respondents that the IIP application is the best long term solution to the challenges currently experienced in the warehouse. 69% of the respondents answered yes when asked about the longevity of the proposed solution, and also 69% said they are not aware of simpler technology to solve their current challenges/ problems.

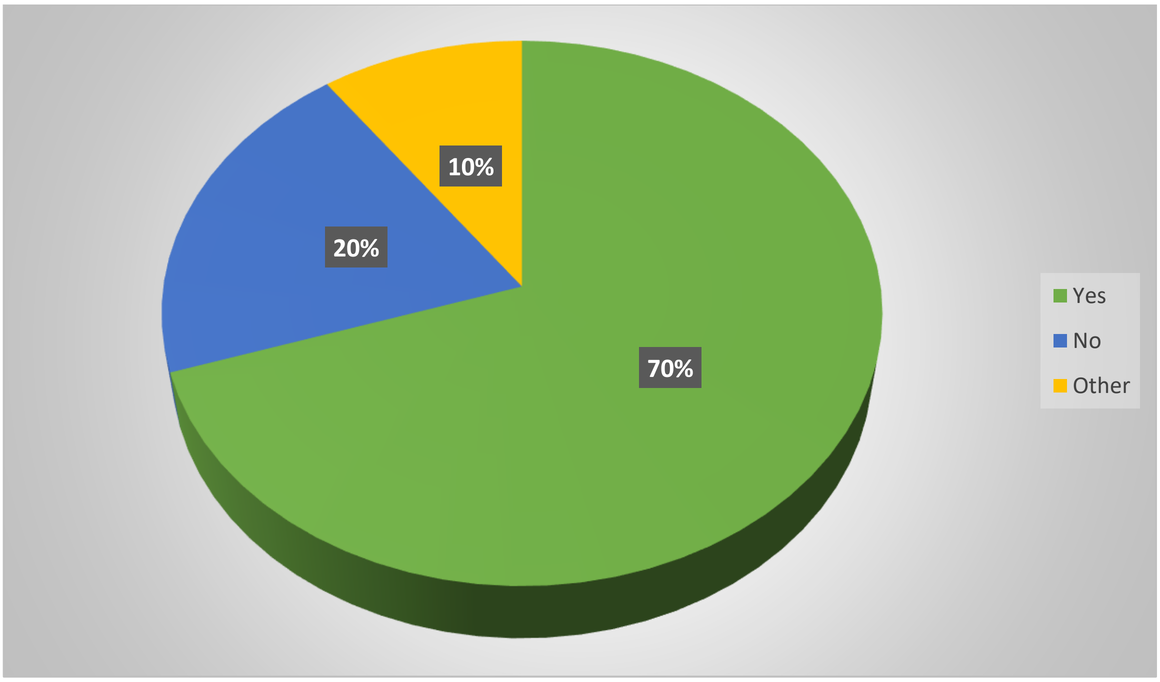

Figure 16: Responses if IIP is the best long term solution to challenges currently experiencing in the warehouse?

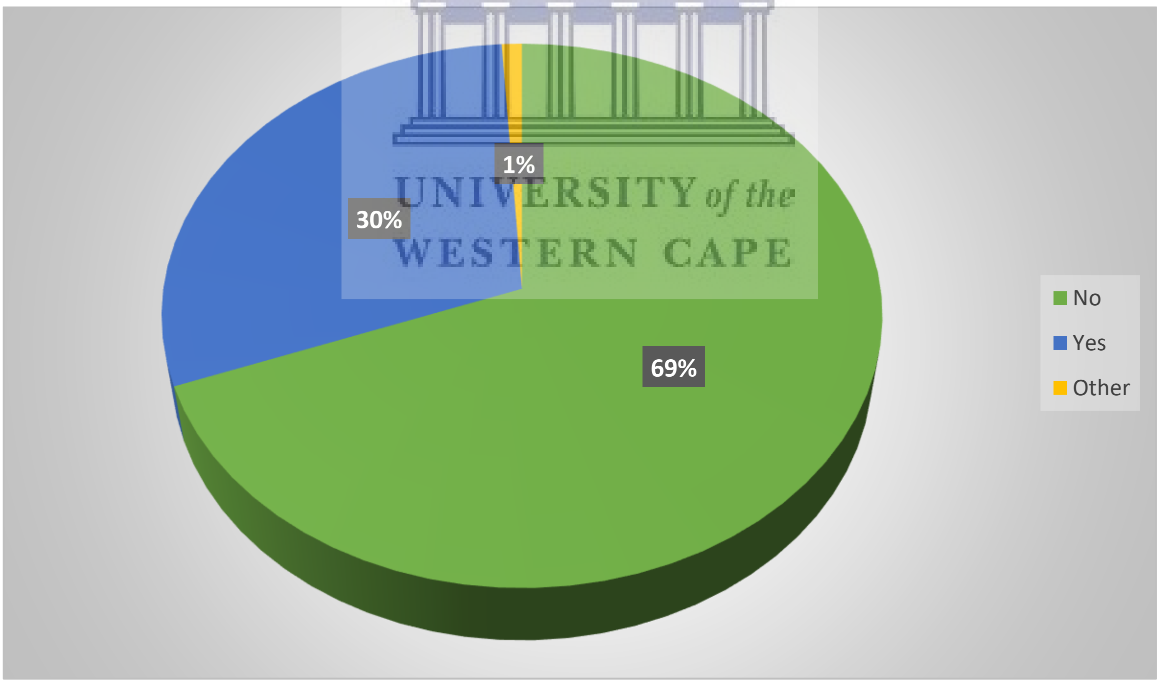

Figure 17: Responses on whether they are aware of simpler technology than IIP to solve the experienced challenges?

4.6.2 Training requirements

The level of technical awareness amongst the personnel that is required to work with the system, are on an intermediate to low level. They generally know their way around emails and basic computer functionality, but training will be required when introducing new IIP technology.

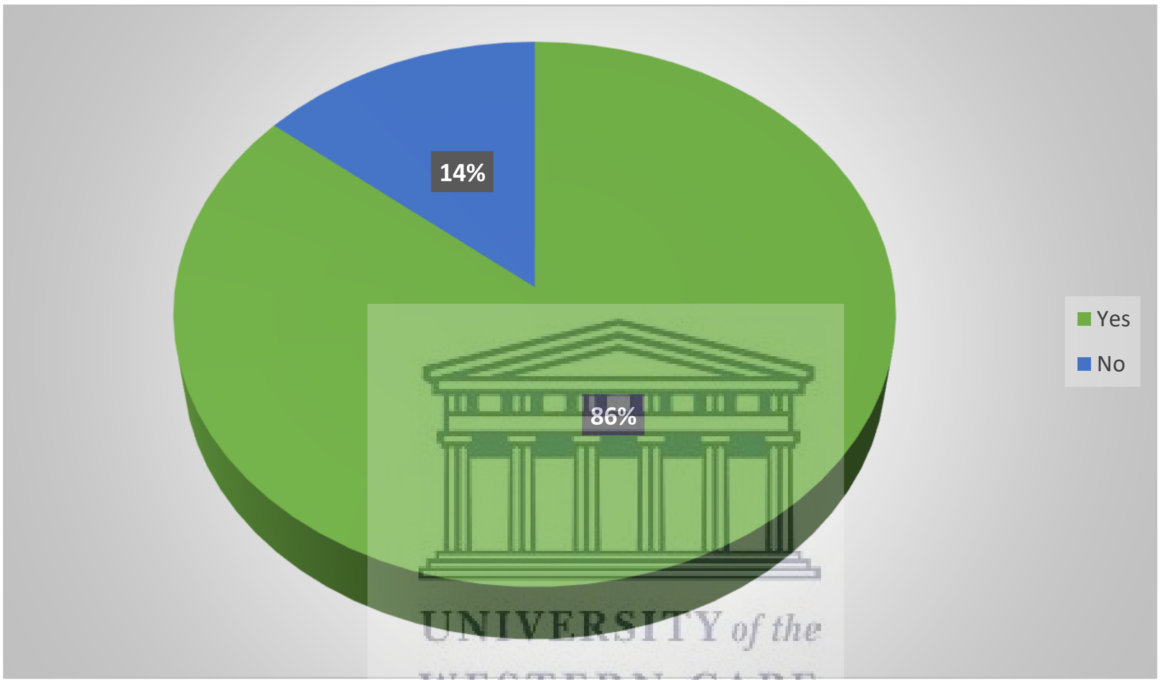

Figure 18: Responses on whether training will be required when implementing IIP technology

4.6.3 Job security

The aim of the IIP application is to automate existing manual processes to improve accuracy and productivity in the warehouse. Essentially this mean current processes executed by people will be eliminated and executed by the IIP application, for example the identification of damaged cartons on the conveyors. From the data analysed from the CI cycle it is evident that the personnel will feel threatened by the IIP application and fears of job security might arise.

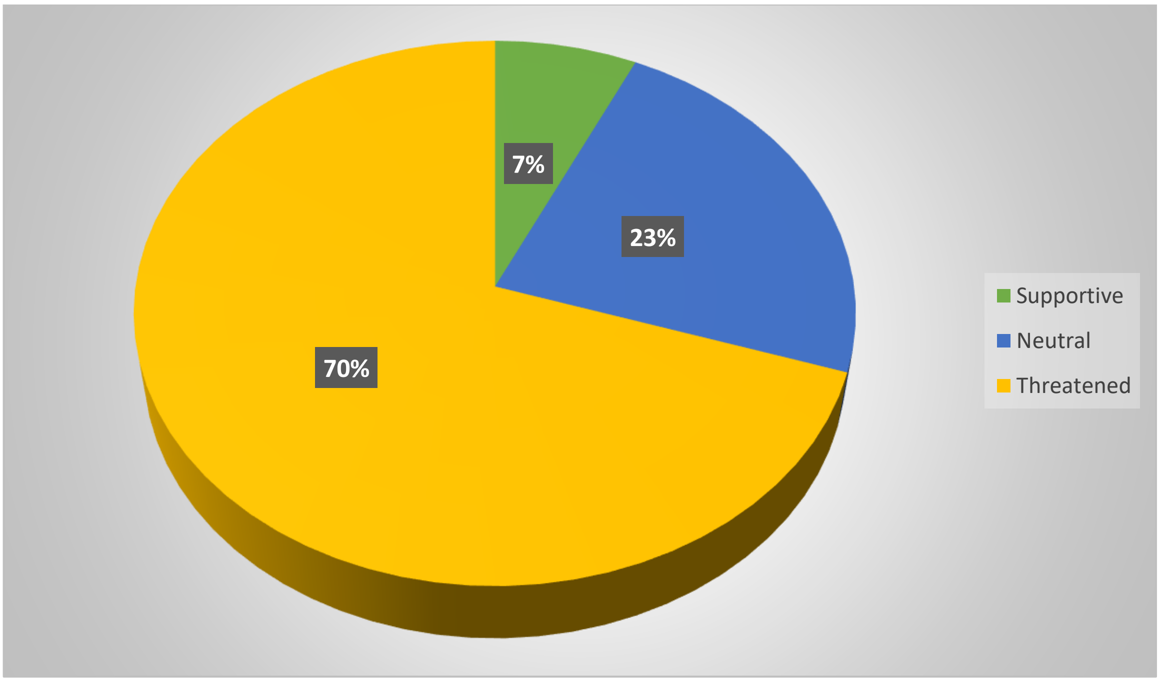

Figure 19: Responses on how the warehouse staff will feel if a machine/ system replaces a human function?

4.6.4 Management support

When new technology is adopted it is vital to have all levels of management support. If management are not supportive or negative, it can have an overall negative impact in the warehouse. This can lead to miss-use of the IIP application or overall abandonment of the application. More than 90% of the respondents feel all levels of management will support the implementation of the IIP application.

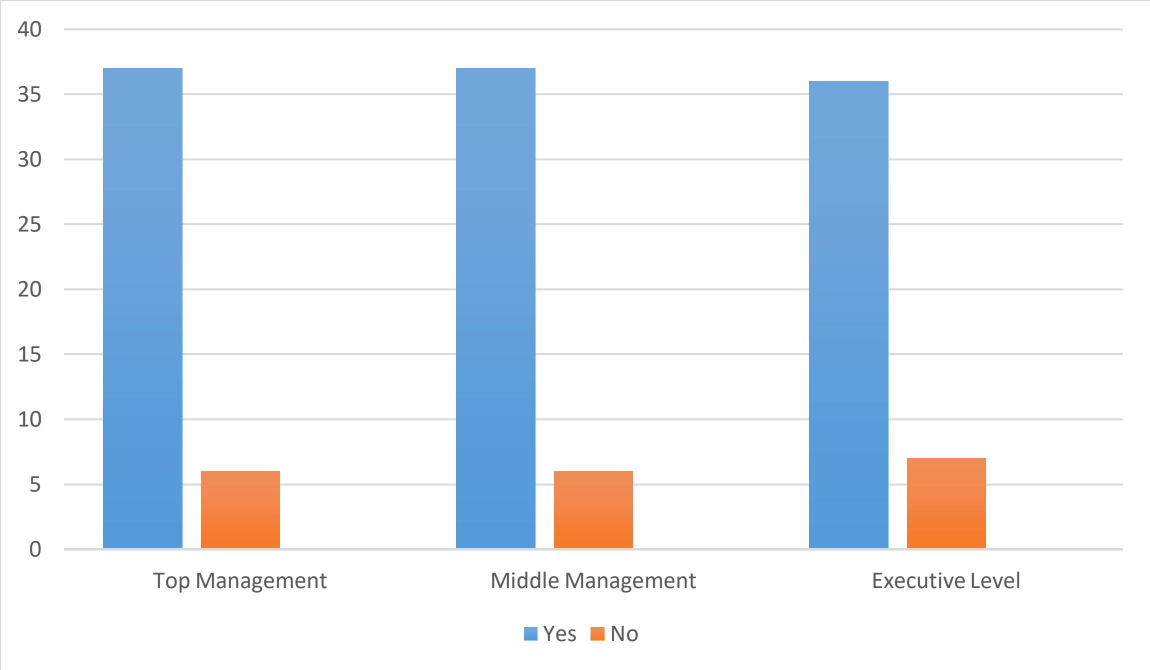

Figure 20: Responses on if management will support the implementation of IIP technology

4.6.5 Design Principles derived from the Change and Impact Cycle

Organisational change requires individual change as well, especially when new technology replace existing processes. This can attribute to personnel fearing the security of their jobs. Thus the ninth design principle can be defined as, there is a high need for Change management initiatives to promote job security and eliminate any stereotypes or bad stigmas around IIP technology. These change management campaigns should include human resources (HR) to ensure reallocation and reskilling of staff whose roles are affected by the implementation of the IIP application. Together with change management, ample training needs to be provided to ensure the users utilise the IIP application to the best of its capabilities. Therefore the tenth design principle is ample training should be provided.

4.7 Chapter Summary

This chapter presented the data collected to address the secondary objectives with the aim to fulfil the main research objective, which was *To establish information system design principles influencing Industrial Image Processing implementation success in Warehouse Management processes in South Africa.* The researcher also identified the design principles for all four DSR cycles in this chapter. The data collected from the questions in the relevance cycle, the researcher could establish a business need for IIP technology. The Rigor cycle identified the level of awareness of industry standards from the participants, and design principles was derived from the responses. The responses from the Design cycle section of the questionnaire identified the IIP system design requirements and perceived benefits. Whilst the Change and Impact section responses identified what change management activities are needed when complementing an IIP system. The next chapter will answer all the resech questions by delving deeper into the findings of the data, categorised by the four cycles of the DSR.

5 Discussion of findings

5.1 Relevance Cycle

One of the main challenges experienced in the warehouses are slow and manual error prone processes. Inventory management and 3D object detection explained in chapter two came out as the most favoured features of an IIP application. The lack of automation with regards to carton scanning and counting in numerous departments are seen as a big hindrance in increasing the productivity. As mentioned in chapter two, carton scanning and counting accounts for the bulk of activities in the warehouses, this is also generally where most of the mistakes are made. The findings of the data derived from the questionnaire supports this notion. The counting of cartons with an IIP application can be used to improve cycle counts and stock takes, as well as the ability to count cartons coming in (receiving) and leaving (despatching) the warehouse.

The detection of damaged cartons or damaged labels on cartons is an efficient way to prevent loss of stock due to stock falling out of damaged cartons and miss-scans respectively. Miss-scans typically leads to the absence of carton information, as barcode scans populate systems with the contents of the carton, like SKU descriptions and quantities. An autonomous IIP application is required to replace current manual scanning of cartons, as well as the detection and counting of cartons whilst moving on the conveyors. The before mentioned functionality should address the identified challenges in the warehouse.

The lack of real time visibility of carton movements throughout the warehouse has also been identified as an area in need of improvement. Dynamic operational reporting, live video feed and BI dashboards has been identified as a replacement to current static reports. Real time carton movement data streaming from the IIP application should be visible in areas of interest, for example carton counting at receiving and despatching departments and scanning information when cartons are moved from one location to another. Real time information flow can identify up to minute customer needs as well as potential bottlenecks or slowdowns across the greater SC. For example, the process after receiving is usually followed by a put-away process into a storage area, real time information can help the inventory department to anticipate how fast and what volumes are being received by the receiving department.

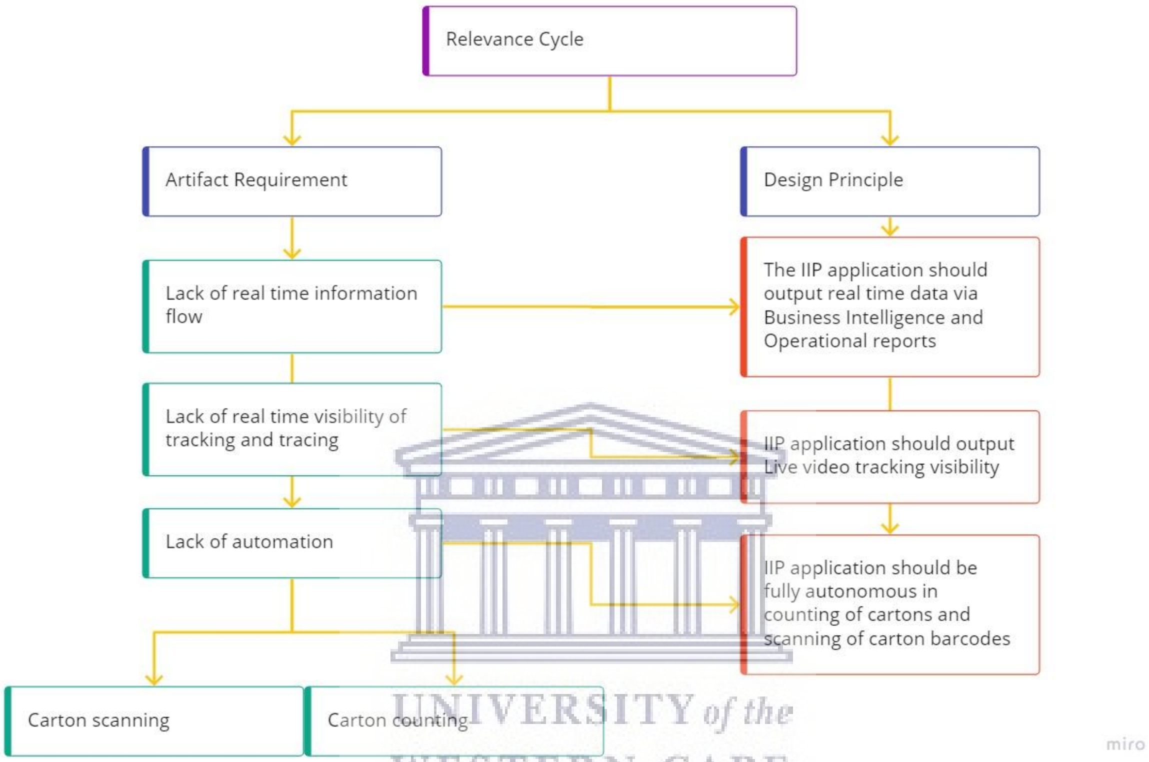

Figure 21: Design Principles derived from the Relevance cycle

5.1.1 Secondary Research Question 1: Is there an established business need for designing and implementing IIP systems in the South African retail WM environment?

Research has shown from multiple authors what aspects need to be taken into account for a warehouse to run efficiently. Bagalagel and El Maraghy (2020) highlights the need for real time data flows and tracking and monitoring of stock. Holubčík et al (2021) makes notion of technological optimisation and big data innovations. With the fourth digital industrial revolution becoming more of a reality than a futuristic concept, warehouse managers need to start embracing technology to address existing challenges within WM. Real time data flows, lack of tracking and tracing of stock, absence of big data storage capabilities are evident in the organisation where the research was conducted.

Respondents feel the manual process of counting cartons in various departments of the warehouse, are time wasting, error prone labour intensive. The areas of concern is mainly at receiving and despatching, where they have to manually count cartons on the conveyors when cartons go missing. This is a process that repeatedly happens in the warehouse on a daily basis. For example, when a transporter delivers stock at the stores and a carton is missing, the warehouse staff go check the current surveillance footage and manually count the cartons on going in the truck at despatching. This is also the case when transporters deliver stock at the warehouse. Doing stock takes and cycle counts in the warehouse is also a lengthy manual process. Typically this process is done by staff with a handheld scanner, by scanning labels on the cartons in an attempt to identify stock levels in the warehouse. During this process no stock can be moved in or out of the warehouse, which translates to long periods of downtime for the warehouse. Monitoring stock is also a vital activity in the warehouse (Bagalagel & El Maraghy, 2020). Defective cartons and damaged labels can caused bottle necks in the flow of the stock in the warehouse. Defective cartons cause contents to fall out of cartons which leads to stock loss, and damaged labels hinder the scanning of cartons.

The lack of real time data flow throughout the warehouse, let alone the different departments in the SC, is another challenge identified by the respondents. Currently warehouse personnel rely on static reports, forcing them to only generate the reports certain times in the day. For example, an inventory report cannot be generated while stock are being received as the quantities change as stock are received. Thus such reporting can only be done after the process has been completed. The lack of visibility of information regarding stock movement can be identified as challenge currently experienced in the warehouse.

IIP systems has the ability to address the aforementioned challenges currently experienced in the warehouses. Vision-based systems like an IIP application can be used for object inspection and detection (Weyrich, Laurowski, Klein & Wang, 2011). A fully automated IIP application which aid in the counting of cartons moving on conveyors, at receiving and despatching can ensure discrepancies being resolved much faster. The detection of not only cartons, but labels as well, can automate the scanning of cartons as it enters and exists the warehouse. Replacing parcel scans, a current manual process with an automated scanning process. With the visibility of live video feed and BI dashboards personnel have access to data generated in real time from the IIP application. The automation of processes were the most beneficial perceived benefit from the participants (65.1%), thus building a strong business case for IIP implementation.

With the business challenges identified from the data analysed from the questionnaire feedback, the researcher can conclude the answer to secondary research question number one is yes, there is a business need for IIP systems in South African WM.

5.2 Rigor Cycle

No clear standards for designing an IIP application in the WM domain was derived from existing literature, apart from some generic guidelines in terms of hardware specifications. When asked if the respondents are aware of bandwidth, pixel density and video quality requirements, by far the majority of them were unaware of the current standards of an IIP application. The expectation from the majority of the respondents are that the IIP application should replace the current manual processes, which drastically amplify their level of dependency on the application. As mentioned previously carton scanning is one the most repeated activities/ functions in the warehouse, thus the expected level of accuracy from the IIP application should always be above 80%. ML applications are only as good as the data they were trained on. To increase accuracy of ML applications a large enough, realistic and a balanced dataset are needed when the model is trained. Multiple angles of cartons and barcodes need to be used to train the ML model, as cartons won't always pass the cameras at the same angles. Images of damaged cartons and labels should also be used to train the ML model to ensure the algorithm can detect damaged cartons and labels.

Output data from the IIP application should be stored between for a minimum of three months, and up to twelve months. A requirement for a sufficient data protection plan need to be put in place whilst in the organisation's storage. A clear and transparent data governance system defining who has control over the data and how the data may be used need to be communicated organisation wide to ensure the increase in value of the data, reduce costs, minimize misuse risks to mention a few. The data governance steering committee should enforce POPIA and existing organisational data policies when managing data generated by the IIP application.

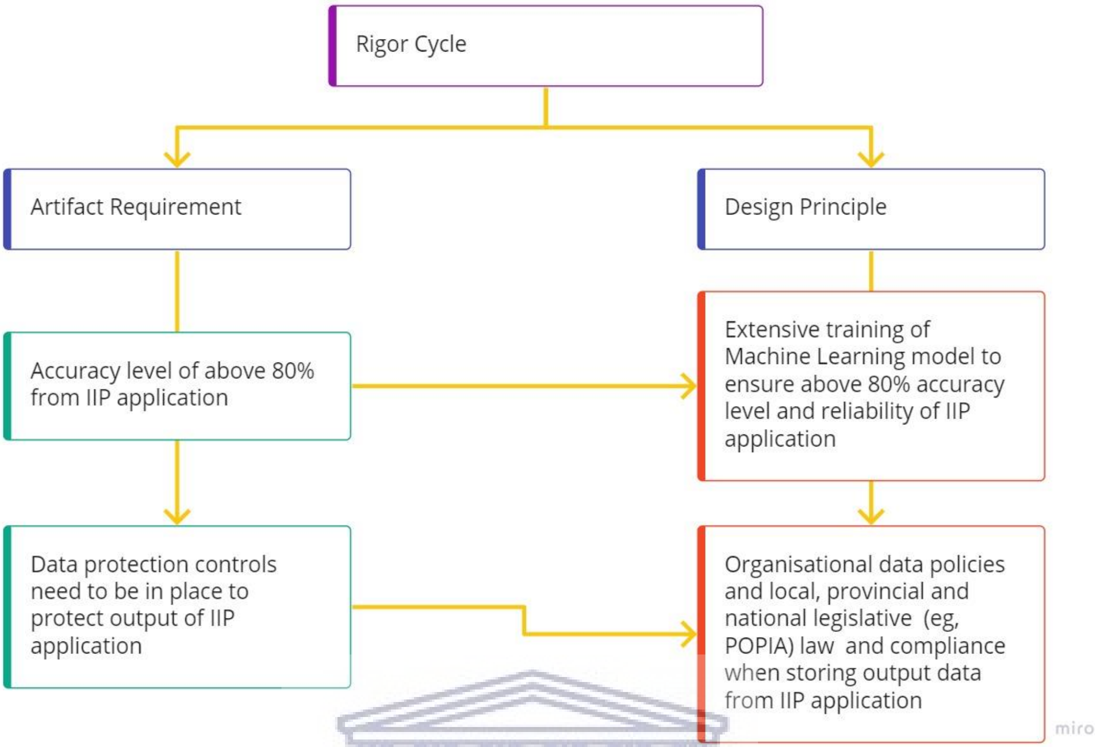

Figure 22: Design Principles derived from the Rigor cycle

5.2.1 Secondary Research Question 2: Are there established IIP design and implementation guidelines currently in use in WM process improvement in SA?

From existing implementation guidelines for IIP implementation is fairly limited. Generalised technical requirements for IIP systems were found, for example, camera quality and bandwidth speeds, which is discussed in chapter two. When similar questions about the technical standards or guidelines were asked, such as video quality and bandwidth speeds, respondents answered with a lot of uncertainty, most of the respondents not knowing. Therefore the answer to the second secondary research question, is No. However from the primary data analysed there were emerging policies or guidelines that should be taken into account in South African WM.

Respondents expects an above 80% accuracy level from the IIP application, which leads the researcher to identify this as a standard. To ensure high accuracy levels in ML models a large enough, realistic and a balanced dataset are needed when the model is trained. This will ensure high reliability on the IIP application.

Like with any typical information system, there is a data storage/ management aspect. With regards to data storage, the respondents feel data need to be stored between three and six months and need to comply with organisational data management policies as well as governmental law, such as the POPIA. The next standard with regards to IIP systems implementation in WM in SA, is data need to be stored between three and six months. The last guideline with regards to data management can be formulated as, Organisational and POPIA policies must be enforced.

5.3 Design Cycle

As discussed when the researcher identified the business need or problem in the relevance cycle, the organisation need automated tracking and tracing functionality from the IIP application. They identified the existing cameras in the warehouses are either not positioned optimally or doesn't output high enough video quality for this purpose. Clear video quality and good positioning are vital for accurate object detection from the ML model. For example, does the ML model detect the carton from the top, side or any angle, or are there additional cameras to detect the carton once it not in the frame of a particular camera any more. The existing cameras in the warehouses are predominantly used for surveillance or security purposes and are not sufficient for IIP purposes. Literature shows in chapter two, highly sensitive with high resolution cameras are required for optimal image processing, which correlates with the expectations from the respondents.

In the warehouse carton scans typically represent an event in the life cycle of a carton throughout the logistics process. This can be the carton entering, exiting the warehouse or even a location change/ movement within the warehouse. This real time scanning information can be very beneficial when shared between SC departments, for example if the information get shared with a third party transporter in real time better route planning and pick up times can be calculated. Thus, integrating real time information between SC departments generated by the IIP application is highly anticipated. A rigorous integration layer capable of integrating between multiple departments will be needed as most respondents saw the benefit of information sharing between more than one department, for example, data flows between the WMS and third party systems.

The organisation feel there are benefit in storing video feed, images and textual data generated from the IIP application. Considering the need to store the data between three and twelve months, the acquisition or allocation of sufficient storage should be taken into account as an important design principle. The need to store images and video creates a need for the organisation to adopt non- traditional data storage, which is distributed storage systems such as Hadoop and not traditional storage like local servers. Common Big Data frameworks are Hadoop, Storm, Spark and Flink, each having their own advantages and disadvantages.

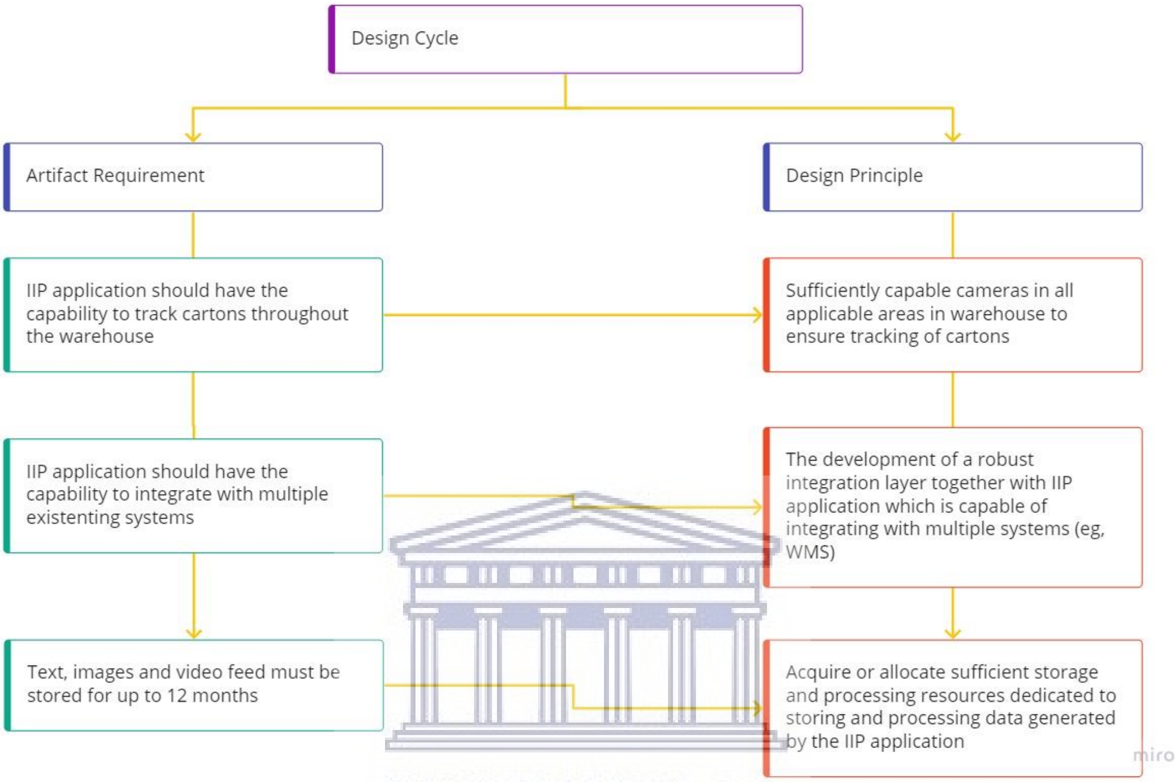

Figure 23: Design Principles derived from the Design cycle

5.3.1 *Secondary Research Question 4: What recommendations can be made from the interpretation of the findings to improve the design of IIP technologies in WM processes in SA?*

The respondents identified the lack of automated processes as one of the challenges the IIP application can resolve. They highlighted the value of what automation can add to increase operational efficiency. Installing additional high quality cameras to facilitate tracking and tracing for autonomous scanning and counting of cartons is a vital part in the successful implementation of the IIP application. The respondents feel the existing camera infrastructure will not be sufficient for the purpose of tracking and tracing. The function of the camera need to be considered systematically when these installations are done. For example, to scan barcodes the camera position might have to be closer to the conveyor than using cameras to count cartons.

Another essential consideration of a successful implementation of the IIP application, is the level of integration between the IIP application and existing systems. The respondents highlighted the flow of real time data generated from the IIP application between numerous existing systems will be invaluable. This can be parcel scans data to the WMS or to speed up the claims process when it comes to reverse logistics. Operational integration is concerned with the efficient operation of the whole SC (Stevens, 1989). Thus it is fundamental for the IIP application to have a robust integration layer to share real time data between other systems to improve operational efficiency.

The respondents requested video feed, images and textual data to be stored for further analysis and decision making. Storing big data requires non-traditional data storage capabilities. Big data capabilities involves the capture, storage and analysis of large volume data (Lamba & Singh, 2017). Reputable big data management frameworks include Hadoop Distributed File System (HDFS), Spark and Storm. For successful implementation of an IIP application sufficient big data storage and processing capabilities needs to acquired or allocated.

5.4 Change and Impact Cycle

When new technology is introduced there is always a possibility of people fearing their jobs. These fears can range from the possibility of being replaced by technology or fear that they won't understand how to operate the technology. In the case off IIP technology being introduced at this organisation, this is exactly the case. It is evident personnel might feel threatened by the technology when it replaces a previously manual process they used to do. Also the technical awareness of the personnel are at a level where they will need training to operate new technology like IIP applications. An extensive change management campaign supported by all levels of management will have to be implemented to ensure any stigmatisation of technology are eliminated, and clear training protocols need to be communicated.

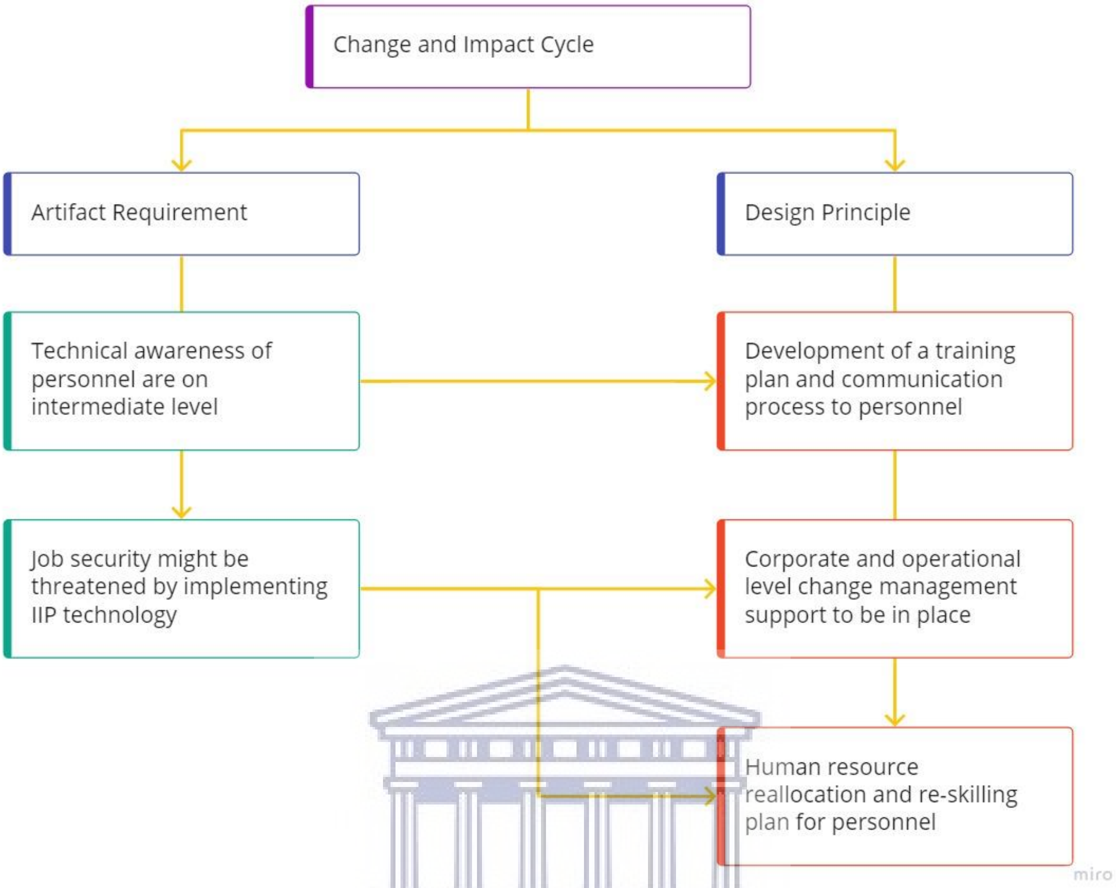

Figure 24: Design Principles derived from the Change and Impact cycle

5.4.1 Secondary Research Question 3: Which change management considerations related to IIP impact WM process efficiency most?

Facilitated by the rapidly growing IS adoption by organisations, change management and training requirements is vital in IS adoption. In spite of many benefits of IS, may implementations fail, because of user resistance (Aladwani, 2001). From the questionnaire data analysed, personnel resistance can emerge from them feeling threatened by the IIP application replacing them in the workplace and the lack of technological awareness to operate the system. These insecurities can be eliminated by management supporting the implementation of IIP applications and by implementing and supporting change management initiatives. Educating personnel on the capabilities and benefits of the IIP application are crucial in maximising the efficiency from the technology.

Organisations should ensure a Human Resource (HR) resource reallocation and reskilling plan for affected personnel are in place. For example, if a particular role or process is being replaced by the IIP application, the personnel need to be reskilled or reallocation to another department to ensure job security. This will ensure high ethical standards set by the organisation and aid in the elimination of insecurities of the personnel.

5.5 Chapter Summary

In this chapter the researcher answered all the secondary research questions based on the four cycles of the theoretical framework. Identifying there is a business need for IIP technology in WM domain, also established recommendations derived from the primary data to improve the design of an IIP application. There are limited existing implementation guidelines for IIP implementation, but from the primary data analysed the researcher could identify emerging policies or guidelines which should be taken into account in the South African WM domain. Important Change Management considerations were also identified to ensure optimal user acceptance of IIP technology. In the next chapter the researcher will address the primary research question.

6 Conclusion

6.1 Introduction

In the previous chapter the discussion of the finding was presented from the data collected via a questionnaire among warehouse management level personnel at a fashion retail company in South Africa. This chapter will conclude the study in an attempt to answer the main research question stated in chapter one.

6.2 Answering the primary Research Question

The main research question for this case study was:

What are the industrial image processing system design principles influencing Warehouse Management process efficiency in South Africa?

As discussed in the above sections that addressed the secondary research questions, there is a business need to improve WM processes efficiency, and the organisation acknowledge that IIP technology is the best technology to resolve the business need/ challenges. Thus the answer to the main research question is: if South African warehouses where to consider / adhere to the above design principles for IIP technology implementation, it will improve the efficiency of WM in SA.

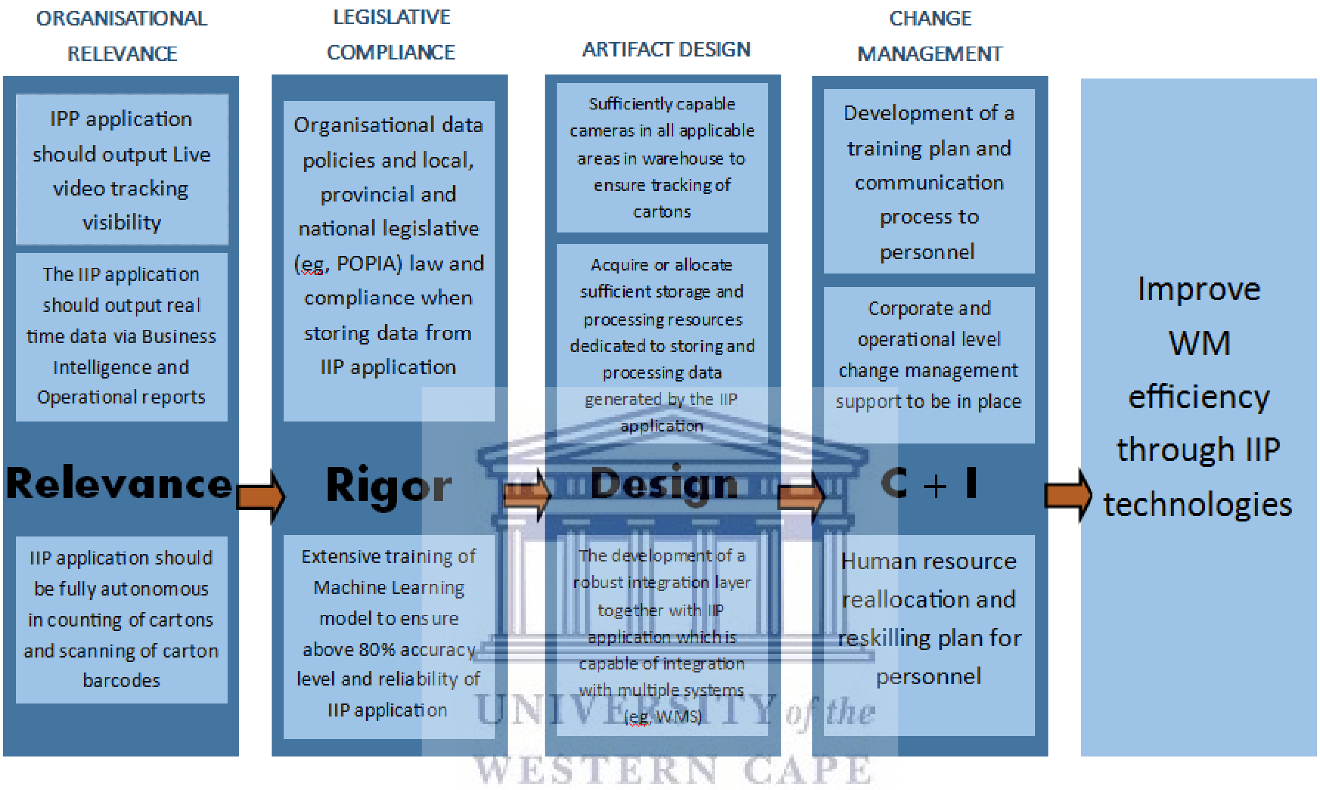

Figure 25: Design Principles derived from study to improve WM efficiency through IIP technologies

6.3 Contribution to the Body of Knowledge

The research confirmed there is organisational relevance for the implementation of IIP applications to improve the efficiency of WM processes, by highlighting numerous manual and error prone processes. The research highlighted the value IIP applications can bring to WM processes, as well as eleven design principles, ranging from legislative compliance, actual artifact design to change management considerations influencing the design of IIP applications to improve efficiency in WM processes.

6.4 Future Research

The research was conducted at one corporate fashion retail company in South Africa. It would be beneficial to expand the research to other industries' WM processes to identify perhaps greater organisational relevance and derive additional design principles.

From the primary data collected, it is clear there is a data management component that is critical in successful implementation of IIP applications. Future research in the data management of IIP applications can also be explored.

6.5 Research Limitations

The research was limited to one organisation. A study across the retail sector would have yielded a more holistic level of findings. This limitation was due to the given time frame to complete the research as well as the fact that the research was done part-time.

Within the case study context, another limitation was that the research was conducted during the COVID-19 pandemic in South Africa. This had an impact on the restriction of movement of the researcher, and on the availability of the participants, because of increased production targets in the warehouse caused by the loss revenue the organisation endured during the pandemic.

6.6 Chapter Summary

The successful implementation of new technology to improve SC efficiency can create a differentiating factor between competing organisations. The literature review in chapter two highlights various areas in WM where IIP technology can be implemented. The data collected from the respondents reiterates this notion, and provides further insights on how to answer the secondary research questions, which in turn enabled the researcher to address the main research question. The research was successful in identifying eleven design principles influencing WM process efficiency in South Africa.

7 References

Aladwani, A.M. 2001. Change management strategies for successful ERP implementation. Business Process management journal.

Alias, C., Kalkan, Y., Koç, E. & Noche, B. 2014. Enabling improved process control opportunities by means of logistics control towers and vision-based monitoring. In ASME 2014 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference. American Society of Mechanical Engineers Digital Collection.

Alias, C., Özgür, Ç. & Noche, B. 2016. Monitoring production and logistics processes with the help of industrial image processing. 27th Annual POMS Conference, 1–10.

Ansari, S. 2020. Building Computer Vision Applications Using Artificial Neural Networks, Building Computer Vision Applications Using Artificial Neural Networks. https://doi.org/10.1007/978-1-4842-5887-3

Babbie, E.R. 1998. *The practice of social research*. International Thomson Publishing Services.

Bagalagel, S. & ElMaraghy, W. 2020. Product mix optimization model for an industry 4.0-enabled manufacturing-remanufacturing system. *Procedia CIRP*, 93(2020): 204–209.

Basias, N. & Pollalis, Y. 2018. Quantitative and Qualitative Research in Business Technology: Justifying a Suitable Research Methodology. *Review of Integrative Business and Economics Research*, 7(1): 91–105.

Bazhenov, N. & Korzun, D. 2018. Use of everyday mobile video cameras in IoT applications. *In Conference of Open Innovations Association, FRUCT*, 22: 305-308.

Berg, J.P.V. Den, Zijm, W.H.M. 1999. Models for warehouse management: Classification and examples. International Journal of Production Economics 59, 519–528. https://doi.org/10.1016/S0925-5273(98)00114-5

Bhattacherjee, A. 2012. Social Science Research: Principles, Methods, and Practices. Textbooks Collection. Book 3.

Bidhandi, R.A. & Valmohammadi, C. 2017. Effects of supply chain agility on profitability. *Business Process Management Journal*, 23(5): 1064-1082.

Bose, N. 2016. Wal-Mart says it is 6-9 months from using drones to check warehouse inventory. Available at: https://www.reuters.com/article/us-wal-mart-dronesidUSKCN0YO26M/ [2021, June 05].

Brown, I. Russell, J. 2007. Radio frequency identification technology: An exploratory study on adoption in the South African retail sector. *International Journal of Information Management*, 27(1): 250–265.

Burca, S.D, & McLoughlin, D., 1996. The grounded theory alternative in business network research. Dublin City University Business School Research Paper, (4).

Burinskiene, A. 2018. New challenges for supply chain: Electronic invoicing and its use perspective. *Journal of Logistics, Informatics and Service Science*, 5(1): 31-42.

Christopher, M. & Towill, D. 2001. An integrated model for the design of agile supply chains. *International Journal of Physical Distribution & Logistics Management*, 31(4): 235–246.

Companik, E. Gravier, M.J. & Farris, M.T. 2018. Feasibility of warehouse drone adoption and implementation. *Journal of Transportation Management,* 28(2): 31–48.

Connolly, C. 2008. Warehouse management technologies. *Sensor Review*, 28(2): 108–114.

Creswell, J. 2015. *30 essential skills for the qualitative researcher*. Los Angeles, CA: SAGE.

Daff, L. 2011. The research proposal. *Accounting, Auditing & Accountability Journal*, 24(4): 553-553.

de Koster, R., Le-Duc, T. & Roodbergen, K.J. 2007. Design and control of warehouse order picking: A literature review. *European Journal of Operational Research,* 182(2): 481–501. https://doi.org/10.1016/j.ejor.2006.07.009

Dehgani, R. & Jafari Navimipour, N. 2019. The impact of information technology and communication systems on the agility of supply chain management systems. *Kybernetes,* 48(10): 2217–2236.

Depietro, R., Wiarda, E. & Fleischer, M., 1990. The context for change: Organization, technology and environment. The processes of technological innovation, 199(0), pp.151-175.

Dillman, D.A., Smyth, J.D. & Christian, L.M. 2014. *Internet, phone, mail, and mixed-mode surveys: the tailored design method*. John Wiley & Sons.

Drechsler, A. & Hevner, A. 2016. A four-cycle model of IS design science research: capturing the dynamic nature of IS artifact design. In Breakthroughs and Emerging Insights from Ongoing Design Science Projects: Research-in-progress papers and poster presentations from the 11th International Conference on Design Science Research in Information Systems and Technology (DESRIST) 2016. St. John, Canada, 23-25 May (pp. 1-8). DESRIST 2016.

Dubey, R., Altay, N., Gunasekaran, A., Blome, C., Papadopoulos, T. & Childe, S.J. 2018. Supply chain agility, adaptability and alignment: Empirical evidence from the Indian auto components industry. *International Journal of Operations & Production Management*, 38(1): 129–148.

Dubey, R., Gunasekaran, A. & Childe, S.J. 2019. Big data analytics capability in supply chain agility: The moderating effect of organizational flexibility. *Management Decision*. 57(8): 2092–2112.

Emmett, S. 2005. *Excellence in warehouse management: how to minimise costs and maximise value*. John Wiley & Sons.

Esau, M., Seymour, L.F. 2019. Radio Frequency Identification Implementation Challenges: A South African Case Study. *Proceedings of ACM SAICSIT*, 1–10.

Etikan, I., Musa, S.A. & Alkassim, R.S. 2016. Comparison of convenience sampling and purposive sampling. *American Journal of Theoretical and Applied Statistics*, *5*(1): 1-4.

Fayezi, S., Zutshi, A. & O'Loughlin, A. 2017. Understanding and development of supply chain agility and flexibility: a structured literature review. *International Journal of Management Reviews*, 19(4): 379-407.

Foggia, P., Saggese, A. & Vento, M., 2015. Real-time fire detection for video-surveillance applications using a combination of experts based on color, shape, and motion. *IEEE TRANSACTIONS on circuits and systems for video technology*, 25(9): 1545-1556.

Garg, N., 2012. Improving Business Logistics using Barcode Scanners. *International Journal of Computer Applications,* 50: 1–5. https://doi.org/10.5120/7844-0815

Ghiani, G., Laporte, G. & Musmanno, R. 2004. *Introduction to logistics systems planning and control*. John Wiley & Sons.

Gill, T.G., Hevner, A.R. 2013. A fitness-utility model for design science research. ACM Transactions on Management Information Systems (TMIS), 4(2), pp.1-24.

Gleissner, H. & Femerling, J.C. 2013. *IT in Logistics*. Springer, Cham.

Glesne, C. & Peshkin, A. 1992. *Becoming qualitative researchers*. White Plains, NY.

Gligor, D.M. 2014. The role of demand management in achieving supply chain agility. *Supply Chain Management*, 19(5/6): 577–591.

Golnabi, H. & Asadpour, A. 2007. Design and application of industrial machine vision systems. *Robotics and Computer-Integrated Manufacturing*, 23(6): 630–637.

Gregor, S., Chandra Kruse, L. & Seidel, S. 2020. Research perspectives: The anatomy of a design principle. *Journal of the Association for Information Systems*, 21(6): 2.

Gu, J., Goetschalckx, M. & McGinnis, L.F. 2007. Research on warehouse operation: A comprehensive review. *European Journal of Operational Research*, 177(1): 1–21. https://doi.org/10.1016/j.ejor.2006.02.025

Henry, G.T. 1990. *Practical sampling (Vol. 21)*. Sage.

Hevner Alan, R. 2007. A Three Cycle View of Design Science Research. *Scandinavian Journal of Information Systems,* 19(2): 87–92.

Hevner, A., Chatterjee, S. 2010. Design science research in information systems. In Design research in information systems (pp. 9-22). Springer, Boston, MA.

Hevner, A., Gregor, S. 2020. Envisioning entrepreneurship and digital innovation through a design science research lens: A matrix approach. *Information and Management*, 103350. https://doi.org/10.1016/j.im.2020.103350

Hofstee, E. 2006. *Constructing a good dissertation*. Johannesburg: EPE.

Holubčík, M., Koman, G. & Soviar, J. 2021. Industry 4.0 in Logistics Operations. *Transportation Research Procedia*, 53, 282-288.

https://www.baslerweb.com/en/products/cameras/line-scan-cameras/ [2021, October 01].

Kaliyadan, F. & Kulkarni, V. 2019. Types of variables, descriptive statistics, and sample size. *Indian dermatology online Journal*, 10(1): 82.

Khan, R.A., Uddin, J., Corraya, S. & Kim, J.-M. 2018. Machine vision-based indoor fire detection using static and dynamic features. *International Journal of Control and Automation,* 11(6): 87-98.

Krugel, L. & Viljoen, C. 2020. Impact of disrupting on South African business. *ACTA UNIVERSITATIS DANUBIUS*, 17(1): 24-42.

Kučera, T. 2017. Logistics cost calculation of implementation warehouse management system: A case study. MATEC Web of Conferences 134. https://doi.org/10.1051/matecconf/201713400028

Lamba, K. & Singh, S.P. 2017. Big data in operations and supply chain management: current trends and future perspectives. *Production Planning & Control*, 28(11-12): 877-890.

Laumer, S., Eckhardt, A. 2012. Why do people reject technologies: a review of user resistance theories. Information systems theory, pp.63-86.

Lee, C.K.M., Lv, Y., Ng, K.K.H., Ho, W. & Choy, K.L. 2018. Design and application of internet of things-based warehouse management system for smart logistics. *International Journal of Production Research*, 56: 2753–2768.

Li, T., Huang, B., Li, C. & Huang, M. 2019. Application of convolution neural network object detection algorithm in logistics warehouse. *The Journal of Engineering,* 2019: 9053–9058.

March, S.T. & Storey, V.C. 2008. Design science in the information systems discipline: an introduction to the special issue on design science research. *MIS quarterly*, 34(2): 725-730.

Mathaba, S., Dlodlo, N., Smith, A. & Adigun, M. 2011. Use of RFID and Web 2.0 technologies to improve inventory management in South African enterprises. *Electronic Journal of Information Systems Evaluation*, 14(2): 228-24.

Miles, M.B. & Huberman, A.M. 1994. *Qualitative data analysis: An expanded sourcebook*. Sage.

Morawakage, P.S. & Perera, A.S. 2016. A case study on modern supply chain management practices. *Logistic Conference Trincomalee: Journal, Naval and Maritime Academy, Naval Base, Trincomalee, Sri Lanka,* 97-111.

Muhalia, E.J., Ngugi, P.K. & Moronge, M. 2021. Effect of Warehouse Management Systems on Supply Chain Performance of Fast-Moving Consumer Goods Manufacturers in Kenya. *International Journal of Supply Chain Management,* 6: 1–11.

Neves, P., Almeida, P. & Velez, M. J. 2018. Reducing intentions to resist future change: Combined effects of commitment-based HR practices and ethical leadership. *Human Resource Management*, 57(1): 249–261.

Nguyen, G., Dlugolinsky, S., Bobák, M., Tran, V., López García, Á., Heredia, I., Malík, P. & Hluchý, L. 2019. Machine Learning and Deep Learning frameworks and libraries for large-scale data mining: a survey. *Artificial Intelligence Review,* 52: 77–124.

Niehaves, B. & Becker, J. 2006. Epistemological perspectives on design science in IS research. *Association for Information Systems - 12th Americas Conference On Information Systems, AMCIS 2006 6, 3567–3577.*

Olmedo, E., De La Calleja, J., Benitez, A. & Medina, M.A. 2012. Point to point processing of digital images using parallel computing. *International Journal of Computer Science Issues*, 9(3): 1.

Peffers, K., Tuunanen, T., Rothenberger, M.A. & Chatterjee, S. 2007. A design science research methodology for information systems research. *Journal of Management Information Systems*, 24(3): 45-77.

Pfeffers, K., Tuunanen, T., Gengler, C.E., Rossi, M., Hui, W., Virtanen, V. & Bragge, J. 2006, February. The design science research process: A model for producing and presenting information systems research. *In Proceedings of the First International Conference on Design Science Research in Information Systems and Technology (DESRIST 2006), Claremont, CA, USA (pp. 83-106).*

Pons, J. 2014. Drone Ready?. Available at: http://www.scanman.co.za/downloads/whitepaperdronereadyscanman.pdf [Accessed 24 October 2020].

Rahmatov, N., Paul, A., Saeed, F., Hong, W.H., Seo, H.C. & Kim, J. 2019. Machine learning–based automated image processing for quality management in industrial Internet of Things. *International Journal of Distributed Sensor Networks*, 15(10).

Ramaa, A., Subramanya, K.N. & Rangaswamy, T.M. 2012. Impact of Warehouse Management System in a Supply Chain. *International Journal of Computer Applications*, 54(1): 14-20.

Ren, S., He, K., Girshick, R. & Sun, J. 2015. Faster R-CNN: Towards Real-Time Object Detection with Region Proposal Networks. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 39(6): 1137-1149.

Robson, C. 2002. *Real world research: A resource for social scientists and practitioner-researchers*. Wiley-Blackwell.

Rukmani, P., Teja, G.K., Vinay, M.S. & Bhanu Prakash Reddy, K. 2018. Industrial Monitoring Using Image Processing, IoT and Analyzing the Sensor Values Using Big Data. *Procedia Computer Science,* 133: 991–997.

Saeed, F., Paul, A., Hong, W.H. & Seo, H. 2020. Machine learning based approach for multimedia surveillance during fire emergencies. *Multimedia Tools and Applications*, 79: 16201–16217.

Saunders, M., Lewis, P. & Thornhill, A. 2007. *Research methods. Business Students 4th edition*. Pearson Education Limited, England.

Saunders, M., Lewis, P. & Thornhill, A. 2009. *Research methods for business students*. Pearson education.

Saxena, S., Sharma, S., & Sharma, N. 2016. Parallel Image Processing Techniques, Benefits and Limitations. *Research Journal of Applied Sciences, Engineering and Technology,* 12(2): 223–238.

Shashidharan, M. 2021. Importance of an Efficient Warehouse Management System. *Turkish Journal of Computer and Mathematics Education*, 12(5): 1185-1188.

Simatupang, T.M., Piboonrungroj, P. & Williams, S.J. 2017. The emergence of value chain thinking. *International Journal of value chain management*, 8(1): 40-57.

Simon, H.A. 2019. *The sciences of the artificial*. MIT press.

Singh, D. & Verma, A. 2018. Inventory Management in Supply Chain. *Materials Today: Proceedings*, 5: 3867–3872.

Stecke, K.E. & Kumar, S. 2009. Sources of supply chain disruptions, factors that breed vulnerability, and mitigating strategies. *Journal of Marketing Channels*, 16(3): 193-226.

Stevens, G.C. 1989. Integrating the supply chain. *International Journal of Physical Distribution & Materials Management*, 19(8): 3-8.

Ten Hompel, M. & Schmidt, T. 2008. *Warehouse management*. Springer Berlin Heidelberg.

Tjahjono, B., Esplugues, C., Ares, E. & Pelaez, G. 2017. What does Industry 4.0 mean to Supply Chain? *Procedia Manufacturing,* 13: 1175–1182.

Tompkins, J.A., White, J.A., Bozer, Y.A. & Tanchoco, J.M.A. 2010. *Instructor's Manual To Accompany Facilities Planning: Third Edition*. J Wiley

Vahab, A., Naik, M.S., Raikar P.G., Prasad. R. 2019. "Applications of object detection system." *International Research Journal of Engineering and Technology (IRJET) 6, no. 4: 4186-4192*.

Vanpoucke, E., Vereecke, A. & Muylle, S. 2017. Leveraging the impact of supply chain integration through information technology. *International Journal of Operations & Production Management*, 37(4): 510-530.

Wang, Y. & Weyrich, M. 2014. An adaptive image processing system based on incremental learning for industrial applications. *19th IEEE International Conference on Emerging Technologies and Factory Automation*, ETFA 2014.

Want, R. 2004. Enabling ubiquitous sensing with RFID. *Computer*, 37(4): 84-86.

Weyrich, M., Laurowski, M., Klein, P. & Wang, Y. 2011. A Real-time and Vision-based Methodology for processing 3D Objects on a Conveyor Belt. *International Journal of Systems Applications, Engineering & Development,* 5: 561–569.

Williams, M.D., Rana, N.P. & Dwivedi, Y.K. 2015. The unified theory of acceptance and use of technology (UTAUT): A literature review. *Journal of Enterprise Information Management,* 28: 443–448.

Williamson, M. 2018. Keeping Up Standards in Machine Vision. *Quality*, 57(13): 33-35.

Wu, K.J., Tseng, M.L., Chiu, A.S.F. & Lim, M.K. 2017. Achieving competitive advantage through supply chain agility under uncertainty: A novel multi-criteria decision-making structure. *International Journal of Production Economics,* 190: 96–107.

Xu, L., Kamat, V.R. & Menassa, C.C. 2018. Automatic extraction of 1D barcodes from video scans for drone-assisted inventory management in warehousing applications. *International Journal of Logistics Research and Applications,* 21: 243–258.

Zhou, Q., Yang, X. & Bu, L. 2015. Analysis of shape features of flame and interference image in video fire detection. *In 2015 Chinese Automation Congress (CAC),* (November): 633-637.