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The Applicability of Radio Frequency Identification Devices to the New Zealand Army

A thesis presented in partial fulfilment of the requirements for the degree of
Masters in Logistics and Supply Chain Management at
Massey University, New Zealand

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Abstract

The purpose of the study was to examine if the application of Radio Frequency Identification Devices (RFID) to the New Zealand (NZ) Army Supply Chain would increase the efficiency of the supply chain, improve inventory accuracy and reduce the workload on the NZ Army Supply Technicians (SupTech). An effective supply chain is critical to the NZ Army to ensure soldiers have the required items to perform their roles on operations and during training. Failure to get this right can prevent the NZ Army from meeting its Government outputs, and worst case can cost lives.

Due to reduced numbers of trained SupTech, and an increasingly large and complex inventory, the Sup Tech workload has significantly increased in the last ten years. This has resulted in the NZ Army Supply chain not being as effective or efficient as it should be.

New technologies such as RFID could be a way to improve the effectiveness of the supply chain. RFID is an automatic identification technology that uses radio waves to identify and track objects in real time. RFID technology is considered to have great potential to improve the efficiency and accuracy of many processes in the supply chain by providing detailed information on the flow of the products throughout the entire chain.

This thesis conducts a comparative case study of the NZ Army Supply Chain and that of EastPack Ltd, who have recently implemented RFID. Time and cost analysis is conducted on the main units in the NZ Army and interviews are conducted with the top SupTech in these units to gauge the efficiency of the NZ Army supply chain. At EastPack Ltd interviews examine the RFID implementation decisions and results, and process mapping conducted to determine the efficiency of their supply chain.

The results show that the NZ Army processes are time and labour intensive and units do not have sufficient SupTech to meet compliance requirements and provide a good level of support to their customers. EastPack Ltd had similar problems prior to implementation of RFID but since the technology has been in use they have had significant improvements in their inventory accuracy, gained savings in costs and labour and achieved an early ROI from the implementation.

The study finds that while not all of the problems of the NZ Army Supply Chain can be solved by RFID its implementation would significantly reduce the workload on Sup Tech and help with the accuracy of the inventory in the NZ Army supply chain and improve its effectiveness.

Acknowledgements

During the course of my study there are many individuals and organisations that have contributed and made this research possible. I would like to take the opportunity to acknowledge their contribution

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Chapter 1 - Introduction

1.1 Introduction

This chapter presents the context for this research. It starts with a brief background to the research which justifies the need for the research. It also states the aim and objectives of the research, the methodology adopted and the limitations of the research. Lastly, it describes the structure of the thesis.

1.2 Background

The supply chain of the New Zealand Army is unique in that the efficiencies of the supply chain can mean the difference between life and death for soldiers on operations and while training. The ability for soldiers to have the right equipment and supplies available is critical when they are required to make split second decisions in intensely stressful conditions and extreme environments.

As well as looking after the interests of the soldiers, the NZ Army also has a responsibility to the NZ taxpayer to be as efficient as possible while still providing the directed government outputs. The tight economic times, and small size of the NZ Army, make it necessary to ensure its employees are used in the most efficient manner when conducting it's tasks.

Over the last 15 years the NZ Army has gone through many changes which have severely reduced the numbers of Supply Technicians (Sup Tech) available to look after the Army's inventory (Blythen, 2007). The inventory has significantly increased and become more complex. These factors have led to a reduction in the accuracy of the NZ Army inventory, a reduction in service levels and overloading of SupTech (Gardiner, 2009).

Most of the current processes within the NZ Army supply chain require manual data imputing and actions, which result in errors and inefficient use of highly trained soldiers. New technologies have the potential to reduce the inefficiency of the current processes.

One technology that is having a significant impact on supply chains around the world is Radio Frequency Identification Device (RFID). RFID is an automatic identification technology that relies on radio waves to identify, track and manage objects and collect and store data (Angeles, 2005; Kasap et al., 2009). Heinrich (2005) stated that RFID is among the most exciting and fastest-growing technologies in terms of scope of application in the next generation of business intelligence. In the context of supply chain management (SCM), the technology has been considered as ‘‘the next revolution’’ (Srivastava, 2004, p. 1).

Radio frequency identification (RFID) technology is considered to have great potential to improve the efficiency and accuracy of many processes (Angeles, 2005; Dutta, Lee, & Whang, 2007; Cannon, Reyes, Fraxier, & Prater, 2008). It enables the optimisation of supply chain processes by providing detailed information on the flow of products throughout the supply chain (Whittaker, Mithas, & Krishnan, 2007). RFID brings a lot to the supply chain and if deployed properly can yield serious benefits. Like all new technologies however it must be deployed with forethought and careful planning if its benefits are to be realised (Shepard, 2005).

An organisation that has recently implemented RFID in New Zealand is EastPack Ltd. EastPack Ltd is a kiwifruit post-harvest service provider who have successfully implemented RFID into their supply chain with impressive results. These performance results, and implementation assessment, will be compared with an analysis of the NZ Army supply chain current practices to examine the applicability of this technology to the NZ Army.

Little research has been conducted on the applicability of RFID to a military force since 2005 or on non-profit organisations.

1.3 Aim and Objectives

The aim of this research is to investigate the applicability of RFID to the NZ Army supply chain to see if it could improve the efficiency and effectiveness of the supply chain and reduce the workload on the Army's Supply Technicians.

In order to achieve the aim of this research the following objectives are established:

- Objective One. To review existing literature on RFID in Supply Chains.
- Objective Two. To describe the NZ Army Supply Chain.
- Objective Three. To develop a time and cost assessment for three processes in the NZ Army Supply Chain.
- Objective Four. To investigate the use of RFID in a civilian organisation that has recently implemented the technology.
- Objective Five. To evaluate the effect RFID could have on the NZ Army Supply Chain.

1.4 Methodology

This research is inductive and follows the interpretivism philosophy, the ontological belief of pragmatism and the functionalist paradigm. As this research is both descriptive and exploratory the design selected for the research is a comparative case study which will use both qualitative and quantitative research methods including questionnaires, interviews, observation and secondary data from NZ Army databases.

1.5 Outline of Thesis

Chapter One – Introduction.

The purpose of this chapter is to explain why the research is being carried out, outline the aim, objectives and methodology of the research, identifiy the limitations of the research and provide an outline of the thesis.

Chapter Two – Background.

This chapter provides a summary of the organisations being studied. It begins with a summary of the structure of the NZ Army, the NZ Army Supply chain and some recent changes which have affected the supply chain. EastPack Ltd, a company that has recently implemented RFID is then described and their supply chain outlined.

Chapter Three – Literature Review.

In this chapter a thorough review is conducted on literature representing the existing knowledge regarding supply chains and RFID.

Chapter Four – Methodology.

This chapter describes the research methodology used in the study. It includes the research objectives, philosophy, approach, methods and data analysis.

Chapter Five – Results and discussion.

This chapter provides the analysis of the data with emphasis on answering each of the five investigative questions

Chapter Six – Conclusion.

This chapter presents the summary and conclusions of the thesis. It discusses the findings, the conclusions of the research, and the limitations, and provides recommendations for future work.

Chapter 2 - Background

2.1 Introduction

This chapter provides a summary of the organisations being studied. It begins with a summary of the structure of the NZ Army, the NZ Army supply chain and some recent changes which have affected the supply chain. Then EastPack Ltd, a company that has recently implemented RFID, is described and their supply chain outlined.

2.2 NZ Army

2.2.1 Description of Organisation and Aims

The New Zealand Defence Force (NZDF) consists of the Royal New Zealand Navy, the New Zealand Army (NZ Army) and the Royal New Zealand Airforce. The mission for the NZDF is

> To secure New Zealand against external threat, to protect our sovereign interests, including in the Exclusive Economic Zone (EEZ), and to be able to take action to meet likely contingencies in our strategic area of interest. (NZDF Annual Plan 2009, p. 17)

NZDF is responsible to the NZ Government to meet this mission and as part of that the NZ Army has specific roles, largely based around land forces. The mission for the NZ Army is “to provide world-class operationally focused land forces that are led, trained and equipped to win” (NZ Army, 2010).

The NZ Army is made up of 7,434 personnel consisting of 5,003 Regular Force, 1,709 Non-Regular and 722 civilians. It has a budget of $656 million dollars a year which is 32% of NZDF budget (NZDF Annual Plan, 2009). The organisation of the NZ Army is shown in Appendix A.

Within the NZ Army the Royal New Zealand Logistic Regiment (RNZALR) is responsible for all aspects of Logistics. This includes the planning and carrying out the movement and maintenance of force including providing provisions, supplies, maintenance, repairs, transport and movement and sustenance in support of the wider Army in operational and non-operational environments. (NZ Army, 2009).

Logistics is a critical area within the military that has the ability to destroy an operation if done badly, or can significantly aid in the achievement of a mission if done well (ADF, 2003). Logistics plays a significant role in any military action whether the action is part of war, peacekeeping, civil emergencies or a training activity. Logistics is responsible for the force generation, deployment, sustainment, maintenance, redeployment and reconstitution of military forces through these types of military action (ADF, 2003).

Within RNZALR the trade responsible for supply functions in the NZ Army is that of Supply Technicians (Sup Tech). Sup Tech are posted to every major unit in the Army to provide integral support (First Line Support) to those units. They are also posted to Logistics Battalions where they provide higher level support (Second Line Support) and to Logistics Command (Land) which is the organisation that provides through life support and policy advice to the equipment and material needed by the NZ Army. Third and Fourth Line Support (higher level procurement, distribution and warehousing) is conducted by civilian contractors.

2.2.2 Recent Supply Chain Changes

The NZ Army, and all of NZDF, has gone through a number of major changes in their supply chain over the last 15 years. These changes include restructuring, upgrading of information management systems and commercialising.

In December 1996 the Royal New Zealand Corps of Transport, the Royal New Zealand Army Ordnance Corps, and the Royal New Zealand Electrical and Mechanical Engineers were disbanded and amalgamated into the new organisation called the Royal New Zealand Army Logistics Regiment. As part of this amalgamation the trade of Storeman All Arms and the trade of Supplier were combined to a new trade of Supplier/Quartermaster (later renamed Sup Tech). The trade of Storeman All Arms had focused on first line supply within units and the trade of Supplier had focused on second and third line supply at supply depots. This amalgamation of trades created significant losses in expert knowledge and a case of “jack of all trades, master of none” (Diamond, 2009, p. 7).

In 1998 the SAP Enterprise Resource Planning System, supply and finance software modules, were implemented as the new logistics and finance information system. This was a significant upgrade from the old customer-developed systems which had limited capability. The implementation of SAP required a radical change in the way the NZDF conducted business because NZDF processes had to be changed to fit the SAP solutions. Unfortunately the implementation caused problems due to; incomplete and incorrect purification of accounts, transaction based training instead of full process training, skill fade on the complex system, increased time to complete transactions due to multi-screen requirement, move of expense line leading to having to manually account for consumable items and restricting management of MRP to only Logistics Executive (name changed to Army Logistics and now called Logistics Command (Land)) (Diamond, 2009, p. 8).

Around this time the New Zealand Army was under increasing pressure to reduce its costs. The cost accounting system was the primary method of measuring costs and this led to traditional cost cutting activities like reducing labour, inventory and equipment. Labour savings were achieved by civilianising large proportions of logistics areas. Civilians were cheaper and can work longer hours with more consistency as there is no requirement for them to conduct on-going training in basic soldier skills, or to attend trade and promotion courses. The civilianisation of some of these functions did reduce operating expenses but it caused a loss of understanding on the uses of some equipment and the reason for surges in demands. A basic example of this is placing an order for utility cord, which is green due to being used in a camouflaged field environment, and having it delivered in white instead.

The reduction of inventory was achieved in three ways. The first was by simply dropping consumable materials off the SAP inventory management system, coincidentally just when the benefits of the SAP automatic replenishment function was beginning to become effective. While this reduced the visible financial inventory levels it led to an increased workload on personnel as the consumable items then had to be manually managed and ordered. The NZ Army is working through a solution to this which is just waiting funding to make the changes on SAP to be implemented (Gardiner, 2009).

The second method involved a deliberate thinning of inventory at all levels and a move to ‘just in time’ procurement. This method was excellent from the financial perspective but led to significantly increased lead-times as civilian providers struggle with the fluctuating nature of NZ Army demands and worldwide demand for common military items placed the sourcing of these at a premium. An example of the problem with difficulties in sourcing common military items, with no safety stock in reserve, has resulted in delays of up to a year for spare parts for night vision equipment which was in use with our forces deployed overseas (Diamond, 2009). This area is slowly being improved and inventory optimisation, rather than inventory reduction, is starting to be employed.

The third method was outsourcing the acquisition and warehousing aspects for some items, such as clothing, and the use of contracted suppliers for other items like consumables. In 2000 a new contract eliminated the need for stationery stores in the Army by providing personnel the capability to order items electronically, though unlike the other services, Army still limited access to this capability to Sup Tech. Supplies were delivered directly from the vendor to the customer within 48 hours and Army warehouses removed stationary from their inventory.

In 2001, the management, development, and manufacture of NZDF clothing was outsourced to a prime vendor contractor, Yakka Apparel Solutions. The contractor procures, manages, warehouses, and distributes apparel, footwear, and personal support items used by NZDF service personnel. The contractor's IT system is linked to the NZDF SAP system, which enables NZDF personnel to order on line. All orders, invoices, and payments are managed electronically. The contractor, Yakka Apparel Solutions, won a 2001 New Zealand Logistics Excellence Award for its NZDF contract. By outsourcing this function, the NZDF realized a significant initial saving with the closure of the defence uniform stores and removal of clothing from inventories. (Woon, 2004).

In September 2002, the NZDF signed a contract with a prime vendor to deliver consumable items directly to the customer. Consumable items are defined as nonspecific military materials purchased to meet both non-stock and stock requirements. The reductions in personnel and inventories resulting from contracting with a prime vendor for consumable items and the attendant use of electronic procurement accrued significant savings for the NZDF. (Woon, 2004).

This outsourcing and third party contracting reduced the cost of inventory held, but the price of procuring material through these providers is steadily increasing and the contractors occasionally struggle with the fluctuating nature of demands causing stock unavailability and long lead times (Diamond, 2007; Blythen, 2007).

In 1998 Base Supply Battalion was closed and the function of third and fourth line supply for the Army contracted to a civilian provider. The same happened in 1998 when 4th Logistics Battalion was closed and replaced with a civilian provider. These closures reduced the opportunity for SupTech to gain skills in the areas of "purchasing, inventory management, MRP, batch management, bulk supply management and vendor management" (Diamond, 2009, p. 8). These are all skills that, while not required in NZ, are essential on operations where it is too dangerous, or the environment is too extreme, for civilians to be deployed.

The increasing use of civilian logistics best practices without regard for the unique requirements of the military has led to degraded service to the customers who are soldiers training or on operations. The Army is “still adjusting to try to find the optimal inventory solutions” (Diamond, 2009, p. 8).

Over the last 15 years the Army has gone through a major modernization. This has resulted in inventories that are more complex, more expensive and are significantly larger than before. The increasing use of civilian outsourcing, unit closures, cost reduction measures have all had a significant impact on the workload of SupTech and the inventory management procedures used in the Army.

2.2.3 Reducing Staff and Increased Workload

A report published by Headquarters Logistics Executive in 2007 (Blythen, 2007) found that there was a gradual but continual degradation of the Supply/Quartermaster function within the NZ Army and that was causing increasing concern and risk. It stated that Units felt they were carrying excessive risk in training, operations and account integrity due to inadequate Sup Tech support, while Sup Tech personnel were being overwhelmed and demoralised by the demands of their role (Blythen, 2007). While some action has been taken since this report, such as increased pay, many of the issues still exist. Factors noted in the report as contributing to the concern included:

- Shortages of qualified personnel within already ‘hollow’ units
- Logistic unit establishments that have not been amended or staffed to reflect changes in unit roles, directed outputs and equipment holdings.
- A lack of appropriate experience and skills in key SupQM (now called SupTech) appointments and roles
- Out-dated logistic processes and systems
- The paucity of technology needed to streamline logistic operations and
- A marked increase in the SupQM burden caused by the increased operation and training temp, accountability and reporting requirements, and growing materiel dependencies.

Current establishments of logistic support elements are out-dated. They are based on light infantry oriented dependencies and do not reflect the numbers, ranks and skill-sets now required to deliver effective logistic support to directed outputs (Gardiner, 2009). In addition the Army Transformation Plan has increased the establishments of combat units without a commensurate increase in their integral support personnel or the supporting logistics units.

There has been a steady decline in the number of established and staffed SupTech posts across the Army over the last 13 years. From the amalgamation of the Storemen and Supplier trades 1996 through to 2007 there was “an 18% reduction in established SupQM posts and a 46% reduction in actual SupQM staffing. This translates to a significant drop in ‘manning on the ground’, a reduction from 88% of SupQM posts staffed in 1996 to 68% staffed in 2001, and finally to only 58% staffed in 2007” (Blythen, 2007,p. 2).

As at July 2010 there were 335 SupTech posts in the NZ Army. Of these only 242 (72%) are filled by qualified SupTech with an additional 29 positions being temporarily filled by civilians. In many of these posts soldiers of a lower rank are filling in higher posts with only 52% of posts being filled by personnel of the correct rank and qualification. The numbers of trainee SupTech has been increasing over the last two years but there are still major issues in supervision with only 45%% of the Corporal (CPL) posts and only 44% of the Sergeant (SGT) posts actually being staffed by qualified CPL or SGT (WO1 Burton, 2010). Table 2.1 shows the reduction in SupTech staffing over the last 13 years.

Table 2.1. Supply Technician Staffing Levels

Aspect	Date				Overall Change (qty)	Overall Change (%)
	30 Jun 97	30 Jun 01	30 Jun 07	1 Jul 10		
SupTech as % of Army						
Army Strength	3686	3842	3774	5003	+1317	+36%
Sup Tech Strength[1, 2]	380	259	206	242	-138	-36%
SupTech % in Army	10%	7%	5%	5%		
Estb vs Manned Posts						
Established Sup Tech Posts	434	383	355	335	-99	-23%
Manned SupTech Posts [2]	380	259	206	242	-138	-36%
% of Posts Manned	88%	68%	58%	72%		

1. SupTech currently filling SupTech posts, not including SupTech filling non trade posts such as instructors.

2. Not including personnel under training

Concurrently the NZ army has undergone a rapid and substantial increase in the size, value and accountability of its material as a result of the modernisation program. Since 2000 the number of assets requiring monthly checks has almost tripled “from 1106 in 2000 to 3035 in 2007” (Blythen, 2007, p. 2). The total number of inventory lines has increased by 60% and the value of this inventory has increased by 350% (Stewart, 2009). The greater security and accounting requirements of controlled cryptographic items and sensitive defence articles have greatly increased the checks and audits required at various levels. Many of these checks have fallen on SupTech to fulfil.

In addition to the increased dependency and reduced numbers of SupTech is the increase in operational deployments. This has had a significant impact on SupTech, not only to provide SupTech support on the deployments, but also in support of Pre Deployment Training (PDT) activities. This requires support to increased numbers of personnel conducting intensive training with complex equipment and is an on-going commitment. A PDT support cell was raised, removing qualified SupTech from units, but it is insufficient to provide appropriate support and the Logistic Battalions are required to provide supplementation on an on-going basis. There has been no increase in overall SupTech numbers to cope with this additional workload.

Despite significant automation and the introduction of corporate logistic systems across the Army, there has not been a commensurate reduction in workload or increase in efficiencies for SupTech personnel. This is mainly attributed to the fact that “the systems are providing greater visibility at strategic management level but there is little change at the tactical input level other than replacing pencils and cards with keyboards” (Blythen, 2007, p. 7). In some cases, automation has increased the demands on unit staff through greater data capture requirements.

2.2.4 Current Use of Technology

The NZ Army uses SAP as its Enterprise Resource Planning (ERP) Information Technology solution. The majority of the system is SAP civilian off the shelf specifications and the remainder is modified to make the system fit NZDF requirements. This system was implemented when the logistic focus of the New Zealand Defence Force shifted “from managing inventories to managing information across the logistic continuum; from managing supplies to managing suppliers and from buying inventory to buying response time” (NZDF, 2004, p. 3). The intent was for an electronic commerce system that would allow on line ordering and payments, decreasing the human involvement in transactional activities (NZDF, 2004).

The NZDF has been using SAP software for financials since July 1996, SAP software for logistics since July 1998, SAP software for plant maintenance since December 1999, and SAP software for electronic mail and electronic procurement of clothing since 2000. The NZDF added SAP Enterprise Buyer (SAP EB), a component found in the mySAP® Supplier Relationship Management (SRM) solution, in December 2002 to enable users to purchase stationery and furniture from Corporate Express, and it subsequently expanded its SAP EB catalogues to include Yakka Apparel Systems Ltd. (YASL) for clothing and Blackwoods for consumables (SAP, 2005).

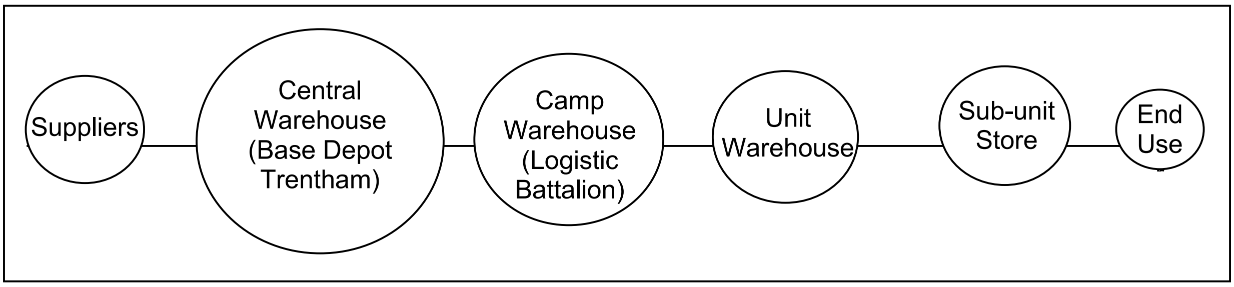
From August to October 2009, the NZ Army introduced SAP Barcode Receipting into the army. This implementation was one of the many initiatives to increase account accuracy and reduce the time associated with conducting receipts (Rennie, 2009). Unfortunately due to software integration issues the introduction was not successful and as at July 2010 very few units were using the functionality.

2.2.5 Current Supply Chain

Generic Military Supply Chains comprise of "lots of small steps in a long interrelated and highly complex chain of activity that occurs across time to meet a particular outcome. Originating in the civilian economy, resources pass through the various echelons of command and control by a series of network logistic systems, functions and processes" (ADF, 2003, p. 2.8).

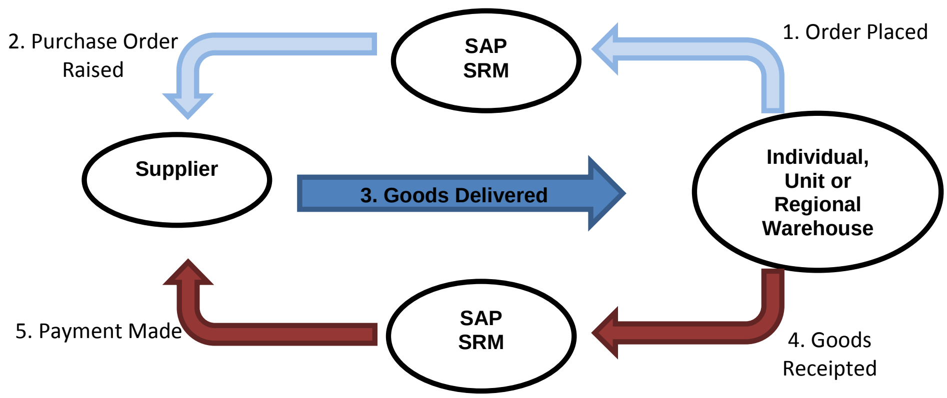
The supply chain for the New Zealand Army follows this generic trend, with a greater emphasis on 'ready for use' civilian provided material than in larger armies, due to our small size and limited resources. The New Zealand Army supply chain has traditionally been a very structured process where, once procured into the army from civilian or other countries militaries, material progresses on a pull system from one central warehouse to regional warehouses, unit warehouses, sub unit warehouses and then the end user as shown in Figure 2.2. This system is still used in the New Zealand Army for military specific items as shown in Appendix B.

Figure 2.1. Supply Chain for the NZ Army Military Specific Items



The non-military specific supply chain, as shown in general in Figure 2.3 and in detail in Appendix B, is a flatter structure that has taken all the internal steps out of the chain. Non-military specific items are all commercially readily available and the New Zealand Defence Force has established contracts with Corporate Express (for Stationary), Blackwoods (for general and trade consumables), and Yakka Apparel Solutions (for clothing). Through SAP SRM purchase orders are placed by individuals, or units directly on to the suppliers. The invoices are automatically paid on receipt of the goods and the goods are delivered directly to the individual's workplace by the supplier.

Figure 2.2. Non Military Specific Supply Chain



If an item is required that is supplied from a non-contracted vendor the unit can place a special purchase order through SAP onto a recognised vendor and have the goods delivered directly to the unit.

The final part of the chain is the reverse logistics chain shown in Appendix C. This chain is generally only used for military specific items as non-military specific items are generally disposed of once used, or sent directly from the unit to a civilian repair agency using SAP purchase orders. Military specific items are sent back to first line workshops, which have limited capability. If these workshops cannot repair the items are sent to more capable workshops and eventually to the civilian contracted fourth line Base Workshop in Trentham for repair. At any stage if an item is deemed beyond repair it will be disposed of according to Army policy for the item type.

2.2.6 NZ Army Logistics Change Program

In February 2009 the Chief of Army directed Commander Logistics (Land) to "transform Army's logistics people, processes and systems so that they are shaped for and relevant to the future" (Gardiner, 2009, p.3). In his report Gardiner made the following comment:

> Since the late 1990s, Army has unwittingly implemented a series of changes which have together had the unintended consequence of fracturing Army's logistics. The overall performance of Army logistics is sub-optimal and some practices are out-dated and untrusted. There are significant capability gaps and weaknesses in corporate logistic skills and process design and management. Army logistics is unsustainable in the longer term. (Gardiner, 2009, p. 4)

In the Army Logistics Transformation Plan (ALTP) deliverables are summarised by the statement "simpler…smarter….better" (Gardiner, 2009, p.3).

Commander Logistics (Land) Colonel Charles Lott said that "The ALTP is a synchronised and coherent programme of work designed to ensure that Army Logistics is shaped for, and relevant to, the future" (Lott, 2010, p. 3). Since the start of the program Logistics Command (Land) has been "simplifying and automating logistics with deliverables like barcoding, automation of materials planning within SAP, shifting the control of Army valuated inventory Logistics Command (Land), reshaping logistics command and control to allow end-to-end management and improving materiel visibility" (Lott, 2010, p. 3). One of the streams of ALTP is the investigation into the use of RFID (Gardiner, 2009).

2.3 EastPack Ltd

2.3.1 New Zealand Kiwifruit Industry

New Zealand Kiwifruit holds 30% of the world market share and is sold to over 55 countries around the world (Zespri, 2010a). The largest markets are in Asia, Europe and the United States. In the year to November 2009, kiwifruit exports amounted to 64.4% of all NZ fruit and nut exports and 45.7% of all horticultural exports from New Zealand. In the 2009/2010 season 380,000 tons of premium quality kiwifruit was sold overseas (Zespri, 2010b).

NZ is unique in that it has a single entity responsible for the marketing and distribution of NZ Kiwifruit and this is the reason that NZ maintains such a dominant position in the world market. In 1988 New Zealand Kiwifruit growers banded together and requested that the New Zealand Government create a single point of entry for exporting New Zealand Kiwifruit. The Kiwifruit Industry Restructuring Act 1999 created the New Zealand Kiwifruit Marketing Board (NZKMB) which in turn became Zespri International Limited in 1997.
Zespri International Limited is a corporatised cooperative and is the sole exporter of New Zealand Kiwifruit outside of New Zealand and Australia. Zespri is owned by current or past kiwifruit producers in New Zealand ensuring constant accountability to more than 2700 growers (Zespri, 2010a).

Zespri International Limited is the world's largest marketer of kiwifruit. The Zespri brand is now firmly established internationally and is known to stand for high quality, good taste, effective promotions and packaging and the well organised and transparent Zespri system for purchasing and distribution (Zespri, 2010a). The statutory framework for the governance and regulatory oversight of Zespri's operations help to "ensure that the New Zealand kiwifruit industry continues to lead the world in kiwifruit innovation, production and supply" (Zespri, 2010a, para 2).

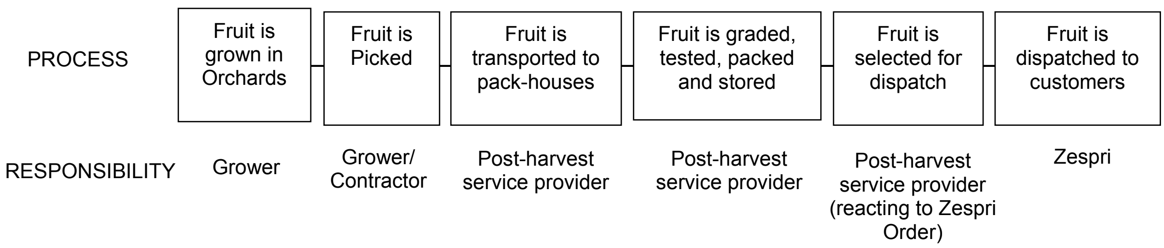
Despite a depressed world market with other fruit suppliers witnessing a collapse in returns, Zespri achieved excellent results for NZ Gold and held the line on NZ

Green kiwifruit against Chilean competitors who received very low wholesale returns. New Zealand with Zespri as the sole marketer was able to increase promotional spend to prompt sales of healthy volumes at good prices, even in markets where consumer spending was down. This would be impossible to achieve if NZ had multi exporters competing in these markets (EastPack Ltd, 2009a).

2.3.2 NZ Kiwifruit Supply Chain

The basic supply chain for NZ Kiwifruit includes Growers, Pack-houses, Coolstores, Suppliers, Transport and Shipping. Throughout the supply chain the kiwifruit is stored and shipped in temperatures that ensure its firmness, safety and taste. The process is summarised in Figure 2.4 below.

Figure 2.3. Kiwifruit Industry Supply



Growers are responsible for the development and growth of the kiwifruit. They either; harvest themselves, contract harvesters or let post-harvest service providers organise the picking of the fruit.

Once ZESPRI® Kiwifruit has been harvested, it is transported to pack-houses and coolstores which are generally post-harvest service providers such as Seeka and EastPack Ltd. Here the fruit is randomly tested by the Ministry of Agriculture. About 10 per cent of harvested crops are reject fruit, most of which is used in fruit beverages or stock feed. The other 90 per cent of Kiwifruit is held in environmentally-friendly coolstores until it is shipped all over the world (Zespri, 2010b).

Zespri conduct marketing and receive orders from around the world. These orders are passed on to the pack-houses, selected and loaded onto trucks for on movement. Every year ZESPRI exports tens of millions of trays of ZESPRI® Kiwifruit out to its markets on ships. 80% goes out on charter vessels - to the main markets of Japan, Asia and Europe. The other 20% goes in container vessels. Kiwifruit not up to export grade is shipped around NZ to Supermarkets and fruit stores for local consumption (Zespri, 2010b).

2.3.3 EastPack Ltd

EastPack Ltd is a Kiwifruit post-harvest service provider that represents 27% of NZ kiwifruit exports. It is the second largest Kiwifruit entity in NZ after Seeka and is the biggest Zespri™ Gold (yellow kiwifruit) post-harvest service provider (EastPack Ltd, 2009a). EastPack Ltd is a 25 year old grower-owned company in which only staff and kiwifruit growers supplying fruit can hold shares. It has a reputation for consistently delivering one of the highest orchard gate returns (OGR) in the industry and has lead the way in transforming their supply chain through the use of Lean Manufacturing principles and the application of RFID (EastPack Ltd, 2009b).

The vision of EastPack Ltd is ‘world class orchard to market’ with the objectives being, operational excellence, sustainable future, excellent customer service and leading financial performance (EastPack Ltd, 2009a).

EastPack Ltd offers a wide range of post-harvest services to its growers such as packing, cool-storage, technical development, management, leasing and financial services. EastPack Ltd grades, packs, stores and dispatches Zespri™ Green, Zespri™ Gold and organic green kiwifruit. The organisation has technical teams which assist growers in managing high performing orchards to help deliver strong orchard gate returns. With access to up to date scientific, research and trial information they focus on translating this technical information into practical and financially sustainable outcomes for its growers. Approved laboratories on all sites conduct maturity testing free for all growers as well as brix testing, dry matter, size, gold flesh colour and reject rate analysis for the use of growers, harvest planners and inventory managers (EastPack Ltd, 2009a).

2.3.3.1 History of EastPack Ltd

EastPack Ltd was formerly known as Rangitikei Fruit Packers Ltd which in 1983 began as a co-operative grower supply system for 23 shareholders. It purchased land in Edgecumbe and started to develop the site into what is now the head office of EastPack Ltd. In its first season it packed 60 000 trays. Over the next decade the business grew steadily with continual investment in infrastructure such as coolstores and the latest fruit sizing machines (EastPack Ltd, 2009a).

In 1996 Rangitikei Fruit Packers Ltd completed the purchase of Opotiki Cooperative which increased its throughput to approximately 3 million trays. In 1997 the companies name was changed to EastPack Limited. With a view to further expansion in 2000 EastPack purchased Zest Company, a Te Puke based packing and Cool-storage operation with clients in Te Puke, Tauranga, Waikato and the Hawkes Bay. These new customers were integrated into the shareholder system and production increased to 6.6 million trays for the 2001 season. This increase in production led to developing a $20 million purpose built pack-house and cool-storage facility in Te Puke (EastPack Ltd, 2009a).

2.3.3.2 EastPack Ltd Current Operations

Today EastPack is supplied by 436 orchards from Coromandel, Tauranga, Katikati, Te Puke, Whakatane/Edgecumbe, Opotiki, Waikato and the Hawkes Bay. It processes 16.1 million trays of kiwifruit for export consisting of 10 million Zespri Green and 6 million trays of Zespri Gold. These trays are processed at the company’s three post-harvest sites in Edgecumbe, Opotiki and Te Puke. (EastPack, 2009a) The capacities at these sites are shown in Table 2.2.

Table 2.2. EastPack Ltd Site Capacities

	Te Puke	Opotiki	Edgecumbe
Coolstorage Capacity – Conventional	4.05 mil trays (16, 20 plt) on site. 1.95 mil trays (4,377 plt) off site	1.3 mil trays (5,200 plt) on site	2.44 mil trays (9,700 plt)
Coolstorage Capacity – Controlled Environment	1.95 m trays (28,800 bins) on site	1.1 mil trays (16,000 bins) on site	850,000 trays (12,140 bins)
Packed in 2009 – Green	4.77 mil trays	2.55 mil trays	3.29 mil trays
Packed in 2009 - Gold	4.38 mil trays	1.2 mil trays	51,000 trays
Coolstores and Canopies	21,000m^2		
Controlled Atmosphere Coolstores and Canopies	6,000m^2		
Packhouse and Canopies	11,000m^2		
Permanent Personnel	60		
Seasonal Personnel	400 per shift		
Shifts	2 x 10.5 hr shifts per day, 7 days a week		

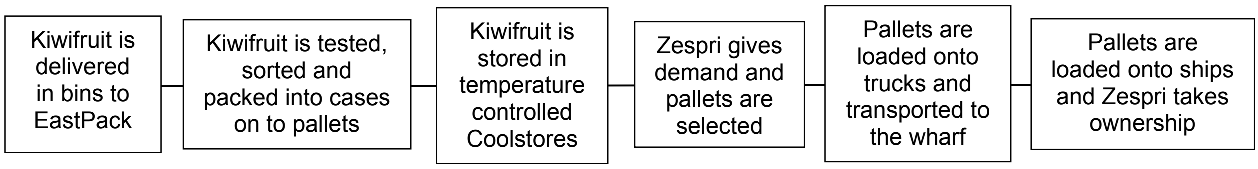
Despite some setbacks such as the 1992 Kiwifruit market crash and 2009 hail event EastPack has continued to grow. Total NZ crop volumes have increased 61% from 62 million trays to 101 million trays since 2000. EastPack Ltd's rate of growth has been 160%, which has been organic growth without any volume contribution from mergers or acquisitions (EastPack Ltd, 2009b).

2.3.3.3 EastPack Supply Chain

From late March, EastPack receives the freshly-picked kiwifruit. The fruit is sorted, packed and stored in temperature controlled cool-houses. In response to Zespri orders, the fruit is then selected and loaded onto trucks for distribution by Zespri.

Throughout this time the ownership of the fruit remains with the growers, but in the custody of pack house operators, until physically stowed on the ship, from which point ZESPRI takes ownership. A summary of the EastPack supply chain is in Figure 2.5 below.

Figure 2.4. EastPack Ltd Supply Chain



Chapter 3 - Literature Review

3.1 Introduction

This chapter conducts a literature review of supply chains and RFID. A literature review is a systematic, explicit and reproducible design for identifying, evaluating and interpreting the existing body of recorded documents (Fink 1998).

This review will begin with an examination of the development of supply chains and the definition of the concept. It looks at the problems and advantages of supply chain management (SCM), reviews some performance measures and looks at SCM in the military context. It then examines the development of RFID and provides a detailed description of the technology. It looks at the advantages and limitations of RFID, the applications, implementation considerations and the application of RFID in a military context.

3.2 Supply Chains

3.2.1 Introduction

In recent years SCM has become more and more important in the business administration field due to the increasing competitiveness introduced by market globalisation. The concept of SCM, according to Thomas and Griffin (1996) represents the most advanced state in the evolutionary development of purchasing, procurement and other supply chain activities. At the operational level, this brings together functions that are as old as commerce itself such as seeking goods, buying them, storing them and distributing them. At the strategic level, SCM is a relatively new and rapidly expanding discipline that is transforming the way that manufacturing and non-manufacturing operations meet the needs of their customers (Gunasekaran, Patel & McGaughey, 2004). Managing the SC has become a way of improving competitiveness by reducing uncertainty and enhancing customer service (Chandra & Kumar, 2000). The increased popularity of the subject is shown by significant increases in academic and practitioner publications, university courses, conferences and professional development programs in the field (Burgess, Singh, & Koroglu, 2006). Mentzer, DeWitt, Keebler, and Min (2001) commented on this when they said that SCM has become such a "hot topic" that it is difficult to pick up a periodical in manufacturing, distribution, marketing, customer management or transportation without seeing an article about SCM or SCM related topics.

3.2.2 History

The concept of SCM first appeared in the literature in the 1980s but the fundamental assumptions on which SCM rests are significantly older (Cooper, Lambert & Pagh, 1997). They include logistics, inter-organisational management, systems integration and more recently sharing of information on inventory. While logistics has been around since the first time humans sold or exchanged excess goods the formal concept is a relatively recent one that was originally defined and developed by the military. After WW2 logistics became a subject for academic and practical study. Around this time studies began in many other areas that contributed to SCM

In the 1940s and 1950s the Total Cost Perspective approach to distribution and logistics was developed (Heckert & Miner, 1940; Lewis, 1956). This approach showed that focusing on a single element in the chain cannot assure the effectiveness of the whole system.

The decade from 1950 to 1960 was the period of fundamental research in economics, operational research, business logistics and distribution channel dynamics. Alderson and Green (1964) discussed the presence of conflict and cooperation among channel members, the emphasis on long-term commitment in channel selection. Their work emphasised the importance of companies looking outside their own business operations to gain long-term partners. In the late 50s intensive analytical inventory management research was conducted (Karlin & Scraf, 1958; Hansmann, 1959). Also during this period Forrester (1961) began studying supply pipelines and channel interrelationships between suppliers and customers. He identified a phenomenon that later came to be known as the bullwhip effect. Forrester noticed that inventories in a company's pipeline (i.e. supply chain) tend to fluctuate the further they are from the ultimate end user. Blanchard (2003) believes that Supply Chain management as a discipline basically evolved out of Forrester's quest to understand and ultimately control these "increases in demand" fluctuations.

The next twenty years from 1960 to 1982 was a period where the previous research findings were integrated and applied to the distribution channel. In the late 1960s Bowersox (1969) contributed to the field of business logistics by research into integrated physical distribution. He was able to demonstrate a need for system integration into the total distribution channel. Bowersox described the state of research in marketing, physical distribution and system analysis and stressed the importance of the quality of comprehensiveness of physical distribution research efforts (Bowersox, 1969). Heskett (1977) stated that logistics is essential to strategy for different sized businesses with different goals.

The period from 1982 to 1997 was characterised by the strategic focus and the continued integration of research findings. In 1982 Oliver and Webber introduced the term SCM. Oliver and Webber (1982) published an article entitled *Supply Chain Management: Logistics Catches up with Strategy*, in which the term Supply Chain Management was used for the first time. The term was used with reference to management techniques which sought to reduce the stocks held in companies of the same supply chain, linked by customer-supplier relationships (Romano, 2003). Oliver and Webber (1982, p. 67) defined SCM as occurring "when an integrated systems strategy that reduces the level of vulnerability is developed and implemented." They described the fundamentals of supply chain management as follows:

- The supply chain is viewed as a single entity, not fragmented areas of responsibility for functional areas such as purchasing, manufacturing, distribution, etc.

- A direct consequence of the first statement is that supply chain management calls for, and depends upon, strategic decision making.
- Supply chain management includes a different perspective on inventories, which are used as a balancing mechanism of last, not first, resort.
- Supply chain management requires a new perspective on systems. Organisations must be integrated, not simply interfaced.

In 1985, Harvard professor Michael Porter's influential book Competitive Advantage (Porter 1985) illustrated how a company could become more profitable by strategically analysing the five primary processes on which the supply chain framework is built, though he used the term value chain rather than supply chain. Like Forrester before him, Porter saw that companies could significantly improve their operations by focussing on interrelationships among business units. Lee and Billington (1993) conducted research into decentralised supply chains and noted that organisational barriers may restrict information flows and constrain the complete centralised control of material flows in a supply chain.

From the late 1990s until today has been the period of SCM growth. The SCM concept was quickly adopted by researchers and practitioners after 1990. For example 189 articles were published in The International Journal of Logistics Management during the period 1990-2001. More than 22% of the articles were related to SCM. Supply Chain Management Review was founded in 1997. From its foundation, until 2005 it published more than 400 articles (Norina, 2004).

Despite the increase of SCM literature there is still confusion about the difference between SCM and logistics. In 1998 the Council of Supply Chain Management Professionals (CSCMP) realised the need to better distinguish logistics from SCM and produced this definition to clarify the difference:

> Logistics is that part of the supply chain process that plans, implements, and controls the efficient flow and storage of goods, services, and related

> information from the point of origin to point of consumption in order to meet consumers' requirements. (CSCMP, 2005, p. 54)

Thus, the CSCMP differentiated logistics as only one function or component contained underneath the umbrella of SCM. In 2006 the Council of Logistics Management (CLM, 2006, p. 54) confirmed this when they defined logistics as:

> That part of the supply chain process that plans, implements, and controls the efficient flow and storage of goods, services, and related information from the point of origin to the point of consumption in order to meet customers' requirements. (CSCMP, 2006, p. 54)

From these definitions it is clear that Logistics management and SCM are similar in that they are concerned with the management of resources from their source to customer. The difference is in the scope of activities that are included, the differences in what source of customer is being considered and the number of organisations involved (Stock & Boyer, 2009).

While logistics is focused on activities from the source to the customer this commonly only looks at the organisation's source to the organisation's customer. SCM looks at the original source into the entire supply chain through to the end customer. This includes all the intermediate organisation sources and customers.

Logistics activities only cover the part of the supply chain process that plans, implements, and controls the flow and storage of goods, services, and related information (Stock & Lambert, 2002). In contrast SCM covers all activities that contribute to providing value and customer satisfaction. These activities include all of the logistics activities as well as the coordination of processes and activities with and across marketing, sales, product design, finance and information technology (CLM, 2006). CLM (2006) also say that SCM is an integrating function with primary responsibility for linking major business functions and business processes within and across companies into a cohesive and high-performing business model.

3.2.3 Definition

Despite the popularity of the subject, Hallsorsson & Arlbjørn (2005) believes that the concept of supply chain management is not particularly well-understood. Many authors such as Croom, Romano and Giannakis (2000) and Cooper et al. (1997) have highlighted the necessity for a clear definition and conceptual framework for supply chain management. This problem has not progressed since 1969 when Bowersox (1969) stated that as with any emerging field, physical distribution currently suffers from a lack of standardised definitions and vocabulary. He claimed that the overall field would gain significantly from a clear definition of subject matter and issues. Mentzer et al. (2001) have also highlighted that the lack of clear definition could inhibit SCM theoretical development.

The aim of a definition is to “provide a precise statement of the essential nature of a thing; a statement or form of words by which anything is defined” (Oxford English Dictionary 2nd Ed, 1989). A definition of SCM should provide clarity regarding what SCM is, and what it is not. A clear definition of SCM is imperative for understanding the concept, achieving acceptance of key elemental functions, and applying SCM in practice and research (Gibson, Mentzer & Cook, 2005). The definition must be appropriate for the marketplace as well as for academics (Gibson et al., 2005). Supply chain management covers such a broad range of ideas that it can be approached from many different angles such as: purchasing and supply, operations management, relationship management, logistics and transportation, industrial organisation, marketing, or strategic management to name a few (Croom et al., 2000). This broad concept is also the main reason why it still lacks a unitary and a widely accepted definition (Cigolini, Cozzi & Perona, 2004).

There is disagreement in even the essential elements of SCM that must be covered in the definition. Gibson et al. (2005) states that the essential elements of SCM are the integration of multiple firms, multiple business activities, and the coordination of those activities across functions and across firms in the supply chain. The multiple firms include all organisations that are involved in the creation and delivery of goods or services to the end customers. The multiple business activities include all the functions of marketing, sales, research and development, forecasting, production, procurement, logistics, information technology, finance, and customer service management (Gibson et al., 2005). Another essential element is the objective of why the supply chain is managed which is to add value and satisfy the customer.

Mentzer et al. (2001) summarised the essential elements by proposing that supply chain management has the following characteristics; first a systems approach to viewing the supply chain as a whole, and to managing the total flow of goods inventory from the supplier to the ultimate customer; second a strategic orientation toward cooperative effort to synchronize and converge intra-firm and inter-firm operational and strategic capabilities into a unified whole; and thirdly a customer focus to create unique and individualized sources of customer value, leading to customer satisfaction. Mentzer et al., (2001) later simplify this to say that the essential elements of SCM include coordination and integration, cooperation among chain members and the movement of materials to the final customer.

Stock & Boyer (2009) conducted an analysis of 173 unique definitions of SCM identified from published sources from 1996 to 2008. They found that some definitions concentrate on supply chain participants and activities while others place emphasis on material flows and inter-organisational collaboration. Some authors include final consumers in their definitions while others exclude them. In early definitions, the term SCM was used, or perhaps misused, synonymously with traditional definitions of logistics management. However, the consensus today seems to be that SCM is somewhat more than logistics (Johnson & Wood, 1996; Lambert, Cooper & Pagh, 1998; Lambert, Stock & Ellram, 1998). As a result of Stock & Boyer's (2009) qualitative analysis of the 173 definitions they identified three major themes of SCM which were; activities, benefits, constituents/components. Within each theme, six sub-themes were identified including material/physical, services, finances and information flows, networks of relationships (both internal and external), value creation, creates efficiencies, customer satisfaction and constituents or component parts.

After examining the contributions of Gibson et al. (2005), Mentzer et al., (2001) and Stock & Boyer (2009) the key elements of SCM that will be used in this examination of the literature on SCM are customer satisfaction, integration of processes, flows of material and information, networks of relationships and value adding. Many definitions contain parts of these essential elements but most fail to cover all the key aspects of SCM.

3.2.3.1 Customer Focus

Handfield and Nichols (1999, p. 2) are the most direct in their focus on customer focus. They said that "The focus of a successful supply chain is on the value the chain may create for customers". Chopra and Meindl (2007) also focus heavily on the customer in their definition which is as follows:

> A supply chain consists of all parties involved, directly or indirectly, in fulfilling a customer request. The supply chain not only includes the manufacturer and suppliers, but also transporters, warehouses, retailers and customers themselves … the customer is an integral part of the supply chain. The primary purpose for the existence of any supply chain is to satisfy customer needs. (Chopra & Meindl, 2007, p. 4)

Mowat and Collins (2000) claim that understanding and meeting consumer needs is of paramount importance in SCM. According to Kuei, Christian and Lin (2001), SCM practitioners must maintain and sustain a customer-driven culture. Taylor (1997) also argues that the most basic purpose of SCM is conforming to customer requirements.

Van der Vorst and Beulens's (2002) definition still focuses on customer satisfaction but also provides a wider view and starts to consider other areas as it covers the integration of processes required in SCM. Their definition is that "Supply chain management is the integrated planning, co-ordination and control of business processes and activities in the supply chain to deliver superior consumer value at minimum cost to the end-consumer while satisfying requirements of other stakeholders" (p 413).

3.2.3.2 Integration of Processes

Stock & Lambert's (2002) definition focuses on SCM as an integration of processes. Their definition is that "SCM is the integration of key business processes from end user through original suppliers that provide products, services, and information that add value for customers and other stakeholders" (p. 54). This definition also covers many of the other elements involved in SCM, such as adding value and consideration of customers but the use of the word 'original' could cause misinterpretation on who is involved.

The next definition from Gibson et al. (2005) continues to emphasise the integration of processes. Their definition is that:

> SCM emphasises the planning and management of all activities involved in sourcing and procurement, conversion, and all logistic management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence SCM integrates supply and demand management within and across companies. (Gibson et al., 2005, p. 5)

This definition does not cover all the processes involved in SCM but does consider which parties are involved. The main drawback with this definition is that it does not say what the end result of SCM is, or discuss the flows of material or information.

3.2.3.3 Flow

Chopra and Meindl (2007) discuss flows when they define SCM as "the management of the flows between and among supply chain stages to maximize total supply chain profitability" (p. 6). The concern with this definition is that it does not give enough details on what type of flows are being managed and does not make it clear on who is involved in the process.

Jones and Riley (1985, p.69) define SCM as "an integrative approach to dealing with the planning and control of the materials flow from suppliers to end-users." While this definition does look at integration and flow it is a very narrow approach in that it does not consider information flows and the flow is only considered one way. According to Stock, Boyer & Harmon (2009) the vast majority of definitions identify flow only as a one-way process. Either material flows one-way from the supplier to consumer, or information flows one-way from the consumer to supplier (Stevens, 1989; Towill, Childerhouse, & Disney, 2000). However, a few authors recognized that material and information travel in two-way flows both up and down the supply chain.

A definition which provides a more detailed description of flows, including the flow in multiple directions, is the one from Mentzer et al., (2001, p.3) which states that "Supply chains are a set of three or more entities (organisations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer." This definition also starts to consider the relationship between the entities in the Supply Chain.

3.2.3.4 Networks

Establishing networks of relationships between interrelated and interdependent organisations, as well as across business units is a key element of SCM. Definitions citing the network of relationships as a key aspect of SCM refer to those relationships as either external to the organisation, internal across business units, or a combination of both (Chandra & Kumar 2000; Morgan & Hunt 1994). SCM has also been described as "the management of the interface relationships among key stakeholders and enterprise functions" (Walters & Lancaster 2000, p.160) and the coordination within and between various supply chain members.
Elmuti (2002) offered the following definition which emphasises the networks of relationships in SCM.

> Supply chain management works to bring the supplier, the distributor, and the customer into one cohesive process... The suppliers and distributors that were once adversaries are now becoming partners for the betterment of both corporations. Managing the chain of events in this process is called SCM. Effective management must take into account coordinating all the different pieces of this chain as quickly as possible without losing any of the quality or customer satisfaction, while still keeping costs down. (p. 49)

Mentzer et al. (2001) also placed heavy emphasis on relationships when they attempted to propose a definition that was broad, not confined to any specific discipline area and adequately reflecting the breadth of issues that are usually covered under the term.

> Supply chain management is defined as the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole. (Mentzer et al., 2001, p. 18)

While this definition does cover the interaction of involved organisations and the end state it is lacking in any detail of the actual function of a supply chain.

Other definitions that solely focus on the networking of relationships are Bowersox, Closs and Cooper (2002, p. 5) who say that the “supply chain (sometimes called the value chain or demand chain) management consists of companies collaborating to leverage strategic positioning and to improve operating efficiency”, and Benton and Maloni (2005, p. 3) who say that “supply chain management involves the strategic process of coordination of companies within the supply chain to competitively deliver a product or service to the ultimate customer.”

Ellram (1991, p. 3) defines SCM as” A network of firms interacting to deliver product or service to the end customer, linking flows from raw material supply to final delivery.” This is a concise definition which covers the key elements of networks and flows but does not cover the other key element of SCM which is the real purpose – to add value.

3.2.3.5 Value Add

In SCM, each supply chain member performs a specific added value function in relation to the product/service as it progresses towards the final consumer. Although SCM adds value to the process, it is important to note that a basic premise of SCM is that value must increase faster than the costs associated with creating that value (Lockamy & Smith 1997).

3.2.3.6 Best Definitions

A comprehensive definition of SCM is that provided by Handfield and Nichols (1999) who state that:

> The supply chain encompasses all activities associated with the flow and transformation of goods from raw materials stage (extraction), through to the end user, as well as the associated information flows. Material and information flow both up and down the supply chain. Supply chain management is the integration of these activities through improved supply chain relationships, to achieve a sustainable competitive advantage. (p. 2)

Though lacking detail on the value adding aim of SCM, this definition is simple to understand and gives a good description of the other elements of SCM

Another comprehensive definition is that provided by Christopher (1994) who defines SCM as a “network of organisations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer” (p 14). This definition covers the key elements but is not explicit in the need for customer satisfaction.

One of the more widely used definitions in the USA is that of the Council of Supply Chain Management Professionals (CSCMP) which is:

> SCM encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all Logistics Management activities. Importantly, it also includes coordination and collaboration with channel partners. In essence, Supply Chain Management integrates supply and demand management within and across companies. (CSCMP, 2009)

Because of the recognition of CSCMP as the preeminent supply chain professional organisation in the USA, many people have adopted their definition of SCM. While this is a comprehensive definition, the words ”management of activities” are subject to misinterpretation and are not as preferable as specific mention of ‘flows of materials and information”. The definition also fails to mention the purpose of SCM which is adding value and customer satisfaction.

Most recently, Stock and Boyer (2009) developed a consensus definition of SCM by performing a qualitative analysis of 173 unique definitions of the field, collected from articles and books published on the subject from 1985 through 2008. Their definition, which is perhaps the most comprehensive, since it is based on the qualitative analysis of an extensive literature review, is as follows:

> The management of a network of relationships within a firm and between interdependent organisations and business units consisting of material suppliers, purchasing, production facilities, logistics, marketing, and related systems that facilitate the forward and reverse flow of materials, services, finances and information from the original producer to final customer, with the benefits of adding value, maximising profitability through efficiencies, and achieving customer satisfaction. (Stock & Boyer, 2009, p, 706)

They stated that they believe their definition is better than those previously published because it is representative of the conceptualisations of both academicians and practitioners and relates to earlier definitions of SCM. More importantly, the proposed definition has three themes that have been widely agreed upon in the SCM literature: activities, benefits, and SCM constituents or components (Stock & Boyer, 2009). In terms of the key elements of SCM used for this literature review it covers all elements and is the definition which will be used in this research.

3.2.4 Supply Chain Management

While supply chains exist regardless of any input, they can be managed to produce extensive advantages to an organisation. Bowersox and Closs (1996) argue that to be fully effective in today's competitive environment, firms must expand their integrated behaviour to incorporate customers and suppliers. Integration improves the flow of information and integrates product development. The integration extends to the belief that each firm in the supply chain directly and indirectly affects the performance of all the other supply chain members, as well as ultimate, overall supply chain performance (Mentzer et al., 2001).

Managing the supply chain has become an issue for three main reasons. The first one is that as companies have become more specialised they search for outside suppliers who can provide low cost, quality materials. It becomes critical for these companies to manage the entire network of supply to optimise overall performance. These organisations have realised that whenever a company deals with another company that performs the next phase of the supply chain, both stand to benefit from the other's success (Stevens, 1989; Lambert, Cooper & Pagh, 1998; Lummus & Vokurka, 1999; Towill et al., 2002).

The second reason is due to increased competition where customers have many more sources from which to choose to satisfy demand. To survive organisations must ensure their products are available when and where required. The traditional method of maintaining inventory at various locations throughout the chain is risky in the dynamic marketplace with demanding and finicky Customers' buying habits. The cost of holding any inventory also means most companies cannot provide a low cost product as funds are tied up in inventory (Lummus & Vokurka, 1999). This approach has been looked at through traditional Logistics methods (Bowersox & Daugherty, 1995) and through strategies to manage the risk (Manuj & Mentzer, 2008; Paulsson, 2004; Wagner & Bode, 2008) and through uncertainty theories (Schwartz & Weng, 2000; Rodrigues, Stantchev, Potter, Naim, & Whiteing, 2008).

The third reason for the shift is due to a realisation that maximising performance of one department, or function, may not result in an improvement to the supply chain and can even lead to less than optimal performance for the whole company. Purchasing may negotiate a lower price on a component and receive a favourable purchase price variance, but the cost to produce the finished product may go up due to inefficiencies in the plant. Companies must look across the entire supply chain to gauge the impact of decisions in any one area. (Forrester, 1961; Heckert & Miner, 1940; Jones & Riley, 1985).

Management of the supply chain enables organisations to integrate and manage the sourcing, flow, and control of materials using a total systems perspective across multiple functions and multiple tiers of suppliers (Mentzer et al., 2001). Langley and Holcomb (1992) suggest that the objective of SCM should be the synchronisation of all supply chain activities to create customer value. This suggests that the boundaries of SCM include not only logistics but also all other functions within a firm and within a supply chain to create customer value and satisfaction. In this context, understanding customers' values and requirements is essential (Mentzer et al., 2001).

3.2.5 Supply Chain Problems

When supply chains are not adequately managed a number of problems can occur such as the Bullwhip Effect, uncertainty and inventory inaccuracy

3.2.5.1 Bullwhip

In the late 1950s when Forrester was studying supply pipelines he noticed that inventories in a company's pipeline tend to fluctuate the further they are from the ultimate end user (Forrester, 1961). The Massachusetts Institute of Technology created a game called the Beer Game to demonstrate this effect (Sterman, 1992). In the 'beer game' simulation participants play the roles of supply chain members of a simplified but realistic supply chain in the beer industry. This game highlighted the slow processing of demands without good flow of information.

In 1997 this effect was given the name of the "bullwhip effect" by Lee, Padmanabhan & Whang (1997). They describe the phenomenon as when the variance of orders may be larger than that of sales, the distortion tends to increase as one moves upstream. The bullwhip effect can lead to excess inventory as well as unused or overused capacity. It dramatically increases the operating costs of the supply chain system and often leads to serious supply and demand mismatches and deterioration in customer service levels (Kouvelis, Chambers, & Wang, 2006)

According to Lee, Padmanabhan and Whang (1997), four distinct causes lead to information distortion and result in the bullwhip effect. These are demand signalling, order batching, fluctuating prices and shortages. All four causes are based on the behaviour of supply chain members trying to maximise profit individually rather than maximising the entire supply chain's profit. The overall costs of the supply chain are higher, resulting from higher inventory levels, unavailability of products, irregular orders, unused overcapacities and higher logistical efforts (Richter, Rochel, Samans & Schäfer, 2004). Simulations of information sharing along the supply chain indicate that the magnitude of the bullwhip effect can be reduced (Joshi, 2000).

Kouvelis et al. (2006) suggests that the most effective response to the bullwhip effect is some form of information sharing to help coordinate the supply chain. Chatfield, Kim, Harrison, and Hayya (2004) present a simulation study to evaluate the causes of the bullwhip effect. Their results include the following insights: (1) without forecast updating there is no bullwhip effect if simple ordering rules are adhered to, (2) lead time variability is a significant cause of the bullwhip effect, (3) information sharing is the most direct way to reduce the bullwhip effect, and (4) making use of information without sharing it is typically worse than ignoring the information completely. This last point is related to the first one. It is the updating following the receipt of new information that leads to the amplification of orders, and particularly so when customer orders are the only data available to a buyer when placing orders with his supplier. These results suggest that policies which stimulate information sharing and coordination are critical mitigants to the bullwhip effect (Kouvelis et al., 2006).

3.2.5.2 Uncertainty

Supply-chain management is a complex process because of the many uncertainties it involves. The uncertainty associated with inter-organisational coordination comes about when the activities of supply-chain participants are not in harmony. Davis (1993) believes that the real problem in managing and controlling complex networks is “the uncertainty that plagues them”. Van der Vorst et al. (2002) agree and claim that uncertainty propagates throughout the network and leads to inefficient processing and non-value adding activities. Persson (1995) takes this further by saying that the more uncertainty related to a process, the more waste there will be in the process. This is explained by Van der Vorst et al. (2002) who say the presence of uncertainty stimulates the decision maker to create safety buffers in time, capacity or inventory to prevent a bad chain performance. These buffers will restrict operational performances and suspend competitive advantage. Mason-Jones and Towill (1998) believe this is such an important point that those companies which cope best with uncertainty are most likely to produce internationally competitive bottom-line performances.

According to Galbraith (1973), uncertainty is defined as the difference between the amount of information required to execute a task and the information that is actually available. In supply chain planning decision processes, uncertainty is a main factor that can influence the effectiveness of the configuration and coordination of supply chains (Davis, 1993; Minegishi & Thiel , 2000; Jung, Blau, Pekny, Reklaitis, & Eversdyk, 2004) and tends to propagate up and down along the SC, appreciably affecting its performance (Bhatnagar & Sohal, 2005).

Van der Vorst et al. (2002) agree and say that supply chain uncertainty refers to decision making situations in the supply chain in which the decision maker does not know what to decide. This could be where they are short of information about the objectives, the supply chain or its environment and lack the ability to predict the impact of possible actions on supply chain behaviour.

There are three main types of uncertainty; uncertainty in demand, uncertainty in supply and uncertainty in manufacturing (Ho, Chi & Tai, 2005)

Demand uncertainty is where there are variations in customer demand. It involves the unknowns associated with product characteristics or environmental factors, which make it difficult to predict and control the demand for a final product. According to Fisher (1997) the nature of the demand for the products the company supplies is the critical element in an analysis of demand uncertainty. Ho et al. (2005) state that the key factors that must be considered in determining demand uncertainties are; the rate of new product introduction (Chopra & Meindl, 2007, Davis, 1993), product lifecycle (Fisher, 1997; Vickery, Roger & Cornelia, 1999), product variety (Chopra & Meindl, 2007), lead-time from design to production (Chopra & Meindl, 2007; Davis, 1993; Fisher, 1997), variation of marketing product mix (Lee & Billington, 1993), number of sales channels (Chopra & Meindl, 2007), accuracy of demand forecasts (Davis, 1993; Fisher, 1997; Whybark & William, 1976), and predictability of product demand (Chopra & Meindl, 2007; Davis, 1993; Fisher, 1997; Vickery et al., 1997).

Failure to deliver as required by the customer is another source of supply chain uncertainty. Davis (1993) found that supply uncertainty may be caused by a malfunctioning production process at the supplier, late delivery due to unexpected weather conditions, or unacceptable quality of the delivered products. Davis (1993) proposed that supply uncertainty is related to unpredictable and uncontrollable factors in the supply of materials. Ho et al. (2005) examined several studies on the subject and determined that the key factors that must be considered when determining supply uncertainties were; frequency of changing suppliers of critical materials (Novack & Simco, 1991; Reve & Johansen, 1982), complexity of critical materials (Lau, Goh & Phua, 1999; Malone, Yates & Benjamin, 1987; Van der Vaart, de Vries & Wijngaard, 1996), complexity of procurement technology for critical materials (Novack & Simco, 1991; Subramaniam & Shaw, 2002), time specificity of materials procurement (Malone et al., 1987; Subramaniam & Shaw, 2002), delivery frequency of critical materials (Novack & Simco, 1991; Reve & Johansen, 1982), delayed delivery of critical Materials (Davis, 1993; Novack & Simco, 1991), and fluctuations in the selling price of critical materials (Lau et al., 1999; Subramaniam & Shaw, 2002).

Manufacturing uncertainty is related to unpredictable and uncontrollable factors in the manufacturing process (Ho et al. 2005). Davis (1993) stated that that variations in manufacturing lead-time were the major source of manufacturing uncertainty and other factors were; variations in product quality, changes in production technology, and the complexity of manufacturing. Ho et al. (2005) reviewed many studies and determined that the key factors that must be considered when determining manufacturing uncertainties were; degree of process interaction (Khurana, 1999), degree of process decomposition (Khurana, 1999), degree of interaction among components (Davis, 1993; Khurana, 1999), degree of product decomposition (Khurana, 1999), process yield stability (Duncan, 1972; Lee et al., 1993), manufacturing lead-time (Davis, 1993; Duncan, 1972), employee turnover rate (Ho, 1996), engineering redesign (Davis, 1993; Khurana, 1999; Le et al., 1993), and frequency of changes in production technology (Duncan, 1972; Vickery et al., 1997).

3.2.5.3 Inventory accuracy

Inventory inaccuracy is a major operational inefficiency that is prevalent in many industries. Inventory inaccuracy is a mismatch between the physical inventory in the store and the system record (Camdereli & Swaminathan, 2009). An empirical study by Raman, DeHoratius and Ton (2001) show that inventory inaccuracy and inventory misplacement are two major operational inefficiencies in the retail stores. They found that the value of the inventory reflected by inaccurate records amounted to 28% of the total value of the on-hand inventory for a leading retailer in the USA. Kang and Gershwin's (2005) study found that the best performing store in their sample study only had 70-75% of its inventory record matching physical inventory during its annual inventory audit. The overall average over all stores was 51%.

Inventory inaccuracy can result in poor customer service, increase in backorders, lost productivity, high product obsolescence, direct hit to profitability, high inventory levels, and inefficient warehouse usage (Oracle, 2007, as cited in Walker, 2006). Fleisch and Telkamp, (2005) found that that lowering inventory inaccuracy will reduce supply chain costs and reduce the number of stock-outs. DeHoratius & Raman (2004) agree with this and claim that because of inaccuracy, systems can order product that is unnecessary or fail to order product that is needed. Heese (2007) found that the reduction in profit due to inventory inaccuracy can be up to 10%.

Atali, Lee and Ozer (2005) give three sources of inventory inaccuracy as follows:
(1) Shrinkage: thefts are generally not captured by the inventory control. As such, this leads to a system inventory which is higher than the actual inventory.
(2) Misplacement of products: goods are not in the correct place and are thus not available for customers. Consequently, inventory is correct but partially not available, introducing an inventory deviation.
(3) Transaction errors: this is related to wrong scanning of products at the check-out counters in retail outlets or switches of products in the supplier's warehouse.
Additional causes include including manual count error, stock number error, location error, or condition code error (Rossetti et al., 2006). Fleisch and Tellkamp (2005) give further causes such as incorrect deliveries, damaged and unsaleable/unusable items such as those that are out of date, discontinued, promotional, or seasonal.

In order to combat inventory inaccuracy effects Morey (1985) suggests that companies can increase the frequency of physical counts, maintain additional safety stock, or identify and eliminate the source of errors. Francis (2008) argues that the most effective way of reducing inventory inaccuracy however is to improve supply chain visibility

3.2.6 Supply Chain Visibility

Improving supply chain visibility can help to reduce the problems of the Bullwhip Effect, uncertainty and inventory inaccuracy. While studying the Bullwhip Effect, Lee et al. (1997) discovered that supply chain integration requires increased visibility throughout the value chain. Joshi (2000) investigated the impact of information visibility on a supply chain. He modelled one item through the entire supply chain and found that the inventory costs were reduced forty to seventy percent by increased information visibility.

Supply chain visibility is “the identity, location and status of entities transiting the supply chain, captured in timely messages about events, along with the planned and actual dates/times for these events” (Francis, 2008, p. 181). Supply chain visibility means capturing and analysing supply chain data that informs decision-making, mitigates risk, and improves processes (Tohamy, 2003).

Supply chain visibility is achieved through information sharing and the use of information technology. Bowersox and Closs (1996) claim that information sharing, clear communication, recognition of mutual benefits, and a high level of cooperation lead to the increasing likelihood of supply chain relationship success. Supply Chain members coordinate by sharing information regarding demand, orders, inventory, point of sale data, etc. Timely demand information or advanced commitments from downstream customers helps in reducing the inventory costs by offering price discounts and this information can be a substitute for lead time and inventory (Reddy & Rajendran, 2005).

Information sharing is the willingness to make strategic and tactical information available to supply chain partners, including forecasts, promotions, inventory levels, sales demand, and the movement of goods through the supply chain (Fisher, Hammond, Obermeyer & Raman, 1994; Johnson 1998; Lee & Whang 2000). Information sharing can align the incentives of supply chain partners and improve margins, inventory control, customer satisfaction, and firm performance (Mithas, Krishnan, and Fornell 2005b; Narayanan and Raman 2004). Chen et al. (2000) found that the value of information sharing increases as the service level at the supplier, supplier-holding costs, demand variability and offset time increase, and as the length of the order cycle decrease. Yu, Yan and Cheng (2001) conducted some comparative studies in which no information-sharing policy is compared with full information-sharing policy. They found that an information-sharing policy results in inventory reductions and cost savings.

According to Bowersox and Daugherty (1995) and Currie (1993), benefits of supply chain management can be reached by the use of information technology and the construction of integrated supply chain information systems. Information technology advances have greatly reduced the cost of sharing information and fostered real-time information sharing, coordination, and decision making among companies (Johnson & Whang 2002; Kopczak & Johnson 2003). Information technology helps to link the point of production seamlessly with the point of delivery or purchase. It allows planning, tracking and estimating the lead times based on the real-time data. Recent research considers adoption and benefits of information technologies such as enterprise resource planning (ERP) and customer relationship management (CRM) systems (Cotteleer 2006; McAfee 2002; Stratman 2007; Tsikriktsis, Lanzolla, and Frohlich 2004). Researchers have also shown that information technology improves operational and financial performance by enabling organisational capabilities and coordination with business partners (Bardhan, Mithas, & Lin 2007; Bardhan, Whitaker, & Mithas 2006; Mithas & Jones 2007; Zhu & Kraemer 2002).

In the early 1970s, as computers became more available, the first commercial uses of Material Requirements Planning (MRP) automated the processes of inventory and production planning (Joshi, 2000). MRP systems are used in manufacturing environments for high level scheduling, priority, and capacity management (Chung & Snyder, 1999). MRP combines input from the master production schedule (MPS) which represents the expected demand, the bill of materials (BOM) which lists the components of the product, and the inventory status of items. The computation results in a detailed output with the exact quantity, need date and planned order release date for each of the sub-assemblies, components and materials required to manufacture products listed on the MPS (Joshi, 2000).

With MRP, the used data is limited and the manufacturing system is not integrated with the firm's financial system so the system was modified and Manufacturing Resource Planning (MRPII) was released (Chung & Snyder, 1999). MRP II added the functions of purchasing and capacity planning to the system (Gronau, 2004; Wöhe, 2002). The higher integration of more functional areas within a firm by scenario planning in MRP II provides for a better management of company resources by offering information based on the production plan across functions like purchasing, production, finance, and accounting (Gronau, 2004). Unfortunately MRP II is based on the unrealistic assumptions of; fixed lead times, lot sizes consistent and unlimited availability of resources (Pfohl, 2004). During the 1980s it became apparent that the information and information systems used within firms were much like the organisational structure, rather functional and disconnected. The need to integrate information across more units of the firm led to the appearance of enterprise resource planning (ERP) systems (Joshi, 2000).

ERP systems map workflows, organisational structures, information and data flows of entire organisations (Günthner, Boppert, & Rinza, 2005). They integrate data across the enterprise so that every user of the system, regardless of function, accesses the same consistent data set (Prockl, 2004).

3.2.7 Performance Measures

An issue of significant importance to supply chain practitioners and researchers is how and what to measure relative to the outputs of the supply chain (Stock, 2009). Many companies have not succeeded in maximising their supply chain's potential because they have often failed to develop the performance measures and metrics needed to fully integrate their supply chain to maximise effectiveness and efficiency (Gunasekaran, et al., 2004).

Without clear performance measures, an organisation cannot establish its current state and develop a strategy to fit where it wants to develop (Hammer & Stanton, 1995). The availability of past experiences in the form of objective critical measures, linked to clear expectations, provides a picture of the past and leads to motivated desirable present and future behaviour. Performance measurement is vital in strategy formulation and communication and in forming diagnostic control mechanisms by measuring actual results (Wouters 2009). Christopher (1994) believes that benchmarking of the supply chain should occur not just within the organisation but relative to the competition.

Performance evaluation is defined by Juiping et al. (2009, p. 628) as the "process of quantifying action, or more specifically the process of quantifying and analysing effectiveness and efficiency." On this basis, supply chain efficiency is defined as a measure of how well the firm's resources in a whole supply chain field are utilised to achieve its specific goals (Jiuping, Bin Li & Wu, 2009). Supply chain performance evaluation problems cover a wide range, from evaluating the performance of independent organisations among supply chains to evaluating the performance of a whole supply chain system (Jiuping et al., 2009)

Research scientists have shown an increasing interest in improving the measurement systems design during the last few years (Keebler, Manrodt, Durtshe & Ledyard, 1999; Vitale & Mavrinac, 1995; Caplice & Sheffi, 1995; Kaplan &

Norton, 1992; Eccles, 1991). They have questioned traditional performance measurement and looked at alternates (Holmberg, 2005).

Holmberg (2000) states that many companies still rely too heavily on financial figures as their key performance indicators. Financial metrics are primarily designed to meet external evaluators' needs, to compare firms and to evaluate a firm's behaviour over time. Atkinson, Waterhouse and Wells (1997) agrees by saying that financial information is not required for decision making for many people inside organisations, and the information is often presented too late to make meaningful decisions on actions such as demands and production. Vitale and Mavrinac (1995) argue that success in business today is not solely determined by a strong cash flow or meeting a financial budget. Instead, developing competency, capabilities and skills in areas such as team-based problem solving and innovation are much more important, yet not easily measured in financial terms (Holmberg, 2005). Johnson (1990) claims that financial measures are insufficient for the complex and dynamic characteristics of a supply chain. However, Johnson (1990) does not argue for completely removing financial measures as accounting-based information does play an important role in strategic planning and for monitoring financial results. It is just it must be used in conjunction with other measures more suitable for controlling and improving activities. Maskell (1991) expands on the situations where the measures are used by suggesting that companies should use financial performance measurements for strategic decisions and external reporting, while day to day control of manufacturing and distribution operations should be handled by non-financial measures.

The metrics that are used in performance measurement and improvement should be those that truly capture the essence of organisational performance. A measurement system should facilitate the assignment of metrics to where they would be most appropriate. For effective performance measurement and improvement, measurement goals must represent organisational goals and metrics selected should reflect a balance between financial and non-financial measures that can be related to strategic, tactical and operational levels of decision making

and control (Gunasekaran et al., 2004). Gunasekaran and Kobu (2007) propose the following as the purposes of a performance measurement system:
. Identifying success.
. Identifying if customer needs are met.
. Better understanding of processes.
. Identifying bottlenecks, waste, problems and improvement opportunities.
. Providing factual decisions.
. Enabling progress.
. Tracking progress.
. Facilitating a more open and transparent communication and co-operation.

Balanced scorecard methodology developed by Kaplan and Norton (1993, 1996), is an important tool for performance management. The idea of a hierarchical, balanced set of performance metrics compatible with the top management strategy is repeatedly emphasised in current literature as an essential element of performance measurement (Bhagwat & Sharma 2007). The balanced scorecard method was used by Barber (2008) to measure the performance of the supply chain as a whole. In the measurement Barber included both tangible and intangible elements that impact supply chain success, including participant satisfaction, financial management, strategic management, change management, relationship management, and quality, innovation and knowledge management. Kaplan and Norton (2004) also emphasise the importance of measurements related with intangible assets (human, information and organisational capital) which are evident in the balanced scorecard perspective.

Another popular model for supply chain performance measurement is the Supply Chain Operations Reference (SCOR) model created by the Supply Chain Council (SCC). This model provided guidance on the types of indicators decision-makers can use to develop a balanced approach towards measuring the performance of an overall supply chain (Supply Chain Council, 2004). The SCOR Model advocates a set of supply chain performance indicators as a combination of:

- reliability measures (e.g. fill rate, perfect order fulfilment);
- cost measures (e.g. cost of goods sold);
- responsiveness measures (e.g. order fulfilment lead-time); and
- asset measures (e.g. inventories) (Supply Chain Council, 2004).

Authors such as Lockamy and McCormack (2004), Hwang, Yin and Lyu (2008) and McCormack, Ladeira & Oliviera (2008) all strongly support the use of the model. Hwang et al. (2008) supports the SCOR model as it enables companies to analyse their supply chain performance in a systematic way, to enhance communication among the stakeholders in the supply chain, and to design a better supply chain network.

Akyuz and Erkan (2010) promote the model because it provides the following benefits:

- Providing a standardised way of viewing the supply chain (cross-industry standard).
- Offering a consistent 'scorecard' framework for development of performance.
- Emphasising process orientation and deemphasising functional orientation.
- Enabling cross-industry benchmarks.

Time-based methodologies are another method of performance measurement. They have been developed to provide a process-based approach to supply chain analysis. They have a proven ability to determine the major areas of waste within processes and consequently the opportunity for cost reduction (Stalk & Hout, 1990; Blackburn, 1991). Waste is defined as any activity that does not add value to the product (Stalk & Hout, 1990). One of the key aspects of time-based methodologies is the ability to account for both value adding time and non-value adding time in processes (Gregory & Rawling, 1997). Time based process mapping (TBPM) identifies value adding and non-value adding activities within the supply chain. Value is seen as a part of a product or service that the customer cares about and would be willing to pay for. Value is said to be added to products or services only when the following three criteria are met: firstly the customer cares about the change, secondly the item is physically changed and thirdly the change is done right the first time. Non-value adding activities are everything that does not fit within these three criteria (Blackburn, 1991; Gregory & Rawling, 1997)

3.2.8 Military Logistics and Supply Chains

3.2.8.1 Military Logistics Development

Logistics is integral to any attempt to conduct military operations. Without logistic support, war as a deliberate, organised activity would be impossible. Military units could not be raised or equipped and forces would not reach the battlespace, fight the battle or get home again. Logistics therefore establishes limits on what is operationally possible. However, while logistics may set limits, the goal of the logistic effort is to extend those limits as far as possible (ADF, 2003). Rear Admiral Henry Eccles, USN (Rtd) summarised this nicely when he said that "logistics provides the physical means for organised forces to exercise power. In military terms, it is the creation and sustained support of combat forces and weapons. Its objective is maximum sustained combat effectiveness" (Walden, 2006, p. 222). Sun Tzu the famous Chinese philosopher was more direct in his opinion when he said "without logistics the army is lost" (Walden, 2006, p. 222).

Military Logistics is defined as "the science of planning and carrying out the movement and maintenance of forces" (ADF, 2003, p. 1-9). The concept of military logistics is as old as organised warfare and, like war itself, has evolved considerably over time. The earliest military forces had relatively simple needs. Warriors usually brought their own weapons and provided their own means of mobility, their own feet or a horse. The primary logistic concern was feeding the armies and this was done through foraging or local procurement. Despite this apparent simplicity it was still vitally important. For example the strategy of Alexander the Great relied on logistics and his mastery of it (ADF, 2003).

The Roman Army set the example for the organisation of modern land forces and the field of military logistics with many of their developments still being in use today. The romans recognised that it was unsustainable to live off the land for long as it advanced on operations. Their solution was to issue soldiers with compact, long lasting biscuits, stockpile grain in granaries at main supply bases and fortresses, use baggage trains to carry tents, ammunition and engineering stores. To enable this to work they constructed roadways and stores depots across their empire and made use of the sea and inland waterways to provide strategic logistics. In this way they effectively supplied the needs of remote garrisons and even field armies in a way that would be the envy of many modern forces today (ADF, 2003).

The fall of the Roman Empire meant armies returned to being small disorganised forces and military logistics was once again reduced to immediate support of small forces.

With the emergence of modern armies in the 17th and 18th centuries came the development of dedicated logistics systems and services. The introduction of cannon and firearms created new requirements for supply and transport. The size of armies grew and the relatively static nature of siege warfare meant that foraging was no longer suitable and forces needed to be largely self-sufficient. This led to the creation of a logistics system, similar to the Roman Army, consisting of fixed supply points called magazines and large unwieldy baggage trains which were usually operated on a commercial or contract basis. The logistics system became a limiting factor and a key vulnerability (ADF, 2003).

Napoleon broke this nexus and regained the mobility of operations. He did this by returning to foraging and looting as a means of supporting a faster moving, lighter but larger army. Ultimately however this was also his undoing in the Spanish and Russian campaigns when supplies were unobtainable.

The industrial revolution radically changed the nature or warfare and logistics. Military supplies such as ammunition, weapons, general supplies and foodstuffs could be produced on a much larger scale. More manpower was available as technology reduced the labour requirements. New technologies in weapons increased the lethality of weapons and the amounts of ammunition required to support them. Also the developments in transportation such as railroads and steam ships enhanced the mobility of forces and their support systems. As a result of all these innovations military forces grew larger in size, were more destructive and could move rapidly, but they were also more reliant on organised logistics (ADF, 2003).

The paradigm shift in the focus of military demand from food and fodder to ammunition and fuel transformed the requirements for military logistical planning. In WW2 it was the Allies ability to build up a logistical superiority which allowed them to beat the Germans in the battle of equipment, and thus the war. Much of the structure and systems of modern military logistics can be traced to the methods and lessons of WW2. These include things like daily and automatic replenishment of combat supplies to land forces and the hierarchical lines and levels of support (Australian Army, 2003a).

Prior to the war military had been the leading edge for logistics. With the work done in the 19th century on the business process of physical distribution, and the concept of marketing in the 1950s, civilian business logistics began to make progress and the intellectual development of logistics in the private sector outstripped military thinking (Australian Army, 2003a).

The military had relied on the mass theory of maximum stocks available to produce victories in WW2, Korean War and Desert Storm. Unfortunately this system is not efficient as it was built on the underlying principle that the larger the mountain of supplies the more responsive the support system. This principle is only true when the right goods are in the right place, otherwise the supplies just create a burden on the logistics chain and risk misplacement and loss through obsolescence. A popular quote by General Fred Franks, Commander Op Desert Storm, Gulf War, describes this condition perfectly. He said that “if you move the ball 90 metres but can’t move it the final ten meters, you have failed to score” (Walden, 2006, p. 189). By the end of the war there were 27,000 containers of unknown contents in theatre (Walden, 2006).

The nature of warfare is also changing. New technologies have led to increasingly complex weapons and equipment. These require more specialised maintenance management and sustainment. Improvements in mobility and the increasing lethality and range of the weapon systems are resulting in continuously expanding battlespace. The nature of contemporary warfare is removing the traditional front line/ rear area separations, resulting in logistics installations and capabilities being exposed to the same threats as the traditional combat forces. This is leading to changes in the way logistics is provided (Estevez, 2005). Contemporary military logisticians must meet the challenge of supporting the transformed combat force with fast, accurate, flexible, and mobile sustainment.

As a result of the lessons learned during Operation Desert Storm and the changing nature of warfare, military logistics was required to undergo significant improvements and has been looking to civilian logistics, and subsequently also SCM, for ideas. While significant improvements have been made to many military supply chains through the application of best civilian practices, there is a fundamental difference between military and civilian supply chains that must be considered.

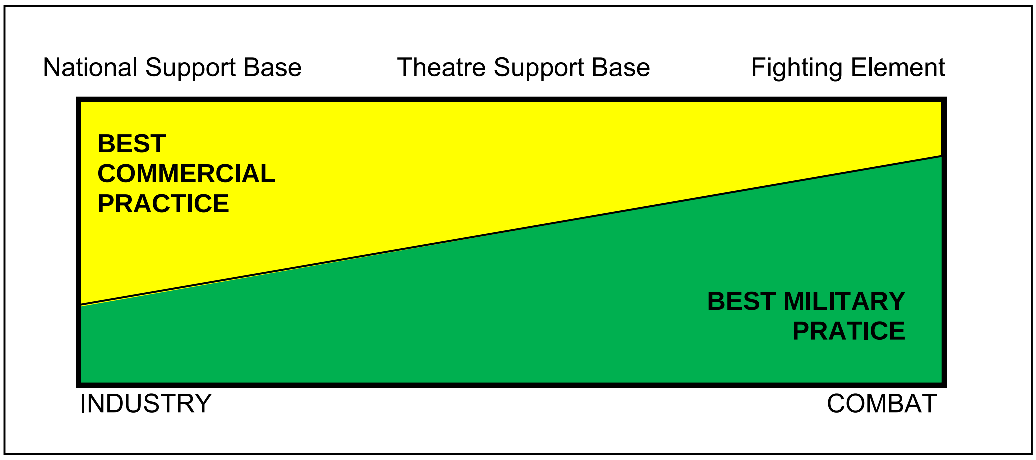
3.2.8.2 Military versus Civilian Logistics

Military logistics is different from commercial logistics. Commercial logistics is focused on the bottom line and lacks the war fighting purpose that defines military logistics. Commercial considerations such as profit motives, regulation, investment, returns, infrastructure and relative certainty must be contrasted with the unique aspects of the military. These aspects include operational uncertainty, the requirement for deployability in unknown and often hostile environments where there may be a deliberate attempt to disrupt the logistics system and the catastrophic consequences of failure in military logistics (ADF, 2003). Van Creveld (1977, p. 1) highlighted the unique nature of operating in the military when he said

> Battle is a worst case condition in which the risks are high, the uncertainty great, and the hardships and 'workplace conditions' are unknown in any other field of human endeavour. If these weren't enough, battle is probably the only leadership environment in which both followers and leaders would rather be somewhere else.

These unique military factors mean that certain inefficiencies in the provision of logistic support must be tolerated in order to provide a level of redundancy and reserve capability. In addition, within the commercial world the word logistics generally only refers to the activities associated with warehousing and distribution, whereas in the military it incorporates a much wider range of functions (Walden, 2006). Defence must strike the right balance between the best commercial practice on one hand and the imperatives of the best military practice on the other as shown in Figure 3.1 (ADF, 2003).

Figure 3.1. Military versus Civilian Logistics



Source: ADDP4.0, 2003, p. 1-13

3.2.8.3 Military Supply Chain

The objective of an effective military supply chain is readiness for war. Generic Military Supply Chains comprise of lots of small steps in a long interrelated and highly complex chain of activity that occurs across time to meet a particular outcome. Originating in the civilian economy, resources pass through the various echelons of command and control by a series of network logistic systems, functions and processes (ADF, 2003).

On a basic level, the military supply chain mimics a consumer goods supply chain. There are manufacturers to make the products, warehouses to store the products (fourth and third), retail stores (general supply units or second line), and local stores (direct supply units, first line). However the key difference is that the major goal of a consumer goods supply chain is to minimise cost and maximise profits while the major goal of the military supply chain is readiness for war. Because of this the military supply chain differs from a consumer goods supply chain in the following ways (Lai, 2003):

1. Diversity in supply,
2. The need to be ready for war at any given time,
3. An unstable and therefore unpredictable demand,
4. Moving end supply points, and
5. Handling of supply orders according to priority.

Firstly the military's inventory consists of a large number of very different types of items, from everyday supplies of food and clothing to specialized military equipment. In order to manage the significant numbers of items they are grouped into ten classes of supplies as shown in Table 3.1 (Australian Army, 2003b).

Table 3.1. Classes of Supply in the Military

Class	Description
1	Subsistence and water
2	Clothing, individual equipment, tools, tents, stationary, general supplies
3	Petroleum, oils, lubricants
4	Construction items
5	Ammunition
6	Personal Demand Items (non-military sales, gratuitous health and comfort pack items e.g. Toothpaste, shaving cream)
7	Major End items/Principle items (vehicles, complete weapons etc.)
8	Medical supplies
9	Repair parts and components required for maintenance of all equipment
10	Material to support non-military programs such as disaster relief and aid programmes

Second, the military must operate at peacetime, yet still be ready for war at any given moment. Equipment and supply readiness is crucial. The metric for military supply chain success is readiness for war, not profit gain (Lai, 2003). Because of this there is a necessity to store resources used on a daily basis as well as store resources for times of war.

Third, the military supply chain is unstable compared to a relatively stable consumer supply chain. Military demand is often variable and unpredictable. Conflict or natural disasters which require military assistance can arise anywhere at any time. To cover this contingency stores are required and there will be sudden surges in demand (Lai, 2003).

Fourth, the end points of the supply chain in theatre are moving points, creating another complication in transportation of supply. In a consumer product supply chain, products are shipped to a fixed network of retail stores. In the military these stores are constantly moving to keep pace with the units on the ground. In addition the routes to these units may become blocked through environmental or hostile activities so alternate routes or methods of supplies must be used.

Fifth, supply is handled according to unit and class of store priority. Priorities are required so the essential stores get to the place they are needed the most in order to carry out the operational plan. This can cause constant amendments to scheduled distribution plans and adds further complication to the supply chain (Lai, 2003)

3.2.8.4 Measuring Military SCM

Traditional commercial performance measurement is not effective for military supply chains. Lai (2003) proposes using readiness and mobility to determine efficiency of military supply chain. The Theory of Constraints (TOC) provides an efficient method of analysing a supply chain and seeking improvements. TOC is a management philosophy developed by Dr Eliyahu Goldratt that applies scientific principles to the management of industry and general life situations (McMullen, 1998).

The first part of TOC is to ensure the goal of the organisation is known. While for most organisations the goal is to make money, however for most military organisations around the world the goal is to provide a military force that is able to respond to the security needs of its government. Therefore the goal of the military supply chain is to ensure the readiness of the military force. The benchmarks against which to measure the goal include:

- Trained personnel available,
- Adequate resources available,
- Size of force able to deploy, and
- Speed of deployment.

3.3 RFID

3.3.1 Introduction

Radio Frequency Identification Device (RFID) is an automatic identification technology that relies on radio waves to identify, track and manage objects and collect and store data (Angeles, 2005; Kasap, Testik, Yüksel & Kasap, 2009). It uses a tag embedded in, or attached to, the target entity that is marked with a unique code (Roussos, 2008). The tag transmits the data across radio waves to a reader which reads and filters the data. The data then passes through middleware software for translating and processing and on to enterprise applications such as enterprise resource planning or supply-chain management systems (Dutta et al., 2007).

Heinrich (2005) stated that RFID is among the most exciting and fastest growing technologies in terms of scope of application in the next generation of business intelligence. RFID technology has been identified as one of the ten greatest contributory technologies of the twenty-first century (Chao, Yang & Jen, 2007). In the context of SCM, the technology has been considered as ‘‘the next revolution’’ (Srivastava, 2004 p. 1) since it allows the tracking of each object or product in real time in the supply chain. According to some estimates, in 2008 there were more than 3.7 billion RFID tags in use, of which more than 1.6 billion were deployed during 2006 alone and this trend is said to be accelerating (Roussos, 2008). Angeles (2005) claims that in the coming years more and more supply chains should begin to feature RFID technology.

RFID technology is considered to have great potential to improve the efficiency and accuracy of many processes (Angeles, 2005; Dutta et al., 2007; Cannon et al., 2008). It enables the optimisation of supply chain processes by providing detailed information on the flow of products throughout the supply chain (Whittaker, Mithas, & Krishnan, 2007).

3.3.2 RFID History

The first application of RFID technology was the Identify-Friend or Foe (IFF) transponder developed by British which was used by the allies in World War II for identification of friendly aircraft. It relied on passive radar reflectors, tuned to the home radar frequency, which made a friendly aircraft much brighter to home radar than an enemy aircraft (Asif & Mandviwalla, 2005). However the birth of RFID is not credited to IFF but to the 1948 research paper by H Stockman on "Communication by Means of Reflected Power".

In Stockman's (1948) landmark paper he discusses the use of a reflected radio signal as a way to identify a remote object based on the reflection signature from the object. After describing the main principle of communication by reflection and reporting his experiments, he concluded that much more research and development work was needed before the field of useful applications could be explored (Stockman, 1948). He was right as it was nearly forty years before commercial applications became feasible.

In the 1950s there was a theoretical exploration of RFID techniques with a number of pioneering research and scientific papers being published (Roberts, 2006). Papers by Harris (1960) and Vernon (1952) spoke of systems in which a transmitted radio signal would yield an identifiable, measurable and recognisable return signal. During this decade the use of radio detection and ranging (radar) was also growing (Shepard, 2005).

The 1960s and 1970s were marked by the research community's interest in RFID. An early breakthrough of this period was a passive RFID transponder developed and patented by Richardson in July 1963. The device could couple and rectify energy from an interrogator's EM field and transmit signals at a harmonic of the received frequency (Richardson, 1963). Later in the decade, Vinding (1967) developed a simple and inexpensive interrogator-transponder system based on inductive coupling, which was granted a U.S. patent in January 1967. Some commercial systems were launched and the electronic article surveillance (EAS) equipment was used as an antitheft device. These systems used 1bit tags detecting the presence or absence of a tag and were used in retail stores attached to high value items and clothing. These proved to be an effective antitheft measure and were arguably the first and most widespread commercial use of RFID (Roberts, 2006). During the 1970s the Los Almos Scientific Laboratory in New Mexico, USA became the centre point for research that led to the development of modern RFID. On 23 Jan 1973 the US Patent Office approved a patient for Mario Cardullo for the first RFID tag. In 1975 Freyman, Depp and Koelle (1975) introduced the novel concept of transponder antenna load modulation as a simple and effective way for backscatter modulation (Roberts, 2006).

Throughout the late 70s products began to appear in the marketplace with uses in toll tracking, livestock tracking, vehicle movement monitoring and supply chain management (Shepard, 2005). A key limitation on development of RFID at this time was the size and simplicity of the electronic components and chip size (Roussos, 2008).

In the 1980s the commercial applications of RFID were expanding into a number of areas. In Europe animal tracking systems became widespread and toll roads in Italy, France, Spain, Portugal and Norway were RFID equipped (Roberts, 2006). Many American and European companies started to manufacture RFID tags and in 1984 General Motors attached RFID tags to car frames to make sure that the right equipment was mounted on each frame (Juban & Wyld, 2004).

At the end of the 1980s there was a rapid miniaturisation of electronics, which offered at the same time lower cost and a higher performance and capacity. Due to this the applications of RFID expanded and a new area was opened in the use of passive inductive tags. These were developed into a variety of contactless smart cards used in applications such as access control and ticketing (Roussos, 2008). In 1987 the first RFID-based toll-collection system became operational in Ålesund, Norway (Chawla & Ha, 2007). It was also around this time that the first electronic door keys were patented by Charles Walton (Takahashi 2004).

Technological developments continued in the 1990s with integrated circuit development and size reduction until microwave RFID tags were reduced to a single integrated circuit (Roberts, 2006). This assisted the commercial growth and in this decade the United States began the widespread adoption of electronic toll collection and in Europe there was a growth in RFID applications including toll collections, rail applications and access control. RFID tolling and rail applications appeared in many countries including Argentina, Australia, Brazil, Canada, China, Hong Kong, Japan, Malaysia, Mexico, New Zealand, South Korea, South Africa, Singapore and Thailand (Slettemeås, 2009).

The Department of Defence adopted the use of active RFID tags on pallets in 1995 in Europe and by 1998 for most shipments in the continental United States. The purpose of these active tags was to provide greater visibility and tracking of supplies in the supply chain (Walden, 2006, p.179).

The increase in commercial use of RFID prompted a need for standards, which led to many standardisation activities in the 1990s. Most of these were conducted by the International Standards Organisation (ISO) and International Electro technical Commission (IEC) which concentrates on global standards for electrical, electronics, and related technologies. Initial standardisation interests were in animal tracking and contactless proximity cards applications (Chawla & Ha, 2007).

The 1990s saw the acceptance of RFID as an important enabler in supply chain management, which spurred a further series of standardisation activities. A milestone came in 1996 with the standardisation of RFID as a data carrier by the Article Number Association (ANA) and European Article Numbering (EAN) groups. In 1999, EAN International, and the Uniform Code Council (UCC) of the United States, now both known as GS1, adopted a UHF frequency band for RFID and established the Auto-ID Centre at the Massachusetts Institute of Technology. This organisation was charged with developing a global RFID standard for product labelling called the Electronic Product Code (EPC). The Auto-ID Centre later evolved into Auto-ID Labs and EPCglobal Inc. The latter is a non-profit organisation, set up by UCC and EAN International, pursuing the commercialisation of EPC technology (Chawla & Ha, 2007). The next years saw accelerating progress. Two years of focused development by EPC pioneers and the MIT AutoID Centre led to the Gen 2 protocol, a milestone in RFID evolution that has closed all of the major gaps at the hardware level. The second wave of new Gen 2 ICs, tags and readers have advanced to the point that performance is exceptional, costs are dropping and interoperability is a given. Software applications have evolved into sophisticated resource and information managers connected to enterprise software through mature, standards-based interfaces (Alien, 2007).

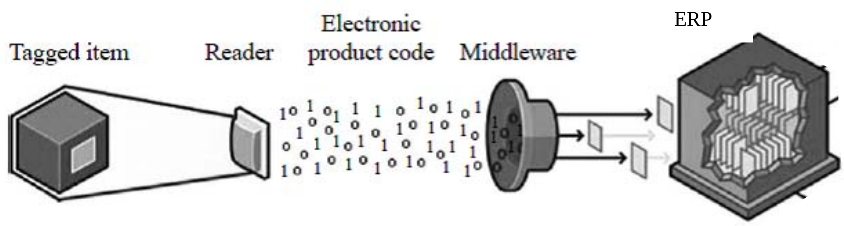
At the beginning of the 2000s RFID came into prominence in SCM due to its unique capability to automatically identify tagged entities at potentially very low cost. Global supply chains, enterprise information systems and the internet had matured to the point that organisations could benefit considerably from the increased precision of RFID (Roussos, 2008).

In 2003, Wal-Mart (Roberti, 2003), followed by the Department of Defence (Collins, 2004), Target and a few other major firms, announced programs that required their top suppliers to use RFID tags on pallets and cases by 2005. The rationale for the use of RFID is to improve velocity in the supply chain by increasing visibility of goods, materials, and merchandise moving through the system (Walden, 2006). Analysis predicted Wal-Mart could save over $8 billion annually using RFID by reducing labour costs of scanning items, out-of-stock items and item theft while making improvements in the supply chain (Roberti, 2003). After these announcements there was an increase in RFID worldwide, leading to several pilot projects introduced by supply chain leaders (e.g. Metro Group, Tesco, Sainsbury's, Marks &Spencer, Albertson, Target, Gillette, Procter & Gamble) (Miragliotta et al., 2009). These projects mainly aim to provide initial results on the strengths and weaknesses of RFID. This has led to a flurry of research as academics and practitioners attempt to provide proof of the benefits and, consequently, in the impact on return on investment of RFID (Miragliotta et al., 2009).

3.3.3 RFID Description

RFID is an automatic identification technology that uses radio waves to identify objects. The technology consists of tags which contain item information. Readers receive this information and send it to middleware which translates the information and sends it to the organisations information systems such as ERP (Angeles, 2005). A summary of this process is shown in at Figure 3.2.

Figure 3.2. Diagram of RFID System



Source: Kwok & Wu, 2009, p, 1171

3.3.3.1 Tag

RFID tags are the most important component of an RFID system. Their purpose is to send information on an object to a reader (Curtin et al., 2007). A typical RFID tag contains the following three components: the integrated circuits (IC) chip, the antenna, and the enclosure. The IC chip is used for the unique data storage and logical operations associated with the RFID tag. The antenna is used for communication to send data between the tag and readers. The enclosure is the packaging around the electronic components (Roussos, 2008).

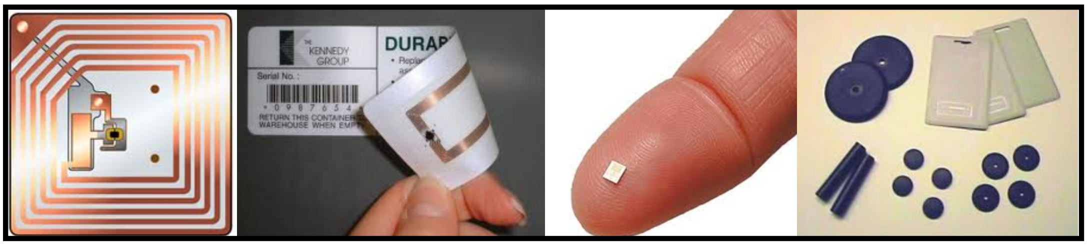
The tag responds to instructions from the reader. As soon as the tag has adequate power for its operation, it initialises itself by running self-check routines and sets itself in a condition where it is ready to receive instructions. Then in response to instructions received, it will move from state to state and provide responses depending on the type of system and its application (Roussos, 2008).

There is a lot of variety in the capabilities of tags in terms of data capacity, range, communication data rate and density. Some of the higher specification tags can even offer advanced authentication and cryptographic protection of their contents, (Roussos, 2008, p. 44). RFID tags can be active or passive according to the supply of electronic power (Kasap et al., 2009).

Passive tags are unpowered and must collect radio wave energy from a tag reader in order to report their stored data to a reader. They are generally small and hold only enough data to uniquely identify and serialize a manufacturer's products in the supply chain (Roussos, 2001). The disadvantages of Passive Tags are their limited range, from a few centimetres up to a few metres in perfect conditions (Roussos, 2001) and limited data capacity.

The advantages of passive tags are their small size, low maintenance, long life, low price and flexibility of application. They range in size from a millimetre through to 10 cm (Gragg, 2003) and can be integrated into plastic and attached directly to objects or printed onto standard sized label rolls (Shah, 1999). As they do not depend on batteries they do not require recharging or replacement. This is clearly a unique advantage, especially for maintenance of large scale systems (Roussos, 2001). Due to their relative simplicity they are relatively cheap and, as the demand for these tags increases, their prices continue to fall. The price for a UHF label tag is down to 12 cents for an order of 10,000 and the price continues to reduce for increased size of orders down to as little as 9 cents. For a specially encapsulated tag which can work on metal the price starts from $2.29 for a medium size tag of 1000-2500mm^2 (ODIN, 2010). Some examples of the types of passive tags available are shown in Figure 3.3.

Figure 3.3. Different Types of Passive RFID Tags



Source: rikheij.wordpress.com, allforcard.com, epn-online.com and media.mit.edu

Semi-passive tags use an internal battery to ensure data integrity, but the data transmission from tag to reader is generated by the energy of the signal from the reader (Curtin et al., 2007). Some are able to partially recharge their battery each time the tag enters the electromagnetic field of the reader (Roussos, 2001).

Active tags contain a battery that powers their data transmission, allowing them to proactively communicate with RFID readers (Roussos, 2001). The disadvantages of active tags are their larger size, increased maintenance, requirement for changing batteries and cost. The advantages are their data storage, range and versatility (Curtin et al., 2007; Roussos, 2001). Active tags can store large amounts of data and some have the ability for internal read and write capability so information on the tag can be updated as required and can potentially store maintenance information, location logs, temperature logs or even measure the frequency of use of an item (Curtin et al., 2007). Due to their increased power they can transmit and be read at longer ranges. At frequencies around 900Mhz, these can be read more than 30 meters from an antenna (Shah, 1999). The increased power also enables them to operate in particularly challenging environments such as locations with significant radio frequency pollution caused by electric machinery (Curtin et al., 2007). It is also relatively straightforward to augment active tags with additional sensing capability, for example temperature sensors, and they can initiate transmission rather than simply respond to readers (Roussos, 2001). Some examples of the types of passive tags available are shown in Figure 3.4.

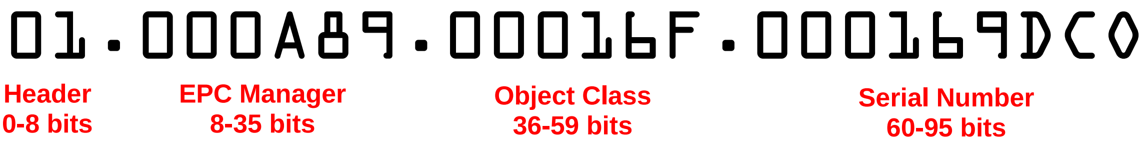
Figure 3.4. Different Types of Active RFID Tags

Source: gaorfid.com, diytrade.com and kimaldi.com

3.3.3.2 EPC

The basic data held on a tag is the Electronic Product Code (EPC). The EPC is a compact numerical naming convention to uniquely identify items in the supply chain (EPC Global, 2005). The EPC consists of an eight-bit header which identifies the EPC version number, the EPC manager (28 bits) which identifies the manufacturer of the product in question, the object class (24 bits) which refers to the exact type of product or stock-keeping unit, and a serial number (36 bits which is the unique code that identifies the specific product item (Angeles, 2005; Brock, 2001). Figure 3.5 shows the makeup of an EPC.

Figure 3.5. The Electronic Product Code



Source: Brock, 2001, p. 20)

3.3.3.3 Readers

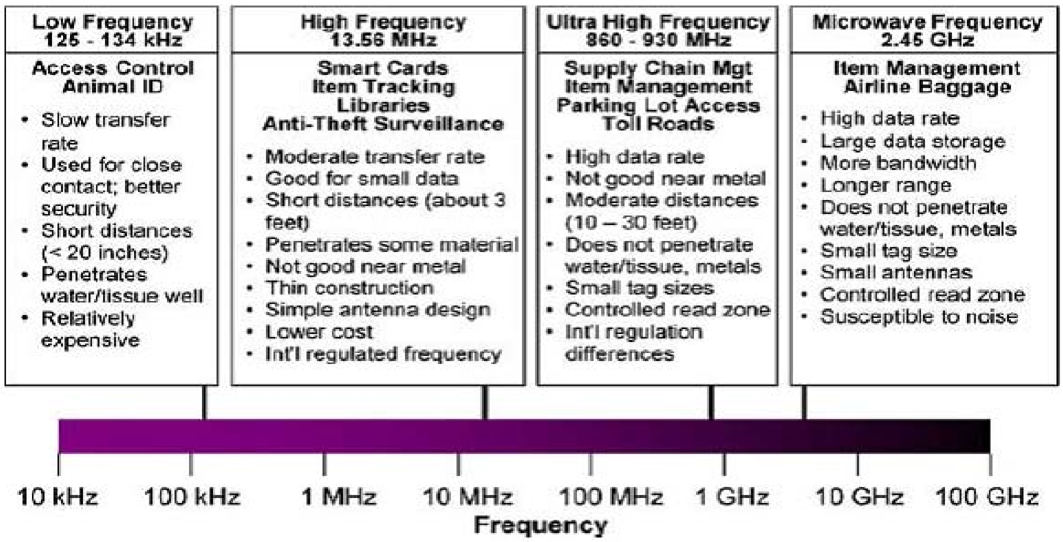
RFID readers are the communication medium between RFID tags and an information system (Jun, Lee & Shi, 2009). Whatever the complexity of the reader its role is to provide energy to, and communicate with, the tag, most often to retrieve its code. Readers can also have other interactions with tags, which may be for example instructions remain silent, or may be write rather than read targets. RFID readers come in a variety of forms. RFID portals are primarily used at door frames or at one end of a conveyor belt. Tagged items go through the portal, which are then read by the portal. However there are also shelf readers and handheld readers which are mobile and can be used by a person to read tagged objects (Jun et al., 2009).

RFID readers consist of a control system, radio interface and antennae. The control system consists of a micro-controller and in some cases additional task and application-specific modules (for example digital signature or cryptographic co-processors) and one or more networking interfaces. The role of the control system is to directly communicate with the tag and interact with applications. The controller directs the scanning plan that the reader executes to collect tag observations, and processes the incoming stream of RFID readings that are produced as a result of the execution of this plan (Roussos, 2008).

The radio interface is responsible for modulation, demodulation, transmission and reception (Roussos, 2008). Through the method of inductive coupling, RFID readers communicate with tags. The coiled antenna of the reader creates a magnetic field with the tag's antenna, which subsequently draws energy from this field and uses this to send back waves to the reader. These waves are transformed into digital information representing the EPC or other data (Angeles, 2005). The read range of the tag depends on both the reader's power and the frequency used to communicate (Roussos, 2008).

The frequency of a RFID system refers to the operating frequency of the reader. The frequency determines the reading range of a system and determines the interoperability of systems for global use (Rochel, 2005). The frequency of RFID tags can be classified into low frequency (LF), high frequency (HF), ultrahigh frequency (UHF), and microwave. The LF system has a short reading distance and is mainly applied in entrance control. HF tags can be read from longer distances but they require more energy output from the readers. The reading distance in the UHF is long and is often applied in the electronic seal of containers (Lin, 2009). Figure 3.6 shows the frequencies and their common RFID uses.

Figure 3.6. RFID Frequencies and Uses



Source: Curtin et al., 2007, p. 90

The antenna is usually very simple hardware components, containing metal strips or plates in a rugged housing. Coaxial cable connects the antennas to the reader which modulates the power to the antennas, creating the electromagnetic field (Shah, 1999). The antenna can vary in size and structure, depending on the communication distance required for a given system performance.

3.3.3.4 Middleware

RFID systems can deal concurrently with a large number of tags that may additionally be moving at relatively high speeds. The resulting observations create streams of RFID readings that must be cleaned, smoothed and further processed into higher level events that can be consumed by applications. This task is carried out by RFID middleware (Roussos, 2008). Middleware interprets events from the raw data streaming from an array of interrogators. It removes incomplete data and filters irrelevant information such as individual items within a pallet (Roussos, 2008). More importantly, it coordinates the updating of information in other enterprise systems like MRP, ERP and CRM (Angeles, 2005). For example, middleware may recognize that a specific tag has disappeared from the field of one reader only to appear in the field of another. In this event, middleware would determine that the item had moved and might credit and debit the appropriate accounts in an enterprise cost accounting system, update the order status in a customer's extranet portal, and place a replenishment order in the manufacturing plant's MRP system (Shah, 1999).

The interface between EPC numbers and the data about the item is provided by the Object Naming Service (ONS) which translates the EPC number into useable information about the manufacturer and product. The ONS provides a lookup service to translate an EPC™ number into an internet address where the data can be accessed (Harrison, Moran, Brusey, & McFarlane, 2003).

3.3.4 RFID Benefits

When successfully integrated into supply chain business processes, RFID technology improves inventory record inaccuracies (Heese, 2007), enhances organisational coordination and control (Cannon et al., 2008), enables real-time data collection and sharing among the supply chain stakeholders (Bose & Pal, 2005; Fosso-Wamba & Boeck, 2008), and improves supply chain efficiency and effectiveness (Bose & Pal, 2005; Michael & McCathie, 2005; Loebbecke, 2007; Loebbecke & Huyskens, 2008; Moon & Ngai, 2008). All these benefits, if realised, would enable the supply chain to operate more effectively, which would improve the competitive advantage at the firm level (Leimeister, Leimeister, Knebel & Krcmar, 2009). The key areas that RFID affect are inventory visibility and levels, supply chain integration and costs of labour, materials, processes etc. (Curtin, Kauffman, & Riggins, 2007; Gaukler, Seifert & Hausman, 2007; Angeles,2005; Cannon et al., 2008; Yee, Tew, Tang, Kim, & Kumara, 2009; Shepard, 2005).

3.3.4.1 RFID versus Barcode

Automated identification of items has been around since Barcoding was first patented in 1949. Barcoding has been in common use since the late 1960s (Mullen & Moore, 2006). Barcodes drastically reduced the amount of labour needed to operate retail stores, improved unit pricing and inventory accuracy, and shortened countless checkout lines. Due to these reasons, and their ability to be printed directly onto packaging or stuck to items which makes them cheap, they are currently the foremost means of inventory identification in the world (Schuster, Allen & Brock, 2007).

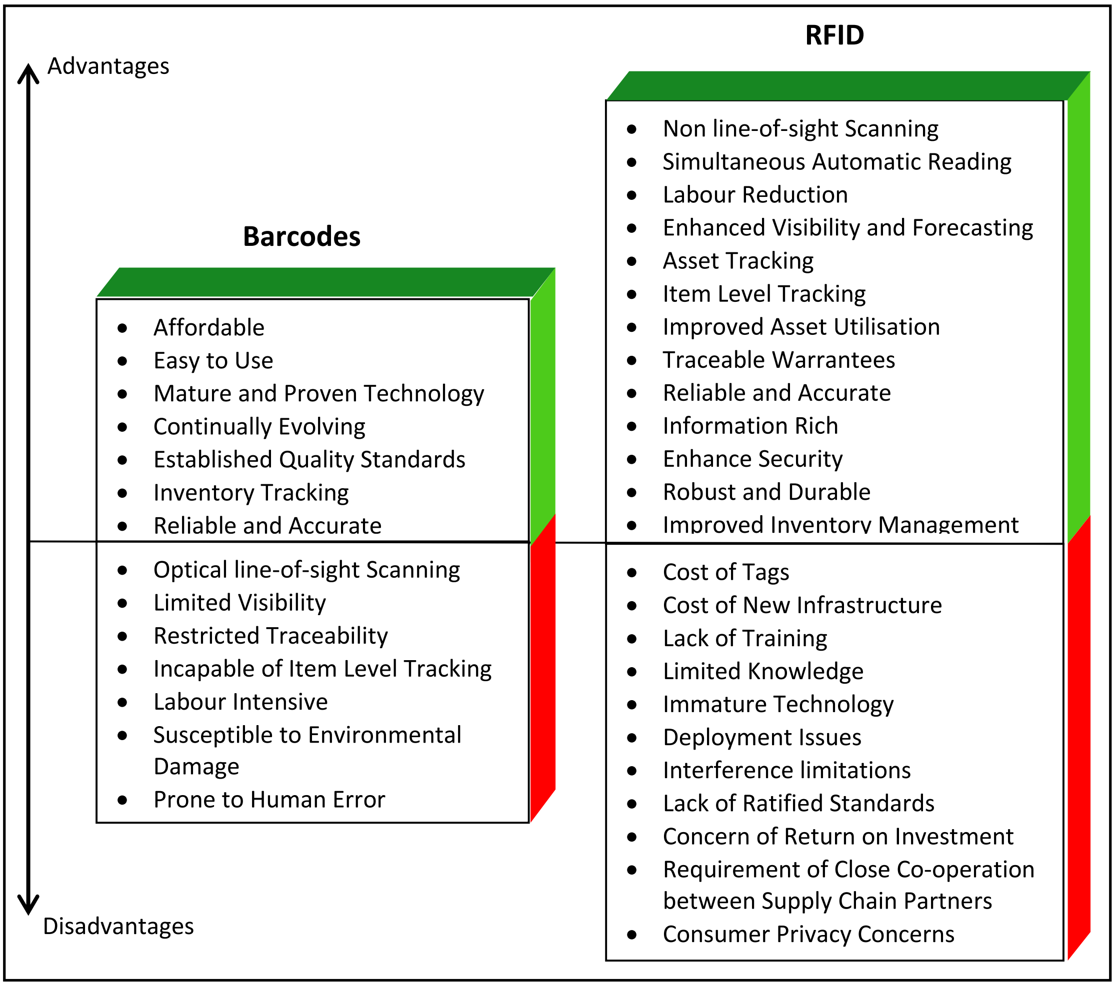
Shephard (2005) believes that while Barcodes will retain a place in inventory management it is RFID which will become the predominant form of item tagging. Roussos (2008) agrees when he says that despite their great success and popularity, bar codes have several limitations. Reading a bar code requires a line of sight between the label and scanner, a process that often involves human intervention. A label is typically printed and affixed to the product packaging and for this reason is exposed and likely to be damaged making it no longer possible to identify the marked product. General purpose bar codes only store a small amount of data. Schuster et al. (2007) claim that it is this last reason which will lead to the demise of the barcode. They say that because of an increase in the intricacy and sophistication of products, the needs of business are moving beyond identification of product type to unique identification of individual objects by serial number. This represents a significant transition because unique identification introduces a much greater degree of complexity in system management.

According to McFarlane and Sheffi (2003) other advantages of RFID systems over barcode systems in supply chain operations are:

- Speed – many tags can be read simultaneously into a computer, rather than reading a single tag at a time.
- The content of various conveyances (such as trailers, cases, pallets, shopping carts) can be read automatically without opening and sorting the conveyance.
- Durability - Bar codes do not work well when exposed to weather elements, when dirty, or if damaged in a way that interferes with clear line-of-sight reading.
- Location – RFID readers can provide rough location information, particularly when the goods being scanned are moving relative to the reader.

Figure 3.7 provides a comparison of the advantages and disadvantages of RFID and Barcodes.

Figure 3.7. Comparison of RFID and Barcodes



Source: (Huber et al., 2007)

3.3.4.2 Visibility

Supply chain visibility is the firm's ability to track the flow of goods, inventory, and information in the supply chain in a timely manner (Veramani et al., 2008). A firm having supply chain visibility can reduce bottlenecks, out-of-stock or low inventory levels in its supply chain. Visibility significantly lowers the uncertainty of goods in a supply chain and allows firms to track and manage the flow of inventory or products. As a result, this decreases bullwhip effects (Arshinder & Arun, 2008). For instance, Wal-Mart reduced its inventory stocks by 10% due to RFID adoption (Roh, Kunnathur & Tarafdar, 2009). The application of RFID can result in significant improvements in supply chain visibility (Angeles, 2005; Muckstadt, Murray, Rappold & Collins, 2001; Suri, 1998; Veramani et al., 2008). In particular improvements can be made on inventory accuracy, stock-outs, shrinkage and inventory reduction.

Inventory Accuracy

RFID in supply chain management provides the capability to provide item-level information visibility. This gives accurate knowledge of inventory levels and can eliminate any discrepancy between a physical count and inventory records (Autry & Sanders, 2008). The benefits of this are reduced error rates, reduced requirement for stocktaking and reduced uncertainty

Inventory accuracy occurs in a large part due to errors in transactions, counts and misplacement. A high proportion of these errors are due to human input. RFID allows more automation which removes this source of inaccuracy (Becker, Winkelmann & Fuchs, 2009). Veeramani, Tang and Gutierrez (2008) believe that RFID enabled automatic identification of pallet loads, cases, locations and loading docks during picking and shipping activities can considerably reduce the possibility of errors. In addition the tracking functionalities that RFID provide, allow an organisation to obtain real-time information about the location and properties of tagged objects (Angeles, 2005). This allows errors to be discovered quicker or eliminated automatically.

Organisations are able to conduct more stocktakes with RFID because they allow rapid inventory counting. This ensures that inventory accuracy remains high despite routine shrinkage. Blanchard (2007) found that one organisation was able to reduce the amount of time needed to track inventory on the sales floor in holding areas and in the back room by as much as 90 percent.

The increase in inventory accuracy through reduced errors and improved stocktaking facilitates a reduction of uncertainty which improves supply chain coordination, reduces inventory, increases product availability, improves total quality, provides better management of perishable items and returns (Zhou, 2009). Key among these areas is the reduction of stock-outs.

Stock-outs

Inventory misplacement is expensive and is prevalent in many industries. Stock-outs occur due to multiple sources of error within an organisation, such as the distribution centres poor product availability, inaccuracy in inventory information from its retail and suppliers stores, and poor store replenishment policies (Hardgrave, Waller & Miller, 2006; Veramani et al., 2008). An empirical study by Raman et al. (2001) shows that the inventory loss proportions can reach significant numbers in retail stores, up to 16% in some cases. When items are misplaced in the store, they become unavailable to the customers until they are found. One of the ways to handle misplaced inventory is through RFID devices (Camdereli & Swaminathan, 2009).

Various authors argue that RFID has great potential to reduce the stock outs at points of sale, generating benefits for both the manufacturer and the retailer (Alexander et al., 2003; Hardgrave et al., 2006; Veeramani et al., 2008). Miragliotta et al. (2009) are in agreement and say that RFID could reduce stock outs through automatic identification of goods. This will increase the accuracy of both the shipping and the receiving processes and improve product visibility along the supply chain. This in turn increases the accuracy of the inventory information and consequently, the service level at both the manufacturer and the retailer facilities. At the retail store, increased visibility can trigger replenishment when there is a stock out on the sales floor, but there may be stock in the backroom. Roh et al. (2009) reported that Wal-Mart experienced a 16% decrease in out-of-stocks after it began using RFID.

Shrinkage

Inventory loss or shrinkage involves all forms of loss of the products available for consumption. Shrinkage can occur because of theft, damage, spoilage, expiration or obsolescence and process errors. Lee and Ozer (2007) report that between 10% and 66% of the original shrinkage observed is reduced after implementing RFID technologies. Without RFID the inventory reduction due to shrinkage is not known to the system until a stocktake is completed. This means the retailer's replenishment decision is often made based on the inaccurate inventory leading to excess or deficient stock (Lee, Cheng & Leung, 2009). RFID is able to affect shrinkage by reducing process errors, the main causes of shrinkage and by preventing the loss of stock through theft or expiration (Alexander et al., 2003; de Kok et al., 2008, Miragliotta et al., 2009).

Proctor & Gamble estimated the loss by product theft was 2% of revenue for consumer goods (Kinsella, 2003). Roh et al. (2009) reported that the total losses that the retail industry faced due to shoplifting and employee theft in 2005 was of the order of $30 billion and Woolworths stated that 55% of all product theft happens in the supply chain before goods reach the retail store. Theft reduction with RFID is effective through deterrence and capture. Blanchard (2007) explains that not only can RFID identify when a consumer leaves the store without paying for something, but it can also set off an alert when an employee tries to steal goods from the warehouse or distribution centre. If an item is successfully stolen the losses can be quickly tracked and attributed to the person responsible for that stage (Miragliotta et al., 2009).

Further losses to stock through expiry or obsolescence can be prevented through use of RFID. With RFID, organisations can store and transmit data, such as when the product item is manufactured, expiration dates for perishable items, and a record of the temperature at which an item is shipped. This allows more proactive stock rotation and better storage (Chen, 2004; Tracy, 2005).

Inventory reduction

The implementation of RFID can contribute to a reduction in inventory mainly due to increased confidence in the system which reduced the need for safety stock (Walden, 2006). Lee, Cheng & Ying (2004) found that the use of RFID enabled the retail store to replenish their shelves more often and at the right time, resulting in a reduction in the need for safety inventory at the store as well as reduced probability of lost sales. Veramani et al. (2008) also identify the ability of suppliers to respond quickly for inventory replenishment, and the increased visibility of this data to suppliers coupled with their ability to quickly replenish inventory, also result in lower inventory and safety stock levels across the entire supply chain. Roh et al. (2009) reported that with the introduction of RFID Wal-Mart was able to reduce its inventory stocks by 10%.

3.3.4.3 Integration

A further major benefit of RFID is its unique capability to share information with business partners, allowing collaboration on inventory management, planning, forecasting, and replenishment (Trailblazer System, 2004; Vijayaraman & Osyk, 2006). Heinrich (2005) agrees and says that RFID systems will improve flows in supply chains. RFID enables any tagged entity to become a mobile, intelligent, communicating component of the organisations overall information infrastructure (Curtin et al., 2007). Anecdotal testimonials from retailers attest to the potential for building supply chain relationships (Angeles, 2005; Arnold & Bures, 2003; Michael & McCathie, 2005; Shim, 2003; Tracy, 2005; Traiman, 2002).

3.3.4.4 Cost and Labour Savings

Another one of the major benefits of RFID is the savings in labour and costs that can be made. Major cost savings come from automation of processes such as the generation of pick lists of items, eliminating the need for restocking the shelves periodically and yielding added savings in labour and time (Roh et al. 2009).

The case study conducted by Tellkamp (2006) showed that process automation of formerly manually performed activities is a strong benefit of RFID systems.

Process automation is the partial and complete transformation of manual tasks performed by people toward automatically performed activities operated by RFID systems. These tasks can include data entry, data processing, shipment reconciliation with bills of lading and packing lists, stocktaking through to generation of pick-lists for restocking shelves (Roh et al., 2009). Automation of these tasks reduces completion durations, error rate and consumption of auxiliary materials. Automation of routine activities can give big gains (Becker et al., 2009).

The requirement for scanning barcodes is one such activity that can see good improvements through the use of RFID as there is no need for repeated search and scanning in the inventory tracking and storing processes (Becker et al., 2009). Katz (2006) found that that RFID can reduce the amount of time to receive product at a warehouse. Instead of scanning each case of product individually with a barcode scanner, the RFID tagged product can be read automatically at a dock door portal. Gillette reported a reduction from 20 seconds to 5 seconds a pallet receiving at their distribution centre due to RFID (Katz, 2006). Katz (2006) reported that the process of receiving was not drastically changed (i.e. forklifts unloaded the product as before). The only change was eliminating the need to manually scan the product. Thus the process became more efficient.

3.3.5 RFID Limitations

While the majority of literature on RFID espouses its benefits there are some major limitations which have been inhibiting the widespread implementation of RFID (Vijayaraman & Osyk, 2006; Brown & Bakhru, 2007; Lee & Shim, 2007; Leimeister, Knebel & Krcmarl, 2007; Edwards, 2008; Shih, Chiu, Chang & Yen, 2008).

In some cases the initial enthusiasm about RFID has at least partly given way to a more disillusioned assessment (Lacy, 2005). Blanchard (2007, p. 248) agrees and says that while “the benefits as promised have been substantial; as delivered they appear to be more ephemeral.” Lee and Ozer (2007) reviewed the estimates of RFID benefits that were reported by numerous consulting companies and solution providers. They concluded that there was a credibility gap in all the reports, and in extreme cases, these amounted to hype.

Part of the problem has been the unrealistic expectations of RFID. Woods (2004) claimed that much of the enthusiasm for RFID tagging projects came from a fundamental misunderstanding of the technology. Wharton (2005) agreed when he said that expectation among many people is that being able to track every unit of inventory in the supply chain will somehow 'magically' improve inventory management.

Another reason is the lack of information on RFID implementations. Moore (2005) reported that most RFID vendors and systems integrators have signed non-disclosure agreements, thereby preventing them from discussing these RFID implementations. Visich, Li, Khumawala and Reyes (2009) highlighted that with all these suppliers deploying RFID there is still a lack of information concerning the quantitative results of those deployments. Hardgrave and Miller (2006) examined the popular myths surrounding RFID and concluded that separating myth from reality should help provide rational expectations and perceptions so that organisations, consumers, and governments have a more realistic understanding of RFID.

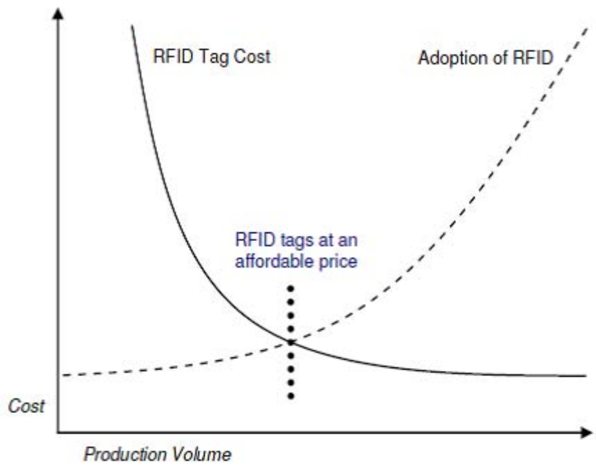
However there are some real limitations of RFID that need to be carefully considered when deciding to implement it. These limitations include cost, security, information processing requirements, readability problems, standardisation and supply chain collaboration.

3.3.5.1 Cost

One of the barriers to the adoption of RFID by organisations is difficulty in assessing the potential return on investment (ROI) (Veramani et al., 2008). Kapoor (2009) claims that it is the vagueness of cost-benefit analysis, which includes both unknown cost structure and unclear future payoff, which is a major impediment of RFID adoption. In general, the costs associated with RFID adoption usually include the costs for infrastructure instalment, marginal cost on various tags and receivers, and opportunity cost. While the instalment cost and marginal cost are relatively easy to measure, the opportunity cost is usually rather difficult to quantify. Kapoor (2009) also believes that as more and more implementations become available, the experience gained from these would provide the necessary information to generate informed estimates of costs and associated returns on investment (ROI).

Henrici (2008) says the costs of RFID tags are often the decisive element in RFID systems because the tags are needed in large quantities. Shepard (2005) states that RFID remains expensive and that this represents a significant barrier to adoption. The price of an RFID tag is relative to the law of economies of scale. Economies of scale refers to the decreased per unit cost as output increases (Besanko, Dranove, Shanley & Schaefer, 2004). Curtin et al. (2007, p. 90) say this is easily recognizable as a “chicken-and-egg technology adoption and diffusion game.” They say it will be necessary for market demand to dramatically increase, creating additional volume-based manufacturing results. However, for the demand to materialize, RFID tags will need to be cheaper and more effective than they are currently (Curtin et al., 2007). Huber et al. (2007) illustrate this in Figure 3.8 which shows that as the price of RFID tags fall and become more affordable, the adoption of RFID will increase.

Figure 3.8. RFID Adoption Model



Source: Huber et al., 2007

Gaukler et al. (2007) disagree with the cost issue being critical. They claim that the cost of RFID tags is over-emphasized. In all the studies that they have conducted, it turned out that the RFID cost could easily be absorbed over a few years. They claim with barcodes, the label cost is low, but the incremental cost of each scan is high, because it typically involves human labour and a break in the material flow. With RFID, the tag cost is higher, but the incremental cost of each scan is very low, because scans can be performed automatically by stationary readers as goods flow by. Das and Harrop (2008) also belief that while RFID implementations are more expensive than a comparable bar code implementation, their benefits through reducing labour, out-of-stocks, shrinkage, etc. are expected to far exceed costs.

Want (2006) thinks that RFID is now at a critical price point that could enable its large scale adoption for the management of consumer retail goods. He says that when adoption begins to take hold it will rapidly accelerate as volume production drives prices down, making it more attractive to deploy the technology to support a wider range of markets.

3.3.5.2 Security

The increasing use of RFID has raised concerns with security. With an increase in applications and in relevance of the RFID technology, the number of attackers will also increase (Henrici, 2008). There are five key areas to be considered with security of RFID. These areas are unauthorised reading of tags, tampering with tag data, eavesdropping on the communication between the tags and readers, removal of tags and privacy issues.

The first issue is the unauthorised reading of tags. While the unauthorised reading of the tag from a product like shampoo appears to present very little danger, this information can be used by a competitor to follow a supply chain to find out how they are being undercut in price (Bumbak, 2005). For more technical or expensive equipment, unauthorised tag reading can be used to determine which store or truck to break into (Roussos, 2008). This is a major concern for the military.

The second issue is preventing the unauthorized changing of the data on the tag. Tools are available that can manipulate tag data. This data change could be done by a thief who could change the identity of the product, making a very expensive good read as a cheaper good at the automated cash register at the exit of some retail store (Roussos, 2008). An even worse scenario could be changing the data on a tag to change the delivery information (Bumbak, 2005). To address this issue some RFID tags have incorporated a defence system that involves cryptography to prevent tag tampering. This system can use a rolling code where the tag identifier information changes after each scan (Autry & Sanders, 2008)

The third issue is preventing someone from eavesdropping on the communication between the tags and readers. The presumed problem here is that if someone can tap in on the communication, he can gain valuable information about the tag, data on it, encryption methods and/or the reader. All that information can later be used for unauthorized access to the tag, identity theft (substituting identity codes on products), tampering with the data or some other forms of malicious wrongdoing (Roussos, 2008). Although readers may only read tags from within the short tag operating range, the reader-to-tag, or forward channel is assumed to be broadcast with a signal strong enough to monitor from long range, perhaps 100 meters (Weis, Sarma, Rivest & Engels, 2004). A solution to this is to limit the number of times when the reader broadcasts an ID number to the tag. The reader can, for example, break up the serial number and only broadcast a part of it. The tags that have the same part of the serial number respond, but this time with the full number. This way full number is only sent in the reverse channel, which is a whisper, compared to the forward channel, which is by necessity a lot louder. By doing this the probability that an eavesdropper will obtain complete serial number is reduced significantly. Another solution is to encrypt communication reader-to-tag and the other way round (Bumbak, 2005).

The fourth issue is preventing the removal or killing of the tag. Many tag specifications include a kill command that enables retailers to permanently deactivate the tag at a consumer's request (Slettemeås, 2009). This has a serious drawback in that it creates a backdoor that those with ill intent could use to circumvent the system. This can be combatted by the use of secret kill codes that the reader needs to send to the tag in order to kill it (Roussos, 2008). Physical removal of the tag is especially worrying for expensive goods retailers and other supply chain participants (Bumbak, 2005). A possible solution to this is integrating the tag into the produce. An example of this is Rolex who now embed an RFID chip into their watches. This helps insurance companies recover stolen watches (Walden, 2006). Other methods are using pressure sensitive labels which fall apart when removed or using tags that would react when tampered with and notify the owner (Bumbak, 2005).

The fifth issue is privacy concerns. Privacy issues surrounding RFID mainly relate to the potential misuse of data by authorised users, leading to the violation and invasion of individual or business privacy (Bhuptani & Moradpour, 2005, Gunther & Spiekermann, 2005; Thiesse, 2007). Some consumer protection organisations are vehemently against the spread of RFID tags in consumer applications due to the concern that tags affixed to products continue to remain functional even after the products have been purchased and taken home (Slettemeås, 2009). The tags could potentially be used for surveillance, and world-readable tags pose a risk to personal location privacy (Autry & Sanders, 2008). Moreover, it does not take much effort to associate tags with their owner’s demographic and other information to violate their privacy and security (Bumbak, 2005).

Roussos (2006) maintains that most consumers do not trust retailers when it comes to complying with the EU Data Protection Directive, and he believes that even though low-level mechanisms and technical tools (such as tag killers or blocker tags) can ensure some compliance with relevant EU directives,“they are unlikely to conclusively address consumer concerns because the users interact with RFID systems at a much higher conceptual level.

3.3.5.3 Information Processing Requirements

An issue not often considered with RFID is the amount of data it generates and the requirement to process this data. Compared to barcodes RFID tags generate more information per scan, and they are scanned more frequently (Kapoor et al. 2009). Even modest RFID systems generate gigabytes of spatial and temporal data per day, a good portion of which is incomplete, thus creating data cleansing, storage, and modelling problems (Derakhshan, Orlowska & Li, 2007). It is estimated that when item-level tags are used, Wal-Mart is expected to generate about 7 terabytes of data every day (Otondo, Pearson, Pearson, Shaw & Shim, 2009). Computing resources such as memory, communication bandwidth, and computer hardware need to be of primary concern when an organisation adopts RFID (Kapoor et al., 2009). A successful RFID application requires a software system capable of consolidating the large amount of data captured by existing SCM software (Bose & Pal, 2005). Such systems used to integrate supply chain members include e-procurement and e-logistic systems, trade exchanges, network communications, electronic data interchange (EDI), and customised middleware (Bose & Pal, 2005; Zahay & Handfield, 2004).

3.3.5.4 Readability Issues

Performance of an RFID system depends on several factors such as the orientation of tag and reader antennas, the material of the item to which a tag is attached, and the environment in which the system operates. Performance degradation can be severe enough in some situations to pose reliability problems (Chawla & Ha, 2007). Issues that can affect readability are physical interference and signal interference.

Physical interference occurs due to the limitations of the ability of the signal to pass through certain materials including human and animal tissue, liquids, various metals, and other types of packaging materials (Asif & Mandviwalla, 2005). The reason for the problems is that these materials inhibit the propagation of electromagnetic waves, which is the medium of communication that RFID uses (Gaukler et al., 2007). For example while tags on liquid containers can be read when there is line of sight between the reader and the tag but they may not be able to read when the container is in the middle a pallet of liquid containers. Possible solutions to this are to ensure there are sufficient air gaps between the bottles on that pallet, or to rotate the pallet while reading tags. That way, the reader will "see" tags at different angles and the tag read rate would increase (Gaukler et al., 2007).

Radio-emitting devices such as machines using electro-motors, microwaves, or radios, TVs and other RFID readers create an environment that is prone to interference with RFID tag reads (Gaukler et al., 2007). This creates signal interference which prevents the reader getting an accurate reading of the signal to and from the tag. This is also a problem when the reader is trying to read several tags in close proximity to each other or through the interference from other readers. This is called reader collision (Curtin et al., 2007). The first type of collision problem occurs when readers are trying to read many tags in the same field (Angeles, 2005). In this case getting an accurate reading of the signal may be hampered by the close proximity of other tags, potentially limiting the number of different items that can be counted in the same container or that can be read at the same time (Curtin et al., 2007). Angeles (2005) identifies that a possible solution for this is to make readers ask tags to respond only if their first digits match the digits communicated by the reader. The reader keeps querying the tags until such time when one and only one tag responds, which is the desired condition.

The second type of collision involves signals from one reader that can interfere with signals from another reader when their physical coverage overlaps (Curtin et al., 2007). Angeles (2005) identifies that a possible solution to this problem is programming the readers to read tags at different times rather than simultaneously.

This will create multiple reads for some items so an ancillary system is needed to delete duplicated codes.

There are two types of errors associated with whether RFID will read a tag or not. The first type error is a false negative read. This is when a tag is not read at a location where it physically is. The second type of error is a false positive read. This is when a tagged object is read in a different location to its physical one. An example of how this might occur is when a shipping staging area is near to a receiving area the system might pick up the signal from the shipments reader from an item physically in the receipts area (Walker, 2006).

It is possible to mitigate many of these issues but it takes time. Walker (2006) says that reader and tag orientation are key to extracting high read rates out of an RFID setup. Gaukler et al. (2007) say that while detailed theoretical scientific research on how to select readers and antennas exists (Keskilammi, Sydanheimo, & Kivikoski, 2003), outside of a laboratory setting, trial and error prevails.

3.3.5.5 Standardisation

The creation and adoption of official standards can powerfully accelerate the adoption of new technology (Bhuptani & Moradpour, 2005) and RFID is no exception. RFID standards generally address issues related to tag and reader frequency, air interface protocols, data structure, data content and format, tag and reader types, tag and reader conformance, code assignment, and data communications (Kapoor et al., 2009).

Currently there is no global public body to govern the frequencies that are used for RFID, and in principle each country can set its own rules (Rochel, 2005). In a global business environment, the lack of interoperability between different RFID based systems will deter users from making large investments in a technology that is intended for global use (Ngai, Moon, Riggins & Yi, 2008). Edmonson (2005) reports that there are currently two standardisation bodies investigating an international unified standard. These are the EPCGlobal incorporation, an organisation formed by technology vendors as well as RFID-deploying companies, and the International Standards Organisation (ISO).

3.3.5.6 Supply Chain Collaboration

Full realisation of the value of RFID requires wide adoption among trading partners (Curtin et al., 2007). Bendavid, Lefebvre, Lefebvre and Fosso-Wamba (2009) underscore the importance of seamless integration of RFID technology with intra and inter-organisational processes and systems to reduce inefficiencies in the supply chain, and to facilitate more collaborative practices. This is supported by studies by Bovenschulte, Gabriel, Gasner and Seidel (2007), and Lai, Wong and Cheng (2006) which concluded that the full benefits realisation of RFID-enabled supply chain projects depends on knowledge-transfer and knowledge-sharing. Bendoly, Citurs and Konsynski (2007) strongly suggest that it is necessary to set frameworks, guidelines, tools, and mechanisms to help define the scope of the RFID supply chain project and the level of organisation transformation, and that it is necessary to identify the realistic benefits and costs at the supply chain level as well as at the firm level. Other areas to be considered across the supply chain are: the integration of RFID systems with existing intra and inter-organisational information systems and business processes and also allocation between RFID implementation costs and the realised benefits for each of the supply chain stakeholders (Bensel et al., 2008).

3.3.6 RFID Applications

There is a wide range of RFID systems currently being used or being developed. The key areas are supply chain, retail, asset management, food traceability, healthcare and manufacturing. In addition there are numerous other applications used which include, but are not limited to, the following: access control for buildings and vehicles transport payments, passports, airport passenger and baggage tracking, tracing blood, payment process systems, libraries aviation, construction, mining and museums (Kasap et al., 2009; Ngai et al., 2008; Chawla & Ha, 2007).

Supply Chain

The benefits of RFID in supply chains include (Angeles, 2005; Chawla & Ha, 2007; Jansen & Krabs, 1999; Twist, 2005):

- automation of warehousing and distribution such as automated receipts, put-aways, issues, order filling and being able to send advanced shipping notices
- superior tracking of goods, leading to a reduction in lost goods
- reduced inventories
- increased inventory accuracy
- anti-counterfeiting using embedded RFID tags to identify genuine products
- improved stock management through real-time awareness of stock

Retail

In addition to the benefits from being part of a supply chain, the benefits to retailers include (Angeles, 2005; Chawla & Ha, 2007; Jones, Clarke-Hill, Hillier & Comfort, 2005; Prater et al., 2005; Karkkalnen, 2003):

- reduced stock-outs
- reduced theft
- reduced misplacement
- reduced inventory
- increased inventory accuracy
- automatic replenishment

Asset Management

According to Curtin et al. (2007) the benefits of RFID in asset management include:

- improved availability
- reduces hoarding
- reduced theft and therefore replacement costs

- reduces the time required to conduct asset inventory checks allowing them to be done more often or in real-time
- reduced time for employees searching for equipment to use it

Food Traceability

Increasing concerns about animal health, potential bio-terrorism, food safety and consumer demand for source information, have made animal and meat traceability essential (Tonsor & Schroeder, 2004). The benefits of using RFID for food traceability include (Pettitt, 2001; Bose, Ngai, Teo & Spiekermann, 2009; Hall & Hampi, 2004; Jones, Clarke-Hill, Comfort, Hillier& Shears, 2005):

- ability to trace and follow an animal or food source throughout the chain
- identification of source of problem goods
- quick and targeted recall of product

Health

The benefits of RFID in healthcare include (Attaran, 2009; Bose et al., 2009; Chawla & Ha, 2007; Venkatesan & Grauer, 2004):

- tracking hospital personnel, equipment, and supplies
- checking for counterfeit products
- preventing errors in healthcare administration
- monitoring the issue and management of drugs, blood, samples
- tracking surgical equipment and supplies e.g. RFID tag alerts the surgeon when a sponge might accidently be left in the patient
- maintenance of shared yet secured medical records

Manufacturing

According to Curtin et al. (2007) and Liu & Miao (2006), the benefits of RFID in manufacturing include:

- coordination of the flow and handling of materials
- tracking manufacturing equipment usage
- automated inventory replenishment

- improved workflows
- elimination of manufacturing bottlenecks due to materials handling delays

3.3.7 Implementation of RFID

RFID brings a lot to the supply chain. It is a powerful, utilitarian technology that, if deployed properly, yields serious benefits (Angeles, 2005). Like all new technologies however it must be deployed with forethought and careful planning if its benefits are to be realized (Shepard, 2005). There are numerous risks associated with the RFID technology than an organisation should carefully address in order to improve its chance for successful deployment (Lim & Koh, 2009).

As the implementation of RFID has the potential for affecting other parties in the supply chain so the decision to implement it needs to be made by considering more than just the single company. The needs and requirements of upstream suppliers, downstream customers as well as logistics providers need to be part of the decision process for the implementation of RFID (Gaukler et al., 2007). This is especially essential in the case of mandated implementation. Cannon et al. (2008) believe that most firms evaluating RFID are doing so primarily to satisfy the needs or wants of their most important customers. A key example of this was Wal-Mart's initial requirement that every case or pallet from its top 100 suppliers be RFID tagged by the end of 2006 (Roberti, 2003).

Several authors agree that the development of complex projects, such as the implementation of RFID requires a clear definition of steps and activities to prevent its failure (Kim, Lee & Gosain, 2005; and Nah, Lau & Kuang, 2001; Bottani, Montanari & Rizzi, 2009). The following are the steps Reyes & Jaska (2007) recommend for implementation of RFID: achieve an understanding of what RFID can and cannot do, building the ROI business case, analyse the business processes presently in place and determine which processes need to be changed to fully utilize the RFID technology, conduct a pilot and finally the implementation and monitoring of the new system.

3.3.7.1 Understanding of Technology

Before an organisation decides to implement RFID there must be a clear understanding of what RFID can and can't do (Reyes & Jaska, 2007). As with past technologies, hype tends to create unrealistic expectations, which could lead to artificial perceptions of the technology. Hardgrave and Miller (2006) identified that many of the myths people had about RFID were exaggerated or untrue. The most important myth Hardgrave and Miller (2009) identified was that RFID is the panacea for creating the perfect supply chain, solving all of the problems in the supply chain. Organisations need to be aware that while RFID can improve supply chain performance it is not the panacea for creating the perfect supply chain (Reyes & Jaska, 2007).

3.3.7.2 Work out ROI

The second step is to look at the ROI for implementing RFID. Measurement of ROI of a new technology is always a challenging problem. The process of developing a ROI case for RFID implementation needs to be framed within an organisation's business context (Angeles, 2005).

The implementation costs of an RFID project include both the initial investment and recurrent annual costs. The initial investment includes the costs of hardware (e.g. readers, antennas, tags and possibly increased computer processing and data storage equipment, the software (middleware and software development/integration), and project management (design, implementation, test and change management, project management). The recurrent costs include the cost of tags (on pallet loads and/or cases), the maintenance of the RFID infrastructure, and the information transmission costs (Miragliotta et al., 2009).

Researchers have resorted to various methods and techniques for ascertaining the business value of RFID. Typically, business value is determined by collecting data through surveys of senior managers, and analysing the data using statistical techniques (Reyes & Jaska, 2007). Another approach is to conduct detailed case studies of firms that adopted the technology, and assess qualitatively the value of the technology over time (Bose et al., 2009). A third approach is to measure value quantitatively by conducting a thorough study of ROI by enlisting the costs and benefits of RFID (Lee & Ozer, 2007). Izadi and Boyd (2008) conducted a best-case and worst-case return on investment analysis on the deployment of RFID at a distribution centre by enumerating all costs and benefits explicitly and found that the savings per year was substantial. A limitation of cost benefit analysis is that some benefits may not be quantifiable. This limitation is addressed by Pal, Sengupta and Bose (2008), who used an assessment based on the Analytical Hierarchy Process that performed cost benefit analysis with estimates of the intangible costs and intangible benefits as well.

A key aspect when determining ROI is consideration of the allocation of costs for the system. Miragliotta et al.'s (2009) approach is to design a cost-sharing agreement between manufacturers and retailers to divide the tag costs in proportion to the achieved benefits. However this is a challenging situation, since sensitive data will have to be shared and information asymmetry is part of the conventional way of doing business in this industry (Gaukler et al., 2007). In the case of mandated implementation, item level tagging holds the most potential for the retailer, but is the costliest solution for the manufacturer who needs to put on the tags. Hence, in theory in a competitive environment, the manufacturer will generally need some kind of contractual incentive to incur the tag cost, and downstream supply chain partners will need to share in the cost of the tag (Gaukler, 2004).

3.3.7.3 Requirements Analysis

The third step is to conduct a requirements analysis. A thorough analysis of the current system and processes needs to take place. Following the analysis of the present system, a new process model needs to be developed that will utilise RFID to its full potential (Reyes & Jaska, 2007). This requires a thorough understanding of the organisation's goals of the implementation as well as RFID capabilities and limitations (Bottani et al., 2009). Nah et al. (2001) state that unclear or ill-defined project aims are one of the main reasons for implementation failure. Primarily, there are two broad objectives: improve efficiency (do something faster), or increase effectiveness (do something better). Within these broad objectives, the specific objectives can be detailed (Bottani et al., 2009). Reyes and Jaska (2007) are clear that defining the current business processes and understanding the requirements is vital in RFID implementation. Research has shown that integrating new technology with process redesign results in more benefits than just the technology alone (Clark & Stoddard, 1996; Riggins, Kriebel & Mukhopadhyay, 1994). Therefore RFID will require considerable process redesign at all stages in the value chain where the technology is to be applied (Chuang, 2005).

Fontanella (2004) identifies four kinds of RFID implementation projects including discrete process, intra-company, inter-company and synchronization. Discrete process is where RFID is applied only to manage a defined process, with the typical aim to improve its accuracy and/or efficiency. An example of a discrete process project is the use of semi-passive RFID temperature sensors in the cold chain (Edwards, 2007). With these projects data is generally not shared and is used in a closed-loop supply chain for the one stated purpose (Fontanella, 2004).

Intra-company projects are where RFID is implemented within a company for the integrated management of several processes (Fontanella, 2004). Most asset management projects fall under the intra-company project type. These allow companies to better track and thus manage their internal assets. For example, many hospitals are now using RFID to keep up with expensive, mobile medical devices (Collins, 2004).

Intercompany projects are where two or more companies exploit RFID technology to share real-time information about product flows (Fontanella, 2004). Detailed planning is required to enable information sharing and integrated management of processes and existing information systems. Examples of intercompany projects have been developed by Metro (Collins, 2006) and Wal-Mart (Swedberg, 2007) and their respective suppliers, such as Procter & Gamble and Unilever.

Synchronisation projects occur when RFID technology is implemented and adopted to manage an entire supply chain, resulting in an RFID supply chain network (Fontanella, 2004). The network is exploited to share EPC data between supply chain partners through the Internet and a suite of selected services (Harrison, 2004). Through this real time data-sharing mechanism, companies have broad and plain visibility over logistic flows and can leverage availability of accurate and updated information to optimize supply chain management (Fontanella, 2004).

3.3.7.4 Pilot Study

The fourth step is conducting a pilot study. A simple pilot project can be used to test different types of tags and readers, understand how RFID works in the firm's unique environment, observe required business process changes, perform rudimentary back-end integration tasks, and upgrade directly affected hardware and software infrastructure elements (Roberti, 2003). Angeles (2005) states that while the financial returns on an early pilot project may not be clear, the lessons learned from early initiation are well worth it.

Choosing the area to conduct the pilot is important. Roberti (2004) advocates using the business processes where the most benefits can be garnered within the shortest period of time in exchange for the initial pilot project investment outlays that will need to be made

Another important consideration according to Angeles (2005) is that it is essential to try the RFID technology with the firm's existing IT business application systems and not just focuses on the technology's ability to read tags. Angeles (2005) says that doing this leaves the firm with an incomplete understanding of the consequences of RFID technology on its existing operations and is an inaccurate representation of how things will eventually run when in production mode.

3.3.7.5 Implementation and Monitoring

The fifth step is the implementation of RFID and monitoring the results. The implementation will need a careful change management program (Hingley, Taylor & Ellis, 2007), detailed training (Jones, Clarke-Hill, Shears, Comfort & Hillier, 2004; Hingley et al., 2007; Goswami, Teo & Chan, 2008), integration of intra and inter-organisational information systems and business processes (Wamba & Chatfield, 2009), support of management (Brown & Russel, 2007; Seymour, Emma & Willuweit, 2007; Ngai & Gunasekaran, 2009), and importantly time to make it work. Once implemented, the RFID system needs to be monitored and continuous improvement measures need to be set in place. This will ensure that the system continues to meet expectations and evolve as needed to meet the needs and goals of the organisation and/or business unit (Reyes & Jaska, 2007).

3.3.8 Military Uses of RFID

United States

The United States Department of Defense (DoD) became involved in RFID during the 1990s due to the identification of supply chain challenges. During Operation Desert Storm in 1991, logistics and materiel distribution was a major problem. The Defense Logistics Agency (DLA) became known for “iron mountains” of unopened shipping containers in the middle of the Saudi Arabian desert (Overby, 2004). The lack of supply chain visibility required 25,000 of the 40,000 containers to be opened in order to identify their contents (Songini, 2004; Savi Technology, 2004). A Defense Research Projects Agency (DARPA) grant was awarded to Savi Technology to identify whether RFID could help prevent similar supply chain problems in the future. This resulted in several initiatives over the following few years. In 1995, the Joint Total Asset Visibility office was formed with a charter to provide asset visibility in-storage, in-process, and in-transit to optimize the DoD’s operational capability (Joint Total Asset Visibility Office, 2004) (Shah, 1999).

The Department of Defence adopted the use of active RFID tags on pallets in 1995 in Europe and by 1998 for most shipments in the continental United States. The purpose of these active tags was to provide greater visibility and tracking of supplies in the supply chain (Walden, 2006).

By 2004, the DoD had joined EPCGlobal™ and ran a pilot implementation, tracking rations from the vendor to the consuming unit through several supply chain participants and locations (Coyle, 2004). The pilot was successful, proving that the combination of sensors and RFID provided the DoD with significant capabilities in tracking supply chain quality in several key classes of material, especially ordnance and perishables (Shah, 1999). The DoD RFID Policy was finalised several months later.

On 30 July 2004, the Acting Under Secretary of Defense for Acquisition, Technology, and Logistics issued a policy requiring the implementation of RFID across DOD. The RFID policy directed military services and Defence agencies to expand immediately the use of high-data-capacity active RFID that currently were used in the DOD operational environment. The policy also directed the phased application of passive RFID by suppliers, who would be required to put passive RFID tags on cases and pallets of materiel shipped to DOD and on the packaging of all items requiring unique identification (Estevez, 2005). Beginning in 2005, DoD suppliers were required to put passive RFID tags on shipments of selected classes of supply going to two of their distribution centres. Additional classes of supply were included and nodes added over the next several years (Estevez, 2005). Full implementation was expected to be complete by 2008 but was not on target. Ray (2008) reported that a report from the Inspector General showed that the US Department of Defence was failing to follow its own mandate for RFID implementation despite sinking $12.2 million into the project.

Currently the US DoD has RFID implemented at all levels in the US and on operations. RFID is playing a critical role in the war efforts in Iraq and Afghanistan, according to Major General James L. Hodge, commanding general of the Surface Deployment and Distribution Command Division at Scott Air Force Base. Hodge (2009) explained that RFID enables the U.S. DOD to track the movements of cargo to and from these regions. Military cargo is tagged with passive EPC Gen 2 UHF RFID tags for warehouse tracking, while cargo containers are tracked by means of active RFID tags. Approximately 16,000 cargo items are tagged a week. He said that most of the supply chain into and out of the Middle East is managed through fixed RFID portals. Where portals are not available, or if closer management of a supply chain is necessary, they are tracked by more expensive satellite technology. Hodge said the tags serve three major purposes. Strategic data provides key leaders with visibility of the supply chain so they can make key decisions regarding the war effort, Operational data from the RFID system helps the military answer such key questions as "where's my stuff?" and tactical information helps those on the battlefield make decisions based on which supplies they have available.

Canada

The Canadian Operational Support Command (CANOSCOM) adopted RFID technology within the Canadian Forces supply chain to deal with challenges relating to the visibility, tracking and traceability of its logistics assets. CANOSCOM determined the technology would provide a means to significantly improve its supply chain efficiency and responsiveness (Xiao, 2008).

Defence Research and Development Canada (DRDC), an agency of the Department of National Defence (DND), responded to CANOSCOM's scientific and technological requirements for RFID systems. For example, a study was undertaken to address quantification and qualification of threats to the cargo and distribution system with the implementation of RFID technology (Xiao, 2008).

Canadian Forces transports many resources—ranging from consumables to tanks—to support its military operations. CANOSCOM's purpose is to provide effective and efficient support to Canadian Forces operations both at home and abroad, improving supply chain execution. One of its achievements in this respect has been to adopt RFID technology to track supplied (Xiao, 2008).

In 2006 Defence DRDC began looking at how to track Canadian assets deployed in Afghanistan. Specifically, DND wanted to track Canadian assets at multiple nodes using active RFID tags, write stations, fixed and handheld readers and early-entry deployment support kits. The solution was to establish a temporary intermediate staging team which used RFID technology to manage the rotation of vehicles and equipment in and out of a theatre of operations (Xiao, 2008).

DRDC then began further investigations into RFID including testing and evaluating different RFID systems, discovering and analysing security threats and researching corresponding countermeasures (Xiao, 2008).

United Kingdom

In 2000 the Defence Logistics Organisation was set up with a priority of giving the forces an integrated system. They developed a system called the Defence Stores Management Solution, but this proved to be unaffordable and technically challenging (Savvas, 2004). In 2002 the U.K. MoD began using RFID in its logistical process and supply chain as part of its total asset visibility (TAV) program (McCue, 2006). It wasn't until 2004 that they started introducing RFID tracking into its supply chain after being criticized at the end of 2004 by Parliament members on the Public Accounts Committee for failing to get the correct equipment to soldiers during the invasion of Iraq, despite spending more than half a billion pounds on asset tracking systems since the first Gulf War in 1991 (McCue, 2006). By 2006 Total Asset Visibility was in place and they began trialling an enhanced active RFID capability to provide further improvements in their consignment tracking capability (McCue, 2006).

Australia

In the late 1990s the Australian Defence Force (ADF) was struggling to track equipment shipments both inside Australia and overseas. During operations in East Timor in 1999, soldiers were reportedly unable to locate parts and supplies that had been shipped in to support them. This occurred again after the 2003 Gulf War. A study by Macmillan-Davies (2003) examined the potential of using RFID in

The Australian Defence Force and concluded that RFID could improve the ADF supply chain. In 2004, the Department of Defence was unable to finalise its annual report due to an A$800m inventory discrepancy, including A$200m in general stores. It was said that the gap was due to lack of visibility rather than theft or other issues. This prompted a project aimed at achieving a single military integrated logistic information system (MILIS) (Withers, 2008).

MILIS is based on a three-tier architecture. Tier one is a fixed, central capability within the national support base and supported with continuous communications. Tier two uses local servers deployed on ADF operations in areas with reliable if intermittent communications back to tier one. Tier three is highly mobile (e.g. laptop) and can be detached from tier one or tier two and deployed in areas with no communications for limited periods (Withers, 2008).

Tags are associated with stores items as they leave warehouses for the theatre, regardless of the mode of transport used. This is generally done at the pallet level, but multi-packs and critical items such as aircraft spare parts may be individually tagged. Fixed RFID readers arranged in portal configurations read the tags as freight enters or leaves warehouses and distribution modes along the supply chain. Mobile readers are used at air terminals and certain other nodes in the chain. Since May 2007 weekly supply flights into the Middle East Area of Operations have had active RFID tags on all cargo containers. These steps improve the visibility of stores and assets across the operational supply chain in support of the warfighter (Withers, 2008).

The ADF selected tags and readers from Savi Technology to allow interoperability with allied forces. Savi's military off-the-shelf system has been widely adopted for use in military supply chains. The contract with Savi was signed in August 2003 and the RFID project was completed in April 2007. The rollout covered 31 sites in Australia plus one overseas (presumably in Iraq), along with 60 field-deployable kits. All major Australian military sites are now equipped with RFID readers, but the focus is on overseas supply chains. One exception is the national support base, which does not use RFID but relies instead on the cargo visibility system. At this stage, the interoperability is potential rather than actual. Australia, the US, Canada and the UK have a memorandum of understanding regarding RFID interoperability, but at this stage only the US and Australia has compatible and interoperable RFID systems (Withers, 2008). An example of the field deployable kits is shown in Figure 3.9.

Figure 3.9. Portable RFID reader used by the ADF

Source: Withers, 2008, Picture 7

Issues affecting the use of the system in the field include ensuring the infrastructure is in place and sufficient bandwidth is available, a defence spokesperson says, along with providing initial and on-going training for personnel and embedding robust processes and procedures. The ADF's integrated logistics support process takes care of these issues, the spokesperson added (Withers, 2008).

New Zealand

The use of RFID in the NZ Army has been limited. Trials are currently underway to tag body armour and NZ Army is closely liaising with the Australian Army over their trials of RFID tags for weapons. The one use of RFID has been for the ordering of clothes for new soldiers.

Yakka Apparel Solutions (YASL) is the contracted supplier for clothing for the NZ Army. They implemented an RFID solution to improve the speed of supplying new soldiers with their clothing (Bacheldor, 2007). Each recruit has an RFID tag placed around their wrist. Once the solider has tried on and found the right size for a variety of clothing they stand in front of an RFID scanner. Each piece of clothing has an RFID tag attached so the scanner is able to read the size for all the layers of clothing the soldier is wearing (Elmes, 2005). Once all the items in the entitlement are accounted for the program automatically sends a purchase requisition in XML format to NZDF's computer system, which authorises the order and sends it through to Yakka via its existing intranet where it is loaded straight into the company's warehousing system. The result is guaranteed accuracy, and an order processing time that is quicker by more than two days (Elmes, 2005) Bacheldor, 2007 reported that NZ Army and YASL found the process eliminated data entry, saved time and ensured accuracy and completeness.

Other Nations

In 2006 the Spanish Armed Forces (SAF) installed an infrastructure of RFID interrogators at select Spanish military and logistics posts to enable the tracking of shipments. The SAF also created RFID interrogation zones at its posts in Afghanistan, Haiti, the Balkans, Kosovo and Bosnia-Herzegovina, as well as in four logistics hubs and naval and air bases within Spain. Spain's military purchased between 2,000 and 4,000 Savi Technology active tags for attaching to the containers of supplies it wants to track. These shipments included commodities such as food and clothing, but not ammunition (O'Connor, 2006)

Many other nations are also utilising RFID including, but not limited to Denmark, Sweden, Singapore, Germany and Poland.

3.4 Conclusion

This chapter reviewed the literature about SCM and RFID. For SCM the review examined the development of SCM, clarified the definition of SCM and its attributes, reviewed the benefits and problems with its use, reviewed how to

measure its efficiency and examined SCM in the military context. For RFID the review examined the development of the technology, gave a description of its attributes, benefits and limitations, reviewed the process of implementing the technology and reviewed where it is being used in a military context.
From the literature review it is easy to identify that supply chain management has been researched in detail in many industries and there is a good balance of theoretical and practical research conducted. One area that has not been examined in much detail is SCM in the military context and the evaluation of the efficiency of current supply chains in non-profit, government or military environments. The review shows that while there has been extensive practical research in many applications on the potential of RFID there is a shortage of research confirming the implementation potential of the technology in non-profit, government or military supply chains.

This research aims to establish a method of reviewing the effectiveness of military supply chains and determine the potential of RFID to improve this effectiveness.

Chapter 4 - Methodology

4.1 Introduction

Research methodology is the "principles and procedures of the logical thought process which are applied to a specific investigation" (Fellows & Liu, 1999, p. 4). According to Vogt (2005) research methodology is the study of research methods, from general problems bordering on epistemology to specific comparisons of the details of various techniques.

Peters and Howard (2001) state that whatever the method chosen, good research must be rigorous, systematic, integrated and focussed. Remenyi, Williams, Money and Swartz (1998) stated that the primary drivers for choosing an appropriate research methodology include the topic to be researched, the specific research questions, and the resources available. A nested research methodology introduced by Kagioglou, Cooper, Aouad and Sexton (2000) can be divided into three main interrelated themes: research philosophy; research approaches and research techniques.

This chapter follows these themes and describes the research methodology used in the study. It includes the research objectives, philosophy, approach, methods and data analysis.

4.2 Research Objectives

The aim of this research to investigate the applicability of RFID to the NZ Army supply chain to see if it could improve the efficiency and effectiveness of the supply chain and reduce the workload on the Army's Supply Technicians (Sup Tech).

In order to achieve the aim of this research the following objectives are established:

- Objective One. To review existing literature on RFID in Supply Chains.

- Objective Two. To describe the NZ Army Supply Chain.
- Objective Three. To develop a time and cost assessment for three processes in the NZ Army Supply Chain.
- Objective Four. To investigate the use of RFID in a civilian organisation that has recently implemented the technology.
- Objective Five. To evaluate the effect RFID could have on the NZ Army Supply Chain.

4.3 Research Philosophy

Saunders, Lewis, & Thornhill (2007) say that research philosophy relates to the development of knowledge and the nature of that knowledge. They state that it provides important assumptions about the way the researcher views the world and underpin the research strategy and the methods chosen as part of that strategy. The three key areas within research philosophy are epistemology, ontology and paradigm (Easterby-Smith, Thorpe & Lowe, 2002).

4.3.1 Epistemology

According to Blaikie (1993) epistemology is the theory of knowledge which presents a view and a justification for what can be regarded as knowledge. Vogt (2005) also believes that it is a philosophy concerned with the nature and criteria of knowledge. Sauders et al. (2007, p. 597) define epistemology as “a branch of philosophy which studies the nature of knowledge and what constitutes acceptable knowledge in a field of study.” Gray (2004) relates it more to individuals and thinks that it can also be viewed as relationship between the knower (researcher) and the known (phenomenon). Oliver (2004) agrees with this view when he says that Epistemology is the study of the grounds on which we claim to know something about the world. Brynian (2004) takes a more practical view and relates epistemology to the question of knowledge acceptability in a discipline, and the methods through which knowledge is acquired. Burrell and Morgan (1985) take this further as they believe epistemology deals with how one might understand the world and communicate this as knowledge to others. The epistemological philosophy can be divided into three main approaches which are; positivism, interpretivism and realism.

Positivism is a term introduced by Auguste Comte (1798 – 1857) to refer to the empirical study of phenomena, especially human phenomena. Comte contrasted the positive knowledge gained in this way with the less scientific knowledge obtained by metaphysics and religion (Vogt, 2005). Most commonly today, positivism refers to a belief, held by some people, that one can study scientifically and or quantitatively things that other people believe cannot or should not be studied in thus way such as religion, emotions ideas etc. (Vogt, 2005). Oliver (2004) agrees with this view when he describes the positivist perspective as one which tends to assume that the research methods of the natural sciences may generally be applied to the social sciences. Sauders et al. (2007, p. 606) define positivism as “the epistemological position that advocated working with an observable social reality.”

Traditional logistics and supply chain management researchers tend to belong to the positivist paradigm (Eisenhardt, 1989). After they reviewed the articles published in the Journal of Business Logistics between 1978 and 1993, Mentzer and Kahn (1995) agree that this approach is still very prevalent in todays management research.

Interpretivism is “the epistemological position that advocates the necessity to understand differences between humans in their role as social actors” (Sauders et al., 2007, p. 600). Love et.al. (2002) believe the interpretivist approach is related to knowledge development and theory built through developing ideas inducted from the observed and interpreted social constructions.

Realism relates to scientific enquiry. According to Sauders et al. (2007) realism is the epistemological position that objects exist independently of our knowledge of their existence. There are two positions within realism. The first is critical realism which is the position that what we experience are sensations and are just images of the things in the world, and not the things directly. The second is direct realism which is the position that what is experienced through our senses is an accurate portrayal of the world (Sauders et al., 2007).

This research follows the philosophy of positivism. It is taking a scientific approach to the assessment of the effectiveness of the NZ Army and providing empirical data to determine if RFID will improve this effectiveness. The role of individuals within the system is not seen as essential to the outcome of the research making interpretivism irrelevant and realism is also discounted as the researcher is focused on what can be directly observed and measured.

4.3.2 Ontology

Ontology is the science or study of being (Blaikie, 1993), or also the nature of reality (Gray 2004). It focuses on the basic questions about the nature of reality, whether an objective really exists or not (Naslung, 2002). Sauders et al. (2007, p. 605) define ontology as "a theory concerning the nature of social phenomena as entities that are admitted to a knowledge system." Studer, Benjamins and Fensel (1998) believe that ontology is a formal, explicit specification of a shared conceptualisation. According to Brynian (2004) the ontological philosophy involves the logical investigation of the different ways in which the different types of things are thought to exist, and the nature of the various kinds of existences.

Ontology can be divided into three main areas; objectivism, subjectivism and pragmatism. Objectivism believes that social entities exist in a reality external to, and independent of, social actors concerned with their existence. Subjectivism believes that entities are created from the perceptions and consequent actions of those social actors responsible for their creation. Pragmatism believes that the most important determinant of the research philosophy adopted is the research question, arguing that it is possible to work within both positivist and interpretivist positions. It applies a practical approach, integrating different perspectives to help collect and interpret data (Sauders et al., 2007).

This research follows the ontological belief of pragmatism.

4.3.3 Paradigms

Paradigms are a way of examining social phenomena from which particular understandings of these phenomena can be gained and explanations attempted (Sauders et al., 2007). Vogt (2005, p. 226) agrees and state that they are "a discipline's general orientation or way of seeing its subject matter." Guba (1990) explain paradigms as a basic set of beliefs that guides action. The specific research method paradigmatic stance adopted by researchers has a strong influence on the shape and form of the subsequent knowledge that is generated (Burgess et al., 2006). Fields such as sociology are sometimes referred to as multi-paradigm disciplines since there are several competing ways of understanding those disciplines and their problems (Vogt, 2005). According to Sauders et al (2007) there are four main paradigm views as follows: interpretive which is about understanding how humans make sense of the world around us, radical humanist which seeks the changing status quo of existing social patterns, radical structuralist which looks to achieve fundamental change based upon analysis of underlying structures that cannot be easily observed. The final view is functionalist which is a philosophical position which is concerned with a rational explanation of behaviour and institutions such as why a particular organisational problem is occurring in terms of the functions they perform.

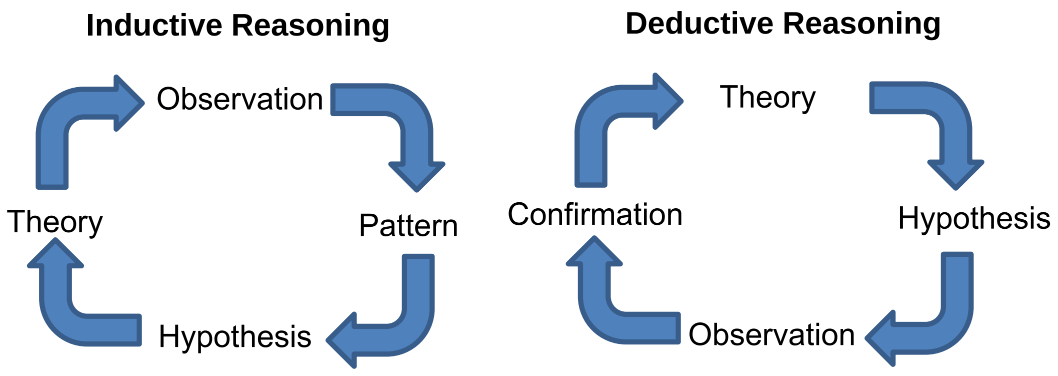
As supply chain management problems are often unstructured, and even messy, real-world problems. Seuring (2005) suggests that to gain relevance for supply chain researchers, "a one paradigm, one approach" perspective should not automatically be the obvious choice.

In the case of this research the functionalist paradigm is used. This research is looking at examining the current efficiency of the NZ Army supply chain and seeks a rational explanation of how it is operating currently and what the causes may be for inefficiency. It also seeks to make a rational comparison with another supply chain who has already implemented the technology.

4.4 Research Approach

To research a topic in a scientific manner, there are two main approaches; deductive and inductive. Walliman (2003) say these approaches can be seen as seeking the truth from opposite directions. Through deductive argument the particular is inferred from the general, while through inductive argument, general truths are inferred from the particular. Sauders et al (2007) say the deductive research approach involves the testing of a theoretical proposition by the employment of a research strategy specifically designed for the purpose of its testing. Gammesson (2000) compares the two approaches by saying that deductive research primarily tests existing theory, whereas inductive research primarily generates new theory. Leedy and Ormrod (2001) expand on inductive reasoning by explaining that Inductive reasoning begins, not with pre-established truth or assumption, but with an observation. In inductive reasoning people use specific instances or occurrences to draw conclusions about entire classes of objects or events. In other words, they observe a sample and then draw conclusions about population from which the sample comes (Leedy & Ormrod 2001 p. 35). Figure 4.1 shows the difference between the two approaches.

Figure 4.1. Process of inductive and deductive reasoning



Source: Based on http://qwickstep.com/search/induction-deduction.html

The approach for this research is inductive reasoning. The research is not attempting to prove a theory. It is seeking to make observations and develop a theory from these observations.

4.5 Research Methodology

4.5.1 Purpose

Leedy and Ormond (2000), identify several different categories of research which are used according to the purpose of the research. These categories are; exploratory, descriptive, and explanatory.

Exploratory research aims to seek new insights into phenomena, to ask questions, and to assess the phenomena in a new light (Sauders et al., 2007). Yin (2003) claims that exploratory studies seek to comprehend and illuminate what is happening with the intention of developing new hypotheses and theories. Saunders et al. (2007) agree with Yin's view and say that it is particularly useful to help to clarify the understanding of a problem. Exploratory research looks for patterns, ideas or hypotheses (Vogt, 2005) and is used where researchers are exploring what is happening because not much is known (Robbins, 2009).

Descriptive research aims to produce an accurate representation of persons, events or situations (Sauders et al., 2007). According to Leedy and Ormond (2000) descriptive research involves either identifying the characteristics of an observed phenomenon or exploring possible correlations among two or more phenomena. Yin (2003) says that descriptive research describes what is happening. Descriptive studies are used when there is fundamental knowledge and understanding and when the study has a descriptive characteristic. The study's purpose is thus to map the facts and their relationships (Florén & Rydh, 2005).

Explanatory research focuses on studying a situation or a problem in order to explain the relationships between variables (Sauders et al., 2007). Explanatory studies are used when a description and explanation of deeper understandings is the objective (Florén & Rydh, 2005).

This research is both descriptive and exploratory. It is descriptive in the aspect of describing the current supply chains for both the NZ Army and EastPack Ltd. It is exploratory in looking for ideas as to what the efficiency of the NZ Army supply chain is and whether it could be improved through the implementation of RFID.

4.5.2 Strategy

The research strategy is concerned with the types of evidence to be collected and the sources of such evidence, as well as the process of interpretation used to obtain satisfactory answers being posed (Easterby-Smith et al., 2002). According to Yin (2003), the selection of a suitable research strategy used depends on the following three conditions: the type of research question posed, the extent of control an investigator has over actual behavioural events and the degree of focus on contemporary, as opposed to historical events. Sauders et al (2007) define six research strategies including: experiment, survey, action research, grounded theory, ethnography, archival research and case study. Each strategy can be used for exploratory, descriptive and explanatory research (Yin, 2003).

Experiment Strategy involves the definition of a theoretical hypothesis, the selection of samples of individuals from known populations, the allocation of samples to different experimental conditions, the introduction of planned change on one or more of the variables, and measurement on a small number of variables and control of other variables (Sauders et al., 2007).

Survey Research strategy involves the collection of information from a large group of entities by selecting a sample from the target population (Sauders et al., 2007). Choosing a survey strategy allows the collection of large amounts of data in an efficient manner. Typically this is done by using questionnaires with which researchers bring together standardised data that can be compared easily. It can also include collection of data from structured observation and structured interviews (Kotzab, 2005).

Action Research Strategy is concerned with the management of a change and involving close collaboration between practitioners and researchers (Sauders et al., 2007). Action research is conducted by members of an organisation over a matter which is of concern to them (Coghlan & Brannick, 2005). It also differs from other methods because its focus is explicitly on action, usually promoting change within the organisation, rather than acquiring knowledge.

Grounded Theory is a research strategy in which theory is developed from data generated by a series of observations or interviews principally involving an inductive approach (Sauders et al., 2007). According to Goulding (2002), grounded theory is helpful for research to predict and explain behaviour with the emphasis being on developing and building theory.

Ethnography strategy focuses upon describing and interpreting the social world through first hand field study (Sauders et al., 2007). It is largely an inductive approach which requires the researcher to immerse themselves in the social world being researched for a long period of time. It can be used to gain insights about a particular context and to better understand and interpret from the perspective of those involved (Sauders et al., 2007).

Archival Research strategy analyses administrative records and documents as principle source of data because they are products of day to day activities (Sauders et al., 2007). This strategy is used to look at research questions focused on the past or to examine changes conducted over time.

Case Study strategy involves the empirical investigation of a particular contemporary phenomenon within its real life context, using multiple sources of data (Sauders et al., 2007).

This research is undertaken using the case study strategy. This method is best suited to the complex and variable environment in which the study is taking place and provides the flexibility to gain the required information to answer the research questions.

4.5.3 Case Study

4.5.3.1 Case Study Definition

A case study is defined as ‘an empirical enquiry that investigates a contemporary phenomenon within its real life context, especially when the boundaries between the phenomenon and context are not clearly evident, and in which multiple sources of evidence are used” (Yin, 2003, p 13). According to Yin (1994), the case study is the preferred strategy in exploratory research because it is an objective, in-depth examination of a contemporary phenomenon where the investigator has little control over events (Yin, 1994). Meredith (1998) cites three outstanding strengths of case research put forward by Bebensat et al. (1987): (1). The phenomenon can be studied in its natural setting and meaningful relevant theory generated from the understanding gained through observing actual practice. (2) The case method allows the questions of why, what and how, to be answered with a relatively full understanding of the nature and complexity of the complete phenomenon. (3) The case method lends itself to early, exploratory investigations where the variables are still unknown and the phenomenon not at all understood. Another strength of using case studies as a research strategy is the ability for the researcher to combine multi data collection methods as a way to have a stronger substantiation of constructs through triangulation (Koulikoff-Souviron & Harrison, 2005). It is usually best to combine data collection methods such as archive searching, interviews, questionnaires and observation. The evidence may be qualitative, quantitative or both (Eisenhardt, 1989).

The importance of case study research in social sciences and management is widely acknowledged. According to Yin (2003), the use of case studies is derived from the desire to understand complex phenomena. McCutcheon and Meredith (1993) say case studies can be comprehended as a particularly useful approach for assessing “real world” examples. It provides a systematic way of collecting data, analysing it and showing the results.

Ellram (1996) agrees that logistics research may benefit from the use of case studies as a methodology, in particular for theory building, for providing detailed explanations of best practices and for providing more understanding of data gathered.

4.5.3.2 Case Study Types

Case studies can be studied for different purposes. Yin (2003) distinguishes three types of case studies. Firstly there is an exploratory case study which is aimed at defining the questions and hypotheses of a subsequent study (not necessarily a case study) or at determining the feasibility of the desired research procedure. Secondly there is a descriptive case study which presents a complete description of a phenomenon within its context. Thirdly there is an explanatory case study which compiles data on cause effect relationships explaining how events happened.

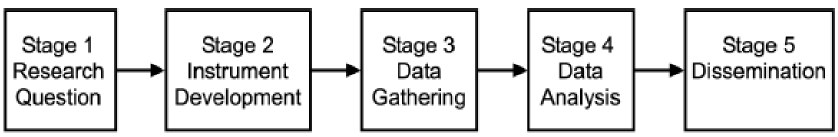
Furthermore Yin (2003) suggests case selection based on two types; single and multiple. Yin (2003) states that a single case study forces a detailed description while multiple case studies provide better generalisations and also there are opportunities of cross deliberations and hypothesis. Yin (2003) explains the difference between the two by saying that single case studies are suitable for bringing out the richness in a particular case and a detailed description. Multiple case studies provide a more rigorous approach and place more importance on the comparison between different settings. For this reason they are considered superior for generalising as compared to single cast study.

This research will be conducting a multiple case study of two supply chains. These will provide a comparison of the effect RFID has on supply chains.

4.5.3.3 Case Study Methods

The research process for case studies is similar to those used for other (empirical) research. Stuart et al. (2002) propose a five-stage research process, as shown in Figure 4.2, and explain in detail how each step should be carried out when conducting case study research. This process is similar to that described by several other researchers (Yin, 2003; Eisenhardt, 1989; Mentzer & Kahn, 1995; Ellram, 1996; Voss, Tsikriktsis & Frohlich, 2002).

Figure 4.2. The five-stage research process model



Source: Stuart *et al.* (2002, p. 420)

It should be emphasised that while a linear, sequential approach is used, the actual process might have to repeat several stages before the research questions are answered. While starting at one research question and/or collecting some evidence on a social or organisational phenomenon, the researcher might have to return to a previous research stage, yielding a much more iterative process

(Golden-Biddle & Locke, 1993). This might then over time allow theoretical constructs to form (Van Maanen, 1979).

4.6 Research Methods

Research methods are the actual tools and techniques used during research (Blaikie, 2003). The methods that are used are quantitative or qualitative research methodology, or possibly there will be a mixture of the two (Neuman, 2006; Fellows and Liu, 1999).

4.6.1 Quantitative

Fellows and Liu (1999, p.15) defined quantitative research as that which "seeks to gather factual data and to study relationships between facts and how such facts and relationships accord with theories and the findings of any research executed previously (literature)." Saunders et al. (2007) are more specific in their definition which is that quantitative data is where data is collected and analysed in a way that generates or uses numeric data. The quantitative approach dominates research in logistic and supply chain phenomena. This approach is overlaid by disciplinary traditions such as economics, marketing and psychology (Golicic, Davies, Reiner & Kotzab, 2005).

The goal of the quantitative approach is to add to the body of knowledge and it is used to answer questions about the relationship between the measured variables with the purpose of explaining, predicting and controlling phenomena (Leedy & Ormrod, 2001). Creswell (2002) explains that a quantitative approach is useful when attempting to test a theory or explanation, or identifying factors that influence results. The quantitative approach allows the researcher to step away from the data in order to develop a more general explanation of the phenomenon (Cresswellm 1998). The quantitative approach employs the use of mathematical and statistical techniques to identify facts and casual relationships, and samples can be larger and more representative (Fitzgerald & Howcroft, 1998). The samples collected from quantitative research are often large and representative and the results can be generalised to the larger population within acceptable error limits (Bryman, 2004).

The quantitative research approach has also received some criticisms from the research community and Bryman and Bell (2003) outlined these as follows: Quantitative researchers fail to distinguish people and social institutions from 'the world of nature, the measurement process possesses an artificial and spurious sense of precision and accuracy, the reliance on instruments and procedures hinders the connection between research and everyday life and the analysis of relationships between variables creates a static view of social life that is independent of people's lives.

4.6.2 Qualitative

Creswell (1998, p. 18) defined qualitative research as "an inquiry process of understanding based on distinct methodological traditions of inquiry that explores a social or human experience." Qualitative data is data that is non-numeric or can't be quantified. The aim of the qualitative approach is to understand the phenomenon in its own terms and maximise realism (Hirshman, 1986).

In social science the qualitative research approaches were originally developed to enable researchers to study social and cultural phenomena (Kasim, 2008) Morgan and Smirchich (1980) believe that qualitative research is an approach rather than a particular set of techniques, and its appropriateness drives from the nature of the social phenomenon to be explored. The qualitative approach provides researchers with access to deeper levels of understanding of new or complex phenomena by yielding a high level of detail and close up view of the topic (Creswell, 1998). Gummesson (2006) states that qualitative approaches allow researchers to deal with complexity, context, persona and their multitude of factors.

The advantage of qualitative research, according to Leedy and Ormond (2000), is that it focuses on phenomena that are occurring in natural settings and they involve studying those phenomena in all their complexity. Creswell (2002) adds that the qualitative approach may be used when researching a phenomenon that hasn't yet been researched extensively. This is because qualitative methods try to analyse the reasons for certain behaviour and analyses the factors lying behind certain phenomena (Aczel, 2002). Qualitative methods have been productively applied where there is a need to describe and explain the phenomenon under study and have been used for examining organizational adoption of various information technologies (Roh et al., 2009).

The first step of the qualitative approach is data collection which is conducted in the natural setting in order to begin to frame an understanding. Then the phenomenon observed is described and substantive theory built (Golicic et. al, 2005). Leedy and Ormond (2000) give many different ways by which researchers conducting qualitative research might gather data including observations, interviews, written documents and audio-visual materials. They also mention that researchers are not limited to only one way of data collection; rather they can work with more and combine them as they think best or as circumstances demand. After data is collected the phenomenon observed is described and substantive theory built (Golicic et. al, 2005).

However, there are criticisms from the research community about the limitations of a qualitative research strategy which are identified by Bryman and Bell (2003) as follows:

- Problems of generalisation. The sample sizes and sampling methods used in qualitative research reduce the capability to generalise the research results.
- Qualitative research is too subjective. The strength of deeper understanding provided by a qualitative strategy is in itself a weakness as it limits confidence in the results.

- Difficult to replicate. Another weakness of qualitative strategy is the limitation in terms of replication by other researchers for example, what one researcher might focus on, might not be the focus of another researcher.
- Lack of transparency. The process of collecting and analysing qualitative data is something difficult to establish and can lack clarity.

4.6.3 Mixed

Quantitative and qualitative methods do not constitute oppositional and contradicting methods. In fact Mayring, (2003) believes that quantitative methods can successfully support the qualitative methods. Hudson and Ozanne (1998) believe that there is no reason the two approaches cannot peacefully coexist or that other middle ground approaches cannot or should not be developed. Golicic et al. (2005) believe that it is necessary to see both views by using a combination of both quantitative and qualitative data is to truly understand and explain a phenomenon. Qualitative and quantitative research approaches are not substitutes for one another; rather they observe different aspects of the same reality (McCraken, 1988). The business environment in which logistics and supply chain phenomena are located is becoming increasingly complex and less amenable to using just one type of research approach (Golicic et al., 2005). Researchers who exclusively chose one approach may delimit the scope of their inquiry and thereby their ability to consistently and effectively contribute to the body of supply chain management research (Golicic et al., 2005).

This research will be conducted using a combination of quantitative data and qualitative data. Observations, surveys and database analysis will use quantitative data and the interviews will use qualitative data.

4.7 Methods Chosen

This research is inductive and follows the interpretivism philosophy, the ontological belief of pragmatism and the functionalist paradigm. As this research is both descriptive and exploratory the design selected for the research is a comparative case study which will use both qualitative and quantitative research methods.

4.7.1 Participant Selection

A sample from the population can be selected by either a probability or non-probability approach. In probability sampling the researcher knows the chance, or probability, of each case being selected from the population. This approach is used when there is a need to make inferences from the sample about a population when answering the research question (Saunders et al, 2007). In non-probability sampling the probability of each case being selected from the population is not known. This means that statistical inferences cannot be made about the population. Non probability sampling is used when there is a specific requirement for the sample to answer a research question. There are several techniques used to select a sample within this method including; quota, purposive, snowball, self-selection and convenience (Saunders et al, 2007).

Due to the focused nature of this research, purposive sampling is used. In this approach researchers rely on their experience, ingenuity and or previous research to deliberately obtain units of analysis in such a manner that the sample they obtain may be regarded as representative of the relevant population (Welman & Kruger, 2001). In this case the researcher used their knowledge of the Army to select the major units as the sample. The units selected as samples provided a mixture of first and second line units and of different outputs. The units selected were:

- 2nd Logistics Battalion (Linton Camp, Palmerston North)
- 3rd Logistics Battalion (Burnham Camp, Christchurch)
- 1st Royal New Zealand Infantry Regiment (Linton Camp, Palmerston North)
- 2/1st Royal New Zealand Infantry Regiment (Burnham Camp, Christchurch)
- 16 Field Regiment (Linton Camp, Palmerston North)
- Queen Alexandra's Mounted Rifles (Burnham Camp, Christchurch)

Permission was gained from the army to conduct the study (Appendix D) and then the Commanding Officer of the selected units were sent a letter requesting permission to conduct research on their units (Appendix E). Permission was received from all units.

For the comparative case study of an organisation which had already implemented RFID, the population available was small. Research was conducted via the intranet using the search terms “RFID” and “NZ”. This identified one company using RFID, some RFID providers and two organisations supporting the implementation of RFID. Through queries to these organisations only one additional company was identified that had implemented RFID recently. One of the two companies was willing to take part in the research so EastPack Ltd was selected as the comparative case study.

4.7.2 Data Collection Methods

The data for this study was collected over a period of three months from August to October 2010. The data was gathered though both primary and secondary data sources.

Primary research is data that does not yet exist and is collected the first time, through methods like for example observations, surveys, interviews, experiments or panels. Primary data has a reliability advantage in the sense that the researcher knows where it came from and how it was collected since they did it themselves (Calantone & Vickery, 2009).

In contrast to primary data, secondary data is data that has been collected and possibly analysed or processed by individuals other than the researcher. A researcher can obtain secondary data from large surveys conducted by other researchers, data from government agencies (census data, labour statistics etc.) and from existing archives. Archival data consists of historical records from individuals (letters, papers, computer files, financial records, diaries) and organizations (business records, administrative files, memos, emails, official correspondence (Calantone & Vickery, 2009).

In this study the use of primary and secondary data is combined, with a focus on primary data. Primary data was obtained from Interviews, questionnaires and observation. Secondary data was obtained from the NZ Army ERP system.

4.7.2.1 Interviews

The Interview method is used in case studies for several reasons such as: research time constraints, highly concentrated knowledge in experts and receiving much more in-depth information than it would be possible with a survey or a questionnaire (Bumbak, 2005).

Structured interviews follow a set of questions in a predetermined order and record the participant's response to each question. This technique is suitable for getting statistically significant data but for the purposes of exploratory research may not give sufficient flexibility to get the full picture on the topic.

Semi structured interviews allow a directed discussion of the topics of interest to elicit the interviewee's ideas and opinions (Cheney, Christensen, Zorn, & Ganesh, 2004). Most questions are prepared in advance and spontaneous questions might be asked where appropriate, or to get more information on a specific topic. Easterby-Smith et al. (2002) mention five situations when semi-structured interviews are appropriate. First, when it is important to understand the construct that the interviewee builds, as a basis for the judgements and views about a specific situation. Second, when the interviewer needs to build a clear understanding of the interviewee's perception of reality and the world, influenced by the interviewer. Third, when the step by step logic of a process is inexplicit. Fourth, when the discussed topic is highly confidential or commercially sensitive. And fifth, when the interviewee will not be completely open about the topic unless discussed in a face to face setting. Due to the openness and interactivity, interview outcomes might suffer from a low reliability, as every interview is different (Cheney, et al., 2004).

As this research is exploratory and descriptive research which is looking to get a clear picture on the current situation the semi structured approach was used. A list of interview questions (Appendix F & G) was developed. The interviews roughly followed the same format but if additional information or subjects were raised the interviewer allowed the participant to expand on their points or bring up new subjects.

The same interviewer was used for all interviews and notes taken during the interview. Immediately after each interview the interview notes were typed up while they were fresh in the interviewers head. In order to encourage open discussion the interviews were not recorded, less those conducted at EastPack Ltd.

4.7.2.2 Observation

In order to determine the time taken to complete processes the self-administered structured observation approach was used. In this approach the participants recorded the length of time it took them to complete each process on a standardised form (Appendix H).

4.7.2.3 Questionnaires

Questionnaires were used to get information on the length of time for the process of stocktaking. As individuals were handed count sheets for a stocktake, they were also handed an information sheet and questionnaire. The questionnaire was completed at the time of the stocktake. The questionnaire used is in Appendix I.

4.7.2.4 Secondary Documentary Data

Secondary data was taken from the NZ Army's ERP system, SAP. Information accessed was unit inventory data, process statistics and inventory accuracy statistics. In addition information on remuneration rates and Army procedures was taken from the NZ Army intranet.

4.7.3 Pilot Study

The questionnaire and observation form design was piloted before its wider distribution. Copies of the questionnaires were given to 3rd Logistics Battalion

Quartermaster Store who were selected because of their small size, typical range of activities and proximity to the researcher. They were asked to review the proposed questionnaires for clarity of instructions, preference for design and ease of use. Also the quality of information gathered was assessed to ensure the relevant information was being captured. As a result of their feedback the questionnaires and observation forms were slightly amended prior to wider distribution.

4.7.4 Data Analysis

Creswell's (2003) six step method was used to guide the data management, processing and analysis:

4.7.4.1 Data organisation and preparation

The data from the questionnaires and observation forms were typed directly from the paper forms into separate Microsoft Excel spreadsheets. The interviews were typewritten and for each question a summary of the interview answers was prepared. Some questions were coded and the data entered onto a Microsoft Excel spreadsheet.

4.7.4.2 Developing an overall picture

The interview answers were read several times to determine if any themes were emerging. Trace (2001) believes this approach ensures that any unanticipated themes are given the opportunity to emerge from the data and that no undue weight is given to any preconceived themes.

4.7.4.3 Data analysis

From the interviews emergent themes were then highlighted and categorised. Different phraseologies of the same themes were examined for different meanings. This was necessary as the answers differed in length and circumstances. The data from the observation and questionnaires was put into process maps to determine the number of steps required for each process. The data was calculated into time per process and a cost value was assigned by using the participants rank and qualifications to determine their salary which was then calculated into a per minute calculation. The information was then examined individually i.e. per unit and also as a whole to determine if the trends were across all the units or if there individual units who were outside the norm.

4.7.4.4 Representation of the collected data

The collected data was summarised and put into charts and tables for easy visual interpretation. The information is presented in the results section of the thesis in Chapter Five.

4.7.4.5 Data interpretation

After the analysis and presentation, the data was further examined in view of the research questions. It was interpreted and parallels, as well as variations in comparison, to findings from the literature were elaborated upon. The interpretation and discussion of the results can be found in Chapter Five.

4.8 Reliability and Validity

Scientific credibility is the degree of what actually is measured to what was supposed to be measured (Ellram, 1996). Whether quantitative or qualitative, good research design requires scientific credibility and this is measured through external validity, construct validity, and reliability (Ellram, 1996). Validity is concerned with the effectiveness of the data, whereas reliability deals with the question of efficiency of the data (Boukani, 2007).

A strong feature of case studies as a research strategy is the ability for the researcher to combine multi data collection methods as a way to have a stronger substantiation of constructs through triangulation. Koulikoff-Souviron & Harrison, 2005) It is usually best to combine data collection methods such as archive searching, interviews, questionnaires and observation. The evidence may be qualitative, quantitative or both (Eisenhardt, 1989).

4.8.1 Construct Validity

Construct validity means to establish “correct operational measures for the concepts being studied” (Yin, 2003 p. 34). Construct validity ensures the measures being used corresponds to the research concepts. Construct validity is achieved through triangulation of multiple data sources, a chain of evidence and key informant reviews (Yin 2003).

Construct validity requires that investigators develop a sufficiently operational set of measures that preclude subjective judgements (Yin, 2003). A primary method of ensuring construct validity in research is through triangulation of data collection and data analysis. Ellram (1996) explains that Triangulation, which is the use of different techniques to study the same phenomenon, provides validity within the case study method.

This research will use interviews, questionnaires, observations, inventory database and intranet as multiple sources of data to ensure triangulation. In order to maintain the chain of evidence the data collected, transcribed and analysed by the researcher and all notes and data has been filed for later reference if required.

4.8.2 External Validity

External validity deals with the question of the applicability of findings beyond the population under study. According to Yin (2003) single case studies can generalise if it is a critical case (compared to theory), extreme or unique (in relation a population of other cases) or if it is revelatory. Yin (2003) also believes that multiple case studies are generalisable based on replication logic. Multiple cases are to be chosen so that they either predict similar results (literal replication) or contrary results but for predictable reasons (theoretical replication)

4.8.3 Reliability

Reliability is the ability to repeatedly yield similar results across similar situations (Mentzer & Kahn 1995). Saunders et al. (2007) add that it is also so that there is transparency in how the conclusions were made from the data.

Reliability can be increased through documenting the research process to such an extent that data could be duplicated even if collected at another time or through another researcher. This is facilitated through the use of a case study protocol to ensure the trail of evidence is thoroughly documented and a case data base to ensure traceability of all data (Yin, 1994).

Reliability will be established in the research design by using the protocol consistently across interviews and a common database for collecting and analysing data. In addition the interviews will be conducted by the same individual and transcribed immediately after the interview to improve data reliability.

An issue with the reliability of this research is the potential bias of the researcher who is a member of the NZ Army. To control this, the researcher's position was clearly stated to all participants and a detailed description of the methodology was recorded for an audit trail as recommended by Merriam (2001).

Even though careful preparations were taken in order to minimise other sources for bias, some possible sources should be taken into consideration. Because the research questions look at a new technology it is possible that the participants have a different understanding of the technology to what the researcher has.
The quality of note taking during the interviews was heavily dependent on the researcher's abilities to simultaneously understand what the interviewee is saying, take notes, and also ask further questions. As the researcher is used to taking notes and asking questions in meetings the possible influence on the correctness of the gathered data should be minimal.

4.9 Ethics

Due to the involvement of human participants during the research, the research had to meet ethics approval from the Massey University Human Ethics Committee. A screening questionnaire was completed to determine which procedure was needed to gain ethics approval. Due to the possible influence the researcher could have over some of the participants the research was assessed as possibly having some risk and required full approval from the Massey University Human Ethics

Committee (MUHEC). The screening questionnaire, ethics application, invitation letters, questionnaire information sheet and format, interview information sheet and questions were submitted. After several interactions between the MUHEC and the researcher to amend aspects of the research it was approved.

Areas that caused concern were confidentiality and conflict of interest. There was a concern that due to the small size of the logistics community in the NZ Army it is likely that the researcher will know most of the participants. In addition the researcher was a direct supervisor of one person who was to be interviewed and of several individuals who will complete questionnaires gathering information about processes and time completion rates. This was mitigated by ensuring the questionnaires which were gathering information about processes and time completion rates did not request names, simply rank, and qualifications to help ensure anonymity. For the interviews and questionnaires the participants were given an information sheet which clearly outlined their rights, especially that participation was voluntary and that during the interview they had the right to not answer a question. Additionally the questionnaires were distributed by an intermediary, not the researcher to reduce the possible pressure to participate on the subjects.

Commercial sensitivity was also a consideration with this research. EastPack Ltd is a commercial organisation and data that they labelled as commercially sensitive and not included in the thesis. In addition the sections of the thesis relevant to EastPack Ltd were sent to them to ensure that they were happy with the information contained.

Information about the NZ Army was also cleared prior to the thesis submission to ensure there were no sensitive matters written in the thesis.

4.10 Summary

This chapter has provided a detailed description of the reasons behind the selection of the research methods and has detailed how the research was conducted. This is summarised in Table 4.1. Issues of reliability and validity were considered and the ethics of the research was examined.

Table 4.1. Summary of Methodology

Research Philosophy	
Epistemology	Positivism
Ontology	Pragmatism
Paradigm	Functionalist
Research Approach	Inductive
Research Methodology	
Purpose	Descriptive and Exploratory
Strategy	Comparative Case Study
Research Methods	Combination of Qualitative and Quantitative
Data Collection	Primary – Interviews, questionnaires Secondary – Database Analysis
Sample Selection	Purposive Sampling

Chapter 5 - Results and Discussion

5.1 Introduction

This chapter will show the results of the research and provide an analysis of the data with emphasis on answering each of the five investigative questions. The data from the interviews and observations in the NZ Army will be examined followed by the results from the interviews and observations at EastPack Ltd.

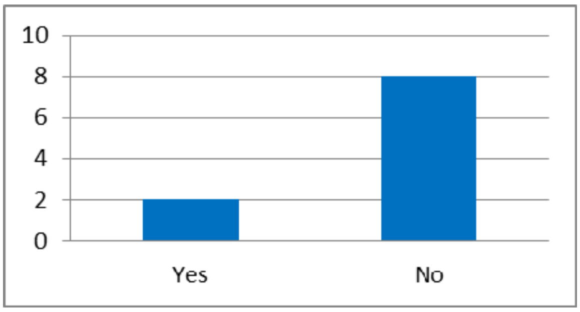
5.2 Results NZ Army

5.2.1 Interviews

Interviews were conducted with eleven army personnel. Seven of these personnel were the top SupTech in their units. Their ranks were from Staff Sergeant to Warrant Officer Class 1 and they had between 12 and 27 years of experience in the Army. They held appointments such as unit logistic officer, Regimental Quartermaster Sergeant and Supply Warrant Officer. Three of the personnel interviewed were the assistants to the top SupTech and they were all SSgt filling the role of Assistant Regimental Quartermaster Sergeant and Material Stock Controllers. The final interviewee was a civilian ledger clerk with ten years of experience with the NZ Army.

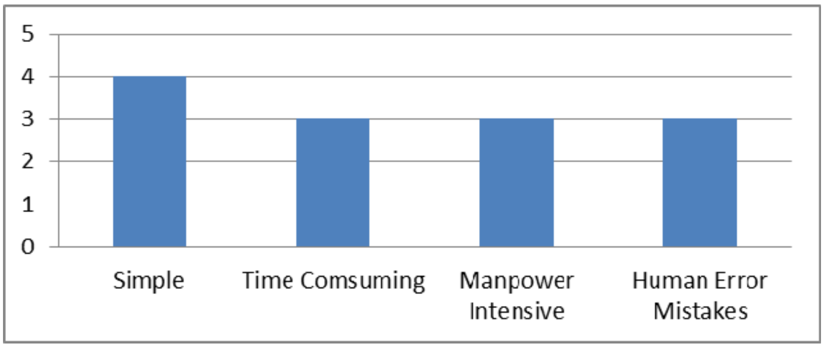
The first question asked "*do you have sufficient personnel"?* A summary of the results is shown in Figure 5.1. The key concerns raised were the ability to continue to operate when personnel were away on tasks, deployed overseas or conducting training. Every one of the participants who said they did have enough personnel put a disclaimer on this saying that that this was only when all of their personnel were present. Other comments were made on the amount of time that compliance (stocktaking) issues took. Proportions of compliance to other work were stated at "*50%"* and "*70%".* In addition comments were made about the establishment (authorised entitlement) which had not increased when the supported elements, quantity of equipment and complexity of equipment had increased.

Figure 5.1. Is There Sufficient Personnel?



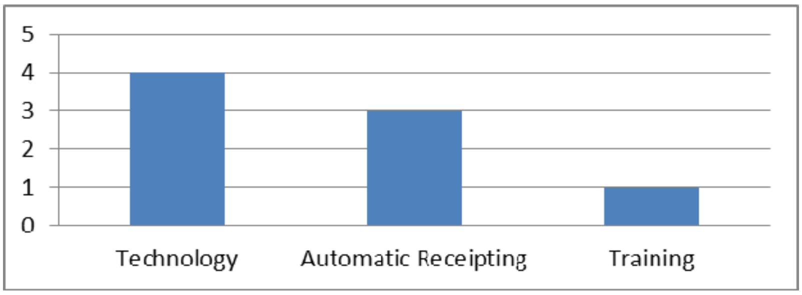
The second question asked the participants to "*comment on current issue and receipts processes.*" A summary of the results is shown in Figure 5.2. The majority agreed that while the processes are relatively simple they are not efficient due to being time consuming, manpower intensive and subject to mistakes through human error. The Barcode scanner which was recently introduced was generally not being used due to many having serviceability issues and the use of the scanner not improving the speed or efficiency of the processes unless large numbers of items were being receipted at the same time.

Figure 5.2. State of Current Issue and Receipts Procedures



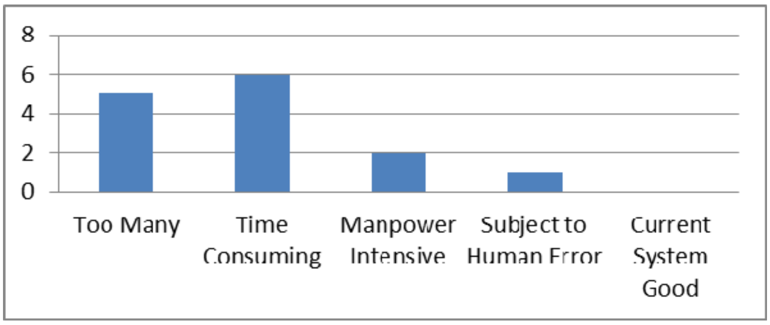
The third question asked "*how could the issues and receipts processes be improved*"*?* A summary of the results is shown in Figure 5.3. The use of technology to enable automatic receipting was the dominant theme.

Figure 5.3. Ways to Improve Issues and Receipts Process



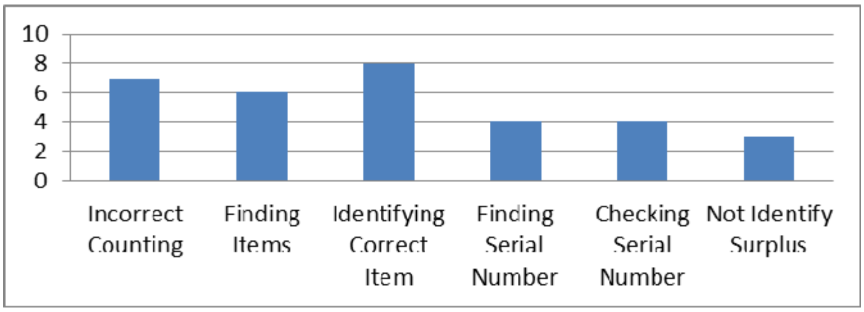
The fourth question asked participants to "*comment on the current stocktaking process.*" A summary of the results is shown in Figure 5.4. None of the participants were happy with the current system. The majority felt that there was too much stocktaking being done and the process was time consuming. One participant commented on the process being subject to human error.

Figure 5.4. State of Current Stocktaking Process



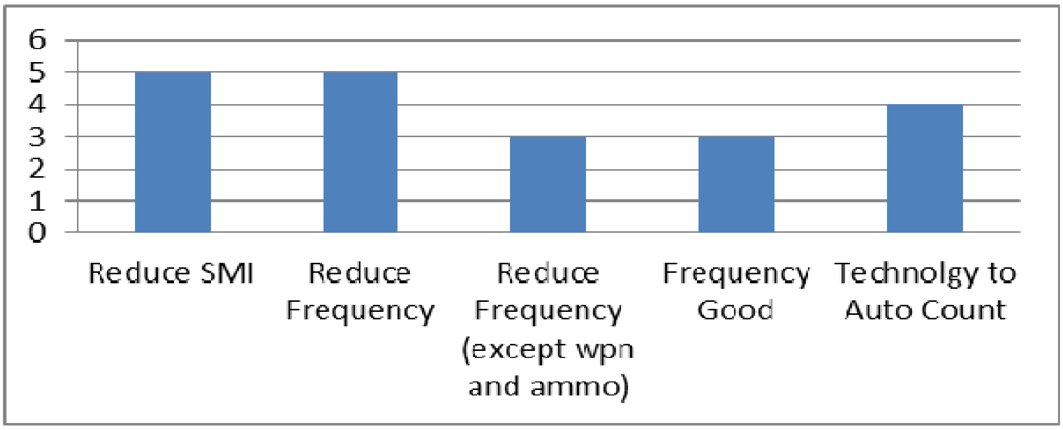
The fifth question asked "*what are the current issues with stocktaking*"? A summary of the results is shown in Figure 5.5. There was a high level of agreement on the key issues with stocktaking. The key issues were the counters had difficulty finding and correctly identifying items. The unclear descriptors used on the SAP documentation was one reason offered for this and the lack of experience of the counters was another. Also the SAP documentation does not always reflect the correct number of zeros in a serial number leading to confusion or incorrect serial numbers recorded. Serial numbers were stated as an issue as they are difficult to get access to and are often faded and in some equipment there are multiple serial numbers on an item. One of the key issues is human related in that the counters do not count correctly, record serial numbers accurately and in some cases do not even physically check items.

Figure 5.5. Issues with Stocktaking Process



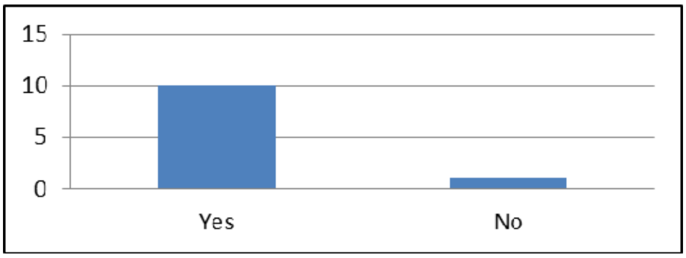
The sixth question asked "*how could you improve the stocktaking function"?* A summary of the results is shown in Figure 5.6. The key suggestion related to adjusting the frequency or quantities to be counted. While many participants agreed that the regular counting of weapons and ammunition was beneficial, recommendations were to reduce the Specially Managed Items (SMI) list to only include key equipment and to remove the need to count items if they have not been moved.

Figure 5.6. Ways to Improve the Stocktaking Process



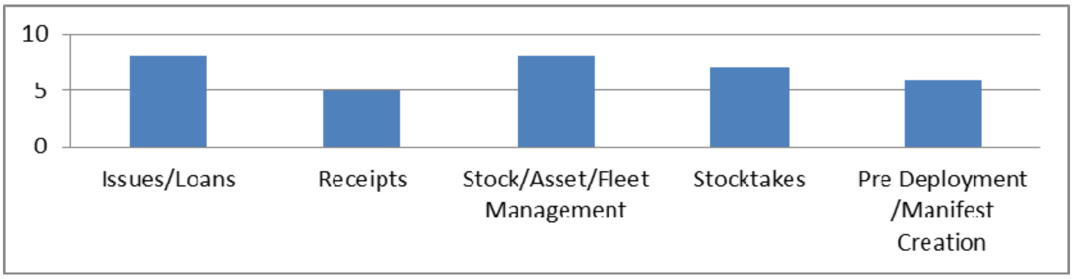
The seventh question asked “*have you heard of RFID”?* A summary of the results is shown in Figure 5.7. There was a good knowledge of the technology though some were unsure what the actual name of it was. Only one participant had not heard of the technology.

Figure 5.7. Have You Heard of RFID?



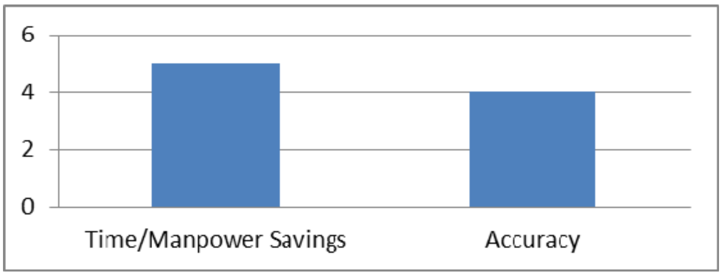
The eighth question asked “*what could RFID be used for in the NZ Army”?* A summary of the results is shown in Figure 5.8. There was high agreement on the key functions that RFID could be used for. These functions include issues and loans, receipts, stock and asset management, stocktakes and some suggestions were raised on its use to improve the pre deployment manifesting of equipment prior to deployments.

Figure 5.8. Applications of RFID in NZ Army



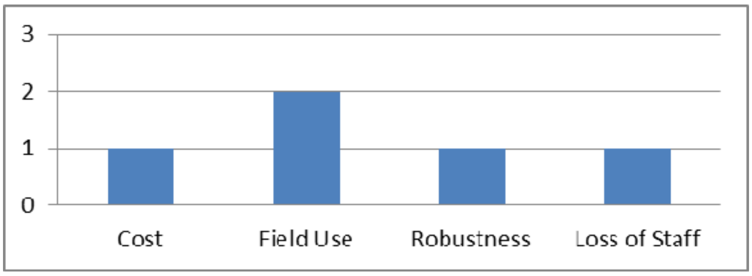
The ninth question asked “*what would the advantages of RFID be in the NZ Army”?* A summary of the results is shown in Figure 5.9. There were two areas identified as advantages which were time/manpower savings and improving the accuracy of the processes and the inventory management account.

Figure 5.9. Advantages of RFID



The tenth question asked “*what would the disadvantages of RFID be in the NZ Army*”? A summary of the results is shown in Figure 5.10. There was a poor response to this question and most participants were only able to come up with one disadvantage. Issues were the need for a good cost analysis, backup systems for field use, robustness of the tags to survive military life and a concern that the implementation of this technology would lead to a reduction in the staff levels.

Figure 5.10. Disadvantages of RFID



5.2.2 Observations

Three processes in the Army Supply Chain were observed to determine the time each process took. The processes were stocktakes, issues and receipts.
Stocktakes

5.2.2.1 Stocktakes

Questionnaires were given to all units to be filled out by all personnel physically conducting stocktakes. 68 questionnaires were returned of which 61 had sufficient information to be used. The questionnaires were separated between barrel counts of weapons, basic count of items or full serial number checks of items and weapons.

The information from these questionnaires was analysed to determine the average time it took to stocktake an item. Using salary tables for the personnel who conducted the stocktakes the cost of the stocktakes were determined. The results for this are at Table 5.1.

Table 5.1. Average Stocktake Counting Time and Costs

Type of Stocktake	Average Time in Seconds	Average Cost
Barrel Count	8.24	$0.01
Item/Serial	64.14	$0.13
Total	**54.97**	**$0.11**

This information was combined with information on inventory levels for the units to determine time and costs involved. Table 5.2 shows the results of this analysis. The total time taken to complete all required stocktakes in a year 19,065 hours and the total cost was $133,239.

Table 5.2. Yearly Stocktake Counting Time and Cost

Unit	Weekly			Monthly			12 Month			24 Month		
	Barrel Count			SMI			Remainder D Plant			Remainder B Plant		
	No of Items	Time (hr)	Cost	No of Items	Time (hr)	Cost	No of Items	Time (hr)	Cost	No of Items	Time (hr)	Cost
1 RNZIR	877	2.0	$12.72	3,884	59	$415.22	137,225	2,096	$14,669.91			
2/1 RNZIR	831	1.9	$12.06	3,659	56	$391.16	205,376	3,136	$21,955.54			
16 Fd Regt	415	1.0	$6.02	951	15	$101.67	52,113	796	$5,571.09			
QAMR	146	0.3	$2.12	559	9	$59.76	21,784	333	$2,328.80			
2 Log Bn Q	537	1.2	$7.79	1,157	18	$123.69	292,342	4,464	$31,252.56			
3 Log Bn Q	303	0.7	$4.40	800	12	$85.52	38,875	594	$4,155.90			
3 Sup Pl										110,325	1,685	$11,794.19
21 Sup Coy										604,197	9,226	$64,591.13
Total	**3109**	**7.1**	**$45.10**	**11010**	**168**	**$1,177.01**	**747715**	**11,418**	**$79,933.79**	**714,522**	**10,911**	**$76,385.33**

Source: SAP BI Information Report MMIC001 - Material Balance Analysis for Sep 10.

Observation recording sheets were issued to the personnel who raised the stocktake documentation, entered the counts and completed the stocktake transactions. These sheets broke the process down into five stages. The information from these observation sheets was analysed to determine the average time it took to process a stocktake. Salary tables were used for the personnel who conducted the stocktakes and the average cost of the stocktakes were determined. These results are shown in Table 5.3.

Table 5.3. Average Stocktake Processing Times and Costs

Action	**Average Time Taken in Minutes**	**Average Cost per PI**
Create PI	3.56	$0.37
Print PI	1.71	$0.18
Enter PI Count	4.78	$0.50
Create Difference Report	2.97	$0.28
Post PI	21.71	$1.93
Totals	**34.72**	**$3.26**

These averages were applied to the expected frequencies of stocktakes and Table 5.4 shows the results of these calculations. The total time taken to complete one month's stocktakes was 188 hours and the total cost was $1,064.

Table 5.4. Monthly Stocktake Processing Times and Costs

Unit	No of Stocktakes	Time in Hours	Cost
A	16	9.3	$52.23
B	31	17.9	$101.20
C	36	20.8	$117.52
D	41	23.7	$133.84
E	110	63.7	$359.08
F	70	40.5	$228.51
G	6	3.5	$19.59
H	16	9.3	$52.23
Total	**326**	**188.7**	**$1,064.19**

Source: SAP Display Inventory Documents for Material for Sep 10

When the stocktake processing time and counting time are added together and adjusted to a yearly figure (less one month off for Christmas closedown period) the annual time spent stocktaking is 21,140 hours and the total cost in salaries is $144,945. This summary is shown in Table 5.5.

Table 5.5. Total Annual Stocktake Time and Cost

Stocktake	Time in Hours	Salary Cost
Yearly counting	19,065	$133,239.00
Yearly processing	2,075	$11,706.10
Total	**21,140**	**$144,945.10**

A detailed description of the stocktaking process is in Appendix J. This process was analysed and a summary of the number of steps required during the stocktaking process is shown at Table 5.6.

Table 5.6. Summary of Number of Process Steps for Conducting Stocktakes

Unit		Process						TOTAL
		Create PI	Print PI	Conduct Count	Enter PI Count	Create Differences Report	Post	
Unit G Non SMI	Number of Steps	13	6	10	11	16	6	62
	No of SAP Steps Only	12	6	0	10	11	4	43
Unit H Non SMI	Number of Steps	32	6	8	11	11	7	75
	No of SAP Steps Only	10	6	0	11	11	7	45
Unit B Non SMI	Number of Steps	15	7	10	11	8	7	58
	No of SAP Steps Only	14	7	0	11	8	6	46
Unit G SMI	Number of Steps	10	6	10	11	16	6	59
	No of SAP Steps Only	9	6	0	10	11	4	40
Unit H SMI	Number of Steps	21	6	10	11	11	7	66
	No of SAP Steps Only	19	6	0	11	11	7	54
Unit B SMI	Number of Steps	24	7	12	13	11	13	80
	No of SAP Steps Only	23	7	0	13	11	4	58
TOTAL AVERAGE	**Number of Steps**	**19**	**6**	**10**	**11**	**12**	**8**	**67**
	No of SAP Steps Only	**15**	**6**	**0**	**11**	**11**	**5**	**48**

5.2.2.2 Receipts

Observation recording sheets were attached to items as they arrived into the relevant buildings and these sheets remained with the item throughout the entire receipting process. Each person in the process chain recorded the time they took for their stage of the process. The process was broken down into six stages. A detailed description of the receipts process is in Appendix K. This process was analysed and a summary of the number of steps required during the receipting process is shown at Table 5.7.

Table 5.7. Summary of Number of Process Steps for Conducting Receipts

Unit		Process					TOTAL
		Uplift Freight	Check Contents	SAP Receipt	Put Away	Ledger Action	
G	Number of Steps	12	5		2	4	**23**
	No of SAP Steps Only						**0**
H	Number of Steps	12	4	9	3	3	**31**
	No of SAP Steps Only			5			**5**
Barcode Scanner	Number of Steps			14			**14**
	No of SAP & Scanner Steps Only			12			**12**
B	Number of Steps	10	5	8			**23**
	No of SAP Steps Only			7			**7**
TOTAL	**Number of Steps**	**11**	**4**	**9**	**3**	**4**	**23**
	No of SAP Steps Only			**8**			**8**

The information from the observation sheets was analysed to determine the average time it took to process a receipt. Salary tables were used for the personnel who conducted the stocktakes and the cost of the receipts were determined. The results for this are shown at Table 5.8.

Table 5.8. Average Receipts Times and Costs

Process	Average Time in Minutes	Average Cost
Uplift Freight	35	$2.37
Check Contents	15	$1.21
Log onto SAP	11	$0.77
SAP receipt	6	$0.50
Put Away	7	$0.52
Ledger Action	9	$0.91
Total Process	**82**	**$6.27**

This information was combined with historical data on the number of receipts conducted in a month to determine the time to complete all the receipts and the cost of that. The total time for conducting receipting over a month was 976 hours and the total cost was $4,856. Table 5.9 shows the results of this analysis.

Table 5.9. Monthly Receipts Time and Cost

Unit	Receipts		
	No of Receipts (Sep)	Time (hr)	Cost
A	1813	440	$2,186.42
B	389	94	$469.12
C	424	103	$511.33
D	80	19	$96.48
E	624	151	$752.52
F	697	169	$840.56
G	543	132	$654.84
H	993	241	$1,197.53
Total	**4027**	**976**	**$4,856.44**

Source: SAP BI Information Report MMIC005 - Material Movements Summary for Sep 10.

5.2.2.3 Issues

Observation recording sheets were given to personnel within units who raised the first stage of issues. The sheets remained with the item throughout the entire issuing process. Each person in the process chain recorded the time they took for their stage of the process. The process was broken down into six stages. A detailed description of the process is in Appendix L. This process was analysed and a summary of the number of steps required during the issuing process is shown at Table 5.10.

Table 5.10. Summary of Number of Process Steps for Conducting Issues

Unit		Process					TOTAL
		SAP Issue	Select and Check Stock	Mov to Uplift Loc	Customer Uplift	Ledger Action	
G	Number of Steps	13	4				**17**
	No of SAP Steps Only	12					**12**
H	Number of Steps	13	2	1	1	1	**18**
	No of SAP Steps Only	11					**11**
TOTAL	**Number of Steps**	**13**	**3**	**1**	**1**	**1**	**18**
	No of SAP Steps Only	**12**					**12**

The information from these observation sheets was analysed to determine the average time it took to process an issue. Salary tables were used for the personnel who conducted the stocktakes the cost of the issues was determined. The results for this are shown at Table 5.11.

Table 5.11. Average Issues Times and Costs

Process	Average Time in Minutes	Average Cost
Conduct SAP Issue	16	$2.03
Select stock	5	$0.39
Check stock	2	$0.14
Mov to uplift loc	3	$0.26
Customer uplift	4	$0.41
Ledger action	15	$1.36
Total Process	**45**	**$4.60**

This information was combined with historical data on the number of issues conducted in a month to determine the time and cost to complete all the issues in a month. The total time for issues over a month was 1,632 hours and the total cost was $9,943. Table 5.12 shows the results of this analysis

Table 5.12. Monthly Issues Times and Costs

Unit	Issues		
	No of Issues (Sep)	Time (hr)	Cost
A	1069	806	$4,912.09
B	144	109	$661.68
C	248	187	$1,139.57
D	40	30	$183.80
E	430	324	$1,975.86
F	233	176	$1,070.64
G	64	48	$294.08
H	77	58	$353.82
Total	**2164**	**1,632**	**$9,943.64**

Source: SAP BI Information Report MMIC005 - Material Movements Summary for Sep 10

5.3 Results EastPack Ltd

5.3.1 Interviews

Interviews were conducted with two EastPack Ltd personnel who were involved with the implementation and management of RFID at EastPack Ltd. One of the participants had worked for the company for a long time and was the IT manager during the assessment and implementation project. The other participant was a recent employee who was specifically hired to *"to provide dedicated support to the RFID infrastructure and look for improvements in the system."*

5.3.1.1 Implementation

The first question asked "*why did EastPack start considering RFID"?* The answer to this was that EastPack was a small company that expanded quickly. *"While the coolstores were able to be built to cope with increase, but the systems and processes could not keep up."* This had caused bottlenecks in the coolstores and they were not meeting DIFOTIS targets which earned penalty fines from Zespri *("$500 per pallet in early harvest and $200 per pallet after that")* and lost sales *("$250 k in lost fruit product just for early start period which was week 24 day 7 of season"*). These problems were occurring largely due to the inaccuracy of the stock locations. When putting stock away the process was to read pallet barcodes with a hand scanner and manually type in the pallets location. This was open to error and *"we could not depend on the accuracy of the information being entered and interpreted." "We were having to employ teams of 'Ferrets' who worked the midnight to 7am shift just to try to find lost pallets."*

In addition to the financial and inaccuracy reasons, EastPack were also suffering high turnover of staff. *"Morale was low as people were frustrated and knew the system was not working". "Due to the immense job, and frustration we burnt through three coolstore managers in three years."* Forklift drivers were another group who were resigning through frustration. *"Some forklift drivers would try really hard to make the system work by trying to remember locations of pallets and working hard to sort things out but the next day they would come in and things would be in a mess again."*

The second question asked "what was the implementation plan". The project started in January 2007. EastPack developed the requirement for what they needed. They determined that the *"system requirement was that it had to record pickups and put downs without human intervention."* They hired a consultant from GS1 to assist in determining the best system to meet their needs.

The first step taken was "*conducting an analysis of the current procedures".* The consultant presented a report with recommended changes. He then assisted Eastpac to develop Requests for Proposal. The proposals were evaluated and a provider selected. *"There were seven providers from international companies who were interested in the project. Motorola set up a demo in one lane of the store and in one day showed improvements that could be made."* From the proposals options presented included floor locators (disregarded due to *"concern about damage to floor and coolstore floor integrity"),* and ceiling locators. The provider selected was Peacock Bros using Skytrax roof mounted reader system.

In July 2007 a trial was conducted in one coolstore with one forklift. Eastpac developed a list of what they thought the problems would be to analyse the system against. These possible problems included "temperature *and light differences between outside and in coolstores.*" The provider then set up the system. *"The initial set up looked at installing the skycards and calibrating them so the computer could recognise the locations. The next stage was implementing the interface between the software middleware and hardware i.e. getting SkyTrack and KiwiPlus (ERP software) talking. Then there was setting up the forklifts and having them interface with the software. Training of forklift operators was very easy and did not take long."*

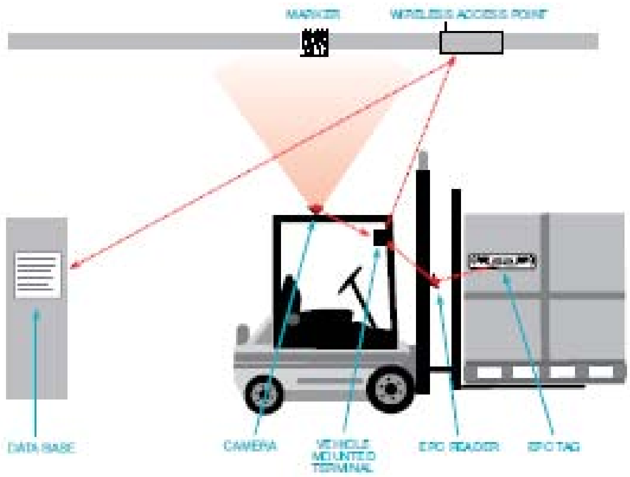
The trial was three months and at the end Eastpac was satisfied that the system could work. In April 2008 Eastpac implemented the system across all 42 coolstores, 3 sites, 80 million pallets and most forklifts. Many issues were encountered and the provider continued to work through the solutions until the system was ready. *"It was delivered late and part way through the packing season but the wait was worthwhile to ensure the errors were fixed and the system was going to work before implementation."*

By December 2008 accuracy was at 99.8% and the project considered complete *"though continual fine tuning and improvements continued to be made"*. *"2009 was* *a consolidation year and 2010 saw the hiring of dedicated RFID Technician, increased spares holdings and a raise in the accuracy to 99.9%".* The RFID Technician looks after the RFID infrastructure and looks for improvements. Audits are conducted to check accuracy. These consist of checkers recording "what *pallets are in what location and then compare to the system. Most errors identified now are legacy issues*."

5.3.1.2 System Chosen

The basic description of how the chosen system works is *"as a forklift approaches a pallet the motion sensor detects the pallet and initiates the system to send transaction of pallet being uplifted from current location. Current location is determined by camera on the roof of forklift scanning barcodes on the ceiling of the store to determine the exact location. As the forklift places a pallet and backs away the motion sensor detects this and initiates the system to send the transaction of the pallet's new location. The information is sent wirelessly to middleware which updates IS system and the forklift screen unit. The location of the forklift is also tracked." "The system has the ability to track the height of the pallet to allow multi level stacking."* This process is shown at Figure 5.11.

Figure 5.11. EastPack RFID System Overview



Source: Smit, 2009, p. 16.

The system consists of the following:

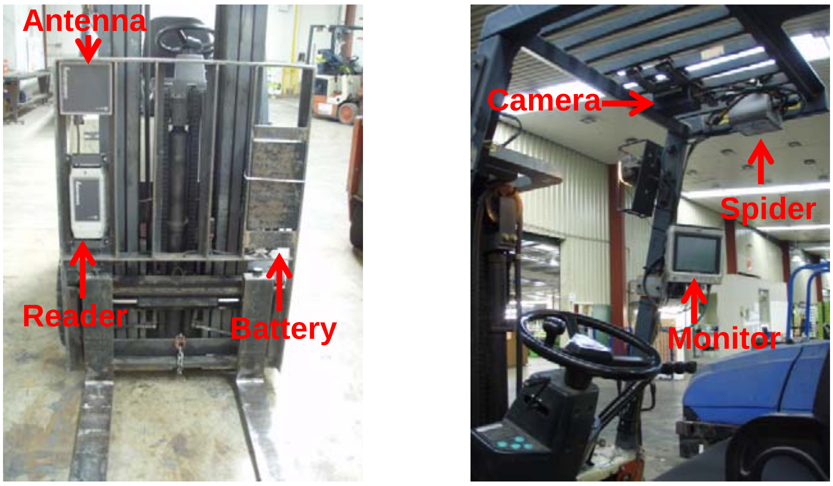
- Inventory Management system is KiwiPlus which is an inventory management system written for the horticulture industry. With the RFID implementation this system can provide a detailed map of where all stock is located and the movements of all forklifts as shown in Figure 5.12.

Figure 5.12. EastPack Coolstore Map Showing Pallet and Forklift Locations

Source: Smit, 2009, p. 21-22.

- MiddleWare is SkyTrack, which is an American company but with an office in Auckland.
- Hardware is from Peacock which is an Australian Company. Hardware consists of CV30 RFID reader (antenna and scanner), motion sensor, battery (in hardwired forklifts replaced with DC converter), camera (to scan roof mounted barcodes, camera power unit, Screen unit (standard Microsoft wireless interface). Total cost approx. $10 000 per forklift, CV30 $3500, most other parts $200. Cost to wire power source to forklift battery $700. This system is shown set up in Figure 5.13.

Figure 5.13. RFID Hardware Mounted on Forklift



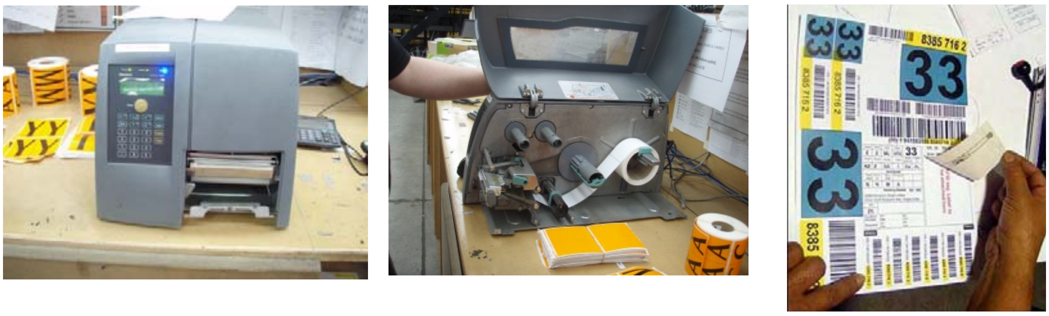
- Location Detection. On ceilings are Skycards (cardboard with barcode sticker attached shown at Figure 5.14) mounted on ceiling by wire. *"Skycard cost approx. $7 per card. The cost is kept down by sourcing fluted card from NZ, ordering the stickers only from Sky Trax and using own staff to put stickers onto fluted card and attach to cables."*

Figure 5.14. Skytrac Location Detection System

Source: Smit, 2009, p. 19.

- Wireless Stations. Cisco Industrial Wireless with industrial outside antenna. One antenna for every three rooms.
- RFID tags are printed onto labels which are stuck onto standard Zespri labels as shown in Figure 5.15. The labels cost *"20-22 cents depending on exchange rate."*

Figure 5.15. EastPack Printer and Labels



Source: left picture Author, right picture: Smit, 2009, p. 21-22.

- There are two printers used. One prints the standard Zespri labels and the other is a RFID reader/writer (Intermec Easy Coder PM41i shown in in Figure 5.15) which *"costs approx. $3000. However Zebra now has a 2 in one printer which would be able to print pallet tag and RFID tag in one go."*

5.3.1.3 Implementation Issues

The third question asked "what were the issues with the implementation". The issues can be broken down into three main areas which are hardware, system and human.

The first hardware issue was the physical setup of the forklift. The key issue was that the hardware was not robust enough. *"The hardware was designed for warehouse and struggled with the moisture of a coolstore. Also it could not cope with the vibration of the forklift and power interruptions."* General solutions found were *"foam under fittings to reduce vibration, forklift checks e.g. tyre balance and reduce worn tyres to reduce vibration and sealing of components to reduce moisture damage."* Some of the issues encountered were:

- Jolts - *"as fork booms extend there is a large jolt which is hard on electronics. Maintenance on hoists, replacing worn-out tyres etc. help to reduce the vibrations."*
- The placement of the battery compartment - *"The doors to the battery compartment have hinges at bottom. When fork move sideways they break the*

doors." The improvement to this is *"to have the hinges nearest the boom so if the fork does move sideways the door just shuts itself."* This has not been implemented yet.

- Screws coming loose on the cameras
- Scratched screens,
- Bent power pins,
- Batteries insufficient causing blown fuses and diodes. *"Currently using Motorcycle Batteries which require frequent recharging and are 12 v when the system requires*
  13 v." The solution found was *"to hardwire the power supply direct from forklift batteries."* One problem encountered with the hardwiring is that *"when forklift operators forget to turn the RFID system off when changing main forklift battery it causes a power surge which damages the Spider* (DC conversion power box to power the camera)*".* The positive outcome of hardwiring direct to the forklift is the "*reduced need to always change batteries*."
- Blown diodes for the Spider. Solution was hardwiring power supply and using a different supplier of diode which are now lasting longer.
- Blow fuses. Solution was changing fuses from 7.5 amps to 5 amp and hardwiring power supply.
- Not enough spare parts initially. Having sufficient spare parts allows modular replacement which reduces downtime for equipment.
- Repair of parts was taking a long time. *"Generally a month turnaround on repairs as the parts had to go to Australia or US. Initially the providers conducted all the repairs but started to conduct own repairs. For example screws were coming loose in the camera units. Rather than ship them off overseas Peacock Bros wrote a process which was simple to follow and Eastpac can repair the problem themselves."*

System issues relate to the RFID setup and procedures. *"As EastPack was the production test prototype for a lot of the systems, the equipment and system*

required amendments and modification as part of the implementation progresses."
Key system issues were:

- Setting of proximity sensors. *"The system was switching on when going through curtain doors and selecting the nearest pallet tag. We lowered sensitivity so it only reads when a pallet is in front, not door curtains or people passing."* Also "we put in a timer in so if after 2-3 seconds of activating no tag was in range the system would switch off."
- The calibration of the SkyCards. *"This was not done correctly in two coolstores and the stock locations were not correctly aligned. This was only discovered once pallets were being loaded into the storerooms. There is still one coolstore which is not calibrated and pallet locations are manually recorded and uploaded into the system."*
- Information Caching. When forklifts leave Wi-Fi zone they are meant to cache information until back in the coverage area when information would upload. *"It was discovered that some new processing machines had inbuilt Wi-Fi and when forklifts left the Wi-Fi zone it would try to download to new machines and crash."*
- Delays in uploading information. *"The original middleware (take data from forklift to main database) was Sybase and RFID anywhere. With this system there were upload delays which could be a problem if a pallet was picked up soon after being dropped off. In the end Peacock Bros programmers wrote another program to perform this function and it was called Beat Anywhere (the programmers first name was Beat pronounced Be-it)."*
- Using correct RFID Tag. "There were issues in ensuring the right RFID tag was attached to the right Pallet Label. The pallet Label is printed on a different printer to the RFID printer. Direction was given for only one set to be done at a time to try to reduce errors."

Human issues relate to the change management, training and following of procedures. They included:

- Drivers not turning system on. This was a key issue during the implementation. *"Drivers were not turning system on as they did not want to be tracked. This* *was fixed by managing the change and not making a big deal of the ability to track the forklift movement. Once the Drivers started to see the benefit of the system to them they became more accepting."*

- Problem notification. *"We had difficulty in getting people to record issues and report problems. They were told if something did not work to write location down manually and record what the issue was. This was not done or the issue was recorded as simply 'Doesn't work."* This issue was especially prevalent with casual staff as "*they do not care as much as permanents and do not report problems*." Some common issues that were not reported were Pallet Cards have wrong RFID tag attached and discrepancies in locations.
- Confirming actions being conducted. Originally the confirming of actions being conducted was done by "*telling the drivers to check their screens when they performed an action to ensure it was recorded. Due to so few errors the drivers stopped checking their screens. The system changed to beep when action conducted so they know if there is no beep there is a problem."*
- Lack of ownership. There was a lack of anyone to take ownership of the system. *"Parts of the system would break down and no one was in charge of repairing them. No one cared when the forklifts broke or parts of the RFID system. New people were not being logged onto the system, no one was monitoring orders or looking at ways to prevent or fix issues. Upgrades were not being completed on all units, especially when they were overseas being repaired so there were frequent problems which were traced back to units using out-dated versions of software."* The solution was to *"hire a RFID technician which has been very successful already. He is now responsible for driver training, log in administrations, repairs, orders and improvements."*

5.3.1.4 Implementation Benefits

The benefits achieved from the implementation of RFID are in the areas of inventory accuracy, reduced fines, reduced spoilage and improved staff morale. The benefits are as follows:

- Improved Accuracy. The old system using barcode and manual input of locations which was not accurate as people imputed wrong locations. RFID has removed this major source of error. Also RFID is finding mistakes in procedures such as ”pallets that are disbanded or mistakes not being deleted from the system which creates phantom containers.” After implementation it was found that *“accuracy rates improved to 80% in the first month”.* Eight months after implementation accuracy was at “*99.8%*” and it is currently sitting at *“99.9%.”*

- Reduced Spoilage. With the RFID system “*we are now able to track the whole history of pallets to see where they are moved, how long they are in each location and who is moving them. This is important for monitoring the cool chain and for issue resolution for complaints on kiwifruit quality at destinations*.” RFID allows *“analysis of pallet time outside coolstores and sends an alert if out they are outside more than 1 hour 50 min.”* This has allowed work practices to change to reduce this time which is reducing the amount of spoilt fruit. Analysis of the system also discovered that the section responsible for producing pallet cards and recording attributes of pallets were not doing FIFO (First in, first out) but were selecting the easiest pallet, leading to pallets sitting too long outside coolstores. These factors have *“reduced fruit losses due to spoilage by 40% from 2007 to 2008 for Green Kiwifruit.”*
- Reduced DIFOTIS Penalties. It has also improved DIFOTIS levels and reduced the penalties paid to Zespri by 65*%. “EastPack is actually earning bonuses now for filling late orders.”*
- Reduced Forklift Requirement. In Te Puke the forklifts required reduced from 24 forklifts to 16, giving a 33% capital saving, despite loading more trays. This also meant 8 less drivers were required.
- Less Paperwork. If data entry was not completed in a timely manner plt can move location a couple of times and end up lost.
- Forklift Movement Tracking. The RFID system can track forklift movement and measure how many pallets workers move in a shift. This information is displayed in public in a whiteboard so the workers know how they are tracking against other people. The benefits of this have been *“improved efficiency now their productivity can be seen and reduced slacking off as managers can see if*

a forklift is static for period of time. Also it has improved ownership of crashes or building damage as they are given a choice of own up or let the system find who did it. All drivers are now owning up to damages they are causing."

- Labour Savings. As well as the 8 less forklift drivers not required, two data entry operators are no longer required as there is less paperwork to process as the data is updated automatically. These savings offset the requirement to hire a RFID technician to manage the system.
- Improved Morale. There is improved morale amongst operators as *"they do not have to stop and do paperwork"* and they *"do not have the frustration of items not being where they should be."*
- Data Requirements. Due to the type of RFID system selected the data storage and processing requirements are not high as the *"system does not generate excess data due to only sending information when uplift or drop off pallets."*
- Phased implementation*. "Conducting a trial was beneficial to resolve most of the issues prior to companywide implementation."*

Overall the response amongst staff has been *"very positive"*, the results have *"exceeded that expected"* and *"the implementation paid for itself in just two years, one year earlier than targeted."*

5.3.1.5 Implementation Negatives

The implementation was not perfect and the following are some of the negatives with the implementation:

- Had to employ RFID technician.
- Late Delivery. The system came on line part way through the packing season instead of at the start as intended. *"It took a little longer to get it right but still had near instant success in improving accuracy to 80%."*
- Human Error. Operators keep forgetting to turn RFID system on. Some forget and move pallets around without their locations being registered. This is a training and management issue which is being resolved.

- Coverage of SkyCards. Not all areas of the warehouse were covered. *"We need the entire warehouse to be covered, especially in Te Puke where new areas are started to be used and are not SkyCarded."*
- Wireless Access. Additional wireless access points were needed to "*cover the wireless deadspots."*
- Manual Backup. *"There is still need a manual backup for if the system goes down, though it is fairly reliable now."*

5.3.2 Supply Chain Comparison Before and After RFID

The detailed steps in the EastPack Ltd supply chain are shown in Appendix M. Currently the first four steps are unchanged with RFID. These steps are picking, receiving, Curing and Controlled Atmosphere Storage and Grading and Packaging. The fifth step is receiving the pallets in which the only change is the printing of an additional label. This is printed concurrently with the pallet label so the only difference in time is sticking the RFID label onto the pallet label.

The sixth step is moving the pallets into storage. The only change is the driver's process for recording the location. Before implementation the driver either manually recorded the location onto a form or using three barcode scans (one on pallet and on a sheet location barcodes one to reflect the coolstore number and one for the row number).

The seventh step is picking pallets for an order. Changes in this step is the automation of pick lists for the forklift drivers and the location recording process, as in step 6, when the pallets are moved to the Load-Out Coolstore. In the eighth step the only change is the automatic issue of the stock when it is loaded onto the forklift.

The physical time savings is only 42 seconds but the secondary effects of these savings is reduced data input requirements and less time by the forklift drivers looking for missing stock.

5.4 Discussion

5.4.1 NZ Army

While the NZ Army Supply chain does work it is not efficient. There are not enough SupTech to complete all of the tasks and units are often forced to choose between ensuring compliance requirements are met and providing proactive support to their customers. In order to enable SupTech to transfer easily between units and to ensure standardisation is maintained the key processes are outlined in official publications. Despite this there are differences in the way processes are conducted which reflect the trade-off between correct procedures and lack of personnel.

The processes of stocktaking, receipting and issuing are all time consuming and labour intensive. Stocktaking in particular has many shortcomings such as trouble finding items, identifying them, counts being done correctly and being done too often. Suggestions for improving the processes were use of technology and changing procedures such as reducing the frequency of checks.

While some improvements can be made to streamline the processes one of the biggest time elements is the use of SAP. SAP requires multiple screens and variations to be set for every process. Automation of processes would reduce the time required to manually input data into SAP. The introduction of the Barcode scanners have made little impact into the processes unless there is a large amount of items to receipt. Smaller amounts require logins to both SAP and the scanner, require up to 10 min for the data to upload once the scanner is back in its cradle and then still require SAP processing to transfer the items to their destination location or off the system if they are items for consumption.

5.4.2 EastPack Ltd

EastPack Ltd made the decision to try RFID technology to combat the issues they were suffering which were inventory inaccuracy, poor DIFOTUS and staff overload. They conducted a phased introduction and the benefits of the implementation were experienced quickly. Many issues were experienced during the implementation relating to hardware issues, system issues and personnel issues. Through a deliberate and planned process they worked through these issues with the technology providers and their employees. Once the employees became familiar with the system and experienced its benefits they became positive toward the change. One lesson they learnt was that they needed someone to take charge of the system and look for improvements so they hired a dedicated RFID Technician. EastPack Ltd achieved an ROI of two years and now has an inventory accuracy rate of 99.9%, reduced staff turnover and reduced capital and personnel costs. They consider the implementation of RFID a major success.

5.4.3 Comparison of NZ Army and EastPack Ltd.

Many of the issues experienced by EastPack Ltd are similar to that of the NZ Army. In particular the staff overload, inventory inaccuracy and DIFOTUS levels not up to their potential. The majority of the NZ Army people were familiar with RFID technology and supportive of using technology to improve their processes.

The system chosen for EastPack Ltd would work in some areas of the NZ Army Supply Chain but the NZ Army Inventory is more complex than that of EastPack Ltd. EastPack Ltd is only concerned with moving standard sized cases and pallets in a controlled environment in their three coolstores. NZ Army has over 5 000 different types of items to manage in several locations serving different types of units.

Despite these differences the concept of RFID could be applied to the NZ Army to great effect and the lessons learnt from EastPack Ltd on implementation and system could be applied to the NZ Army.

Chapter 6 - Conclusion

6.1 Introduction

On the basis of the literature review and the research conducted, this chapter summarises the overall conclusions of the study. This chapter reviews the objectives set at the beginning of the study and for each objective conclusions are drawn. Finally the limitations of the current study and suggestions for future research are given.

6.2 Objectives

The aim of this research was to investigate the applicability of RFID to the NZ Army supply chain to see if it could improve the efficiency and effectiveness of the supply chain and reduce the workload on the Army's Supply Technicians.

In order to achieve the aim of this research the following objectives are established:

- Objective One. To review existing literature on RFID in Supply Chains.
- Objective Two. To describe the NZ Army Supply Chain.
- Objective Three. To develop a time and cost assessment for three processes in the NZ Army Supply Chain
- Objective Four. To investigate the use of RFID in a civilian organisation that has recently implemented the technology.
- Objective Five. To evaluate the effect RFID could have on the NZ Army Supply Chain.

6.2.1 Conclusion for Objective One.

To review existing literature on RFID in Supply Chains. The literature review reveals that effective management of supply chains are essential. Failure to manage the supply chain results in uncertainty and inventory inaccuracy. These result in inventory fluctuations, increased inventory, increased stocktaking requirements, slow response times, more demands at short notice, high obsolescence and poor customer service. The key method to improve these areas is to improve supply chain visibility which can be obtained through better communication and the use of technology such as ERP systems, barcoding and RFID.

Military Supply chains have a different focus from commercial ones. The key difference is that commercial supply chains are focused on profit while military supply chains are focused on readiness for war and operate in conditions of greater uncertainty. This requires different management techniques and generally results in higher inventory levels to provide for contingencies. However the basic principle of requiring supply chain visibility to have an effective system still holds true.

RFID is an automatic identification technology that relies on radio waves to identify, track and manage objects and collect and store data. The key benefit that RFID provides is improved information visibility but it also provides greater automation of processes which improves the speed of processes and reduces human error which leads to greater inventory accuracy. This in turn leads to reduced inventory levels and savings in costs and labour.

There are a number of limitations of RFID which need to be fully understood so companies looking at implementing the technology have a realistic expectation. These limitations relate to cost, readability, and security. Implementation needs to be a carefully planned activity that involves all involved parties and reviews processes rather than just laying the technology over current processes. When implemented the technology has great potential in the areas of warehousing and inventory management including receipting, issuing, demanding and stocktaking. It also can improve asset management and consignment management and be used for security improvements.

6.2.2 Conclusion for Objective Two.

To describe the NZ Army Supply Chain. The NZ Army Supply chain has undergone many changes over the last 15 years with greater commercialisation to reduce costs at the detriment of service levels and SupTech workload. Different supply chains exist depending on the source of an item which leads to SupTech having to learn more processes. The processes used are clearly outlined in formal publications but still vary between units, largely due to lack of staff and high workloads. The key processes of receipting, issuing and stocktaking processes are relatively simple but time and labour intensive. They are also subject to human error which has contributed to inventory inaccuracies.

6.2.3 Conclusion for Objective Three.

To develop a time and cost assessment for three processes in the NZ Army Supply Chain. Through analysis of data gathered through interviews and observations at six units, the time and salary cost for each process was determined. The results of this analysis are summarised at Figure 6.1.

Table 6.1. Summary of Yearly Time and Costs for Processes

Process	Time in Hours	Salary Cost
Stocktakes	21,140	$144,945.10
Receipts	10736	$53,420.84
Issues	17952	$109,380.04
TOTAL	**49,828**	**$307,745.98**

6.2.4 Conclusion for Objective Four.

To investigate the use of RFID in a civilian organisation that has recently implemented the technology. EastPack Ltd was suffering many of the problems encountered by the NZ Army. They implemented RFID from 2007 to 2008, working through a phased implementation and working closely with their technology providers to get the system operating efficiently. The results from the implementation showed a very quick improvement in inventory accuracy and within 8 months had achieved a 99.8% accuracy rate. Their ROI was achieved early, in only two years, and they have made significant savings in labour and capital costs, improved DIFOTIS, improved responsiveness and significantly reduced spoilage.

6.2.5 Conclusion for Objective Five.

To evaluate the effect RFID could have on the NZ Army Supply Chain. RFID applied to warehouses and inventory management would significantly reduce most process times and costs, improve inventory accuracy and reduce the amount of stocktaking that is needed. When comparing salary costs to implementation costs, the ROI could be within two years if not shorter. The key outcome would be a reduction in the workload of the SupTech which would allow them to provide better customer service and give them time to focus on looking for continual improvements. The application of RFID to assets would improve the management, tracking and security of these items as well as speed up the time wasted in processing loans of these equipments.

6.3 Limitations of Study

This was exploratory research and was not concerned with empirical generalisations. The research was conducted over a short time frame and the gathering of data was affected by the high tempo of the organisations being researched. Only one part of the supply chain is analysed, furthermore only three processes are examined in detail. Another severe limitation is that the determination of the the cost of the processes was simply based on the salary of the individuals involved. With military personnel there are high training costs and additional costs such as uniforms, and medical coverage which add to the basic salary cost. There are also other costs associated with processes such as stationary and printing costs which were not analysed. These limitations are necessary due to the time available for the collection of data.

Additionally the quality of the results depends on the data gathered from the NZ Army and EastPack Ltd through observations, interviews and company documents. These limitations narrow the adaptability and generalisability of the study, but it can give crucial insights for similar problems in similar size militaries or non-profit organisations.

6.4 Future Research

Broadening the scope of the research conducted to gather data from different stages of the supply chain and to interview soldiers of all levels would provide a more accurate state of the current NZ Army Supply Chain.

Further research into the results of implementation of RFID into other militaries would provide a better understanding of the technologies application in the unique military environment.

Using techniques similar to those utilised in this study it would be possible to conduct ROI assessments of other government or non-profit organisations for the implementation of RFID or other technologies to their organisations.

6.5 Conclusion

In conclusion, this study was an attempt to determine the applicability of RFID to the NZ Army supply chain. This study has shown that the application of RFID shows definite potential to improve the efficiency and effectiveness of the NZ Army Supply Chain.

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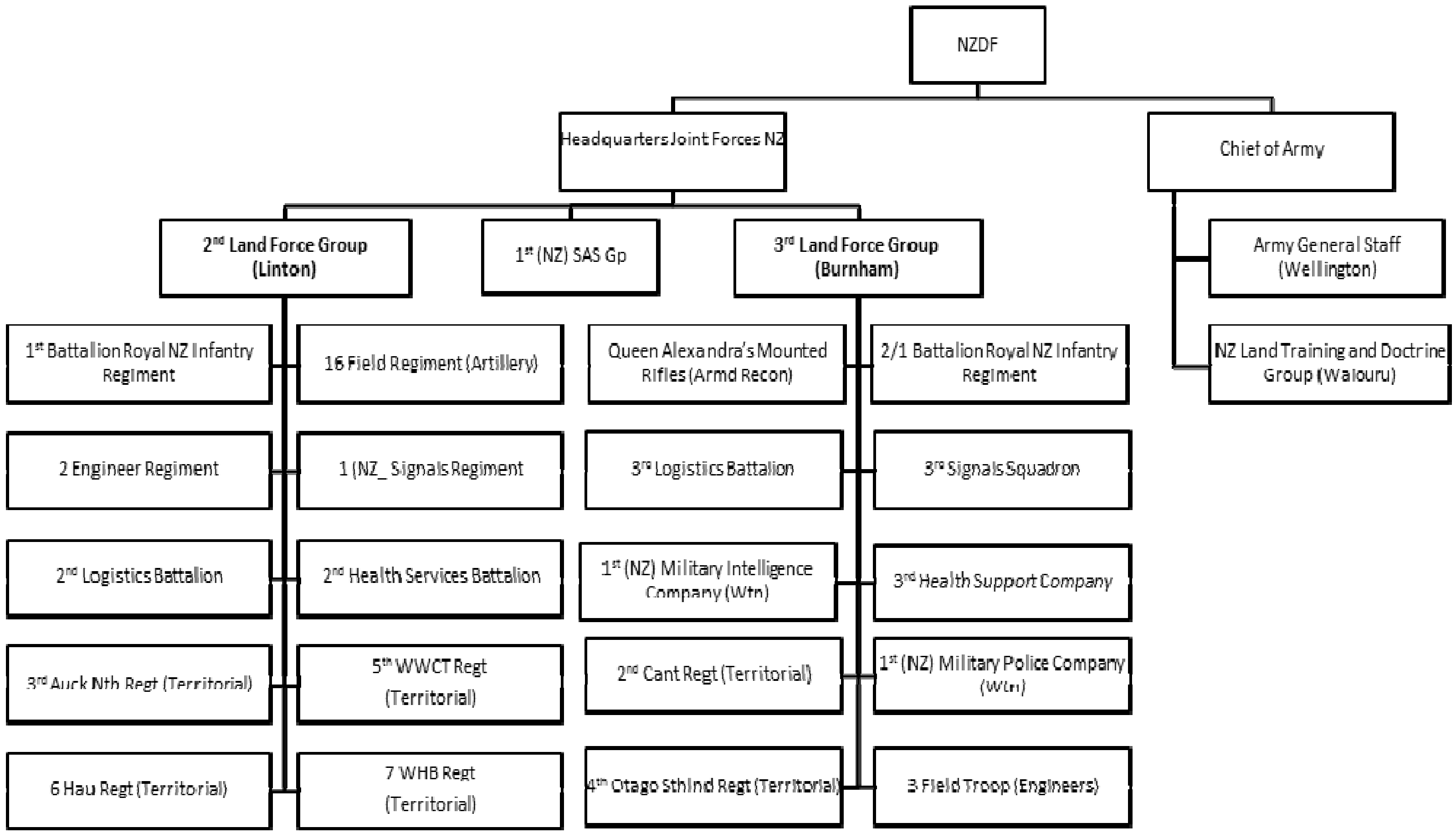
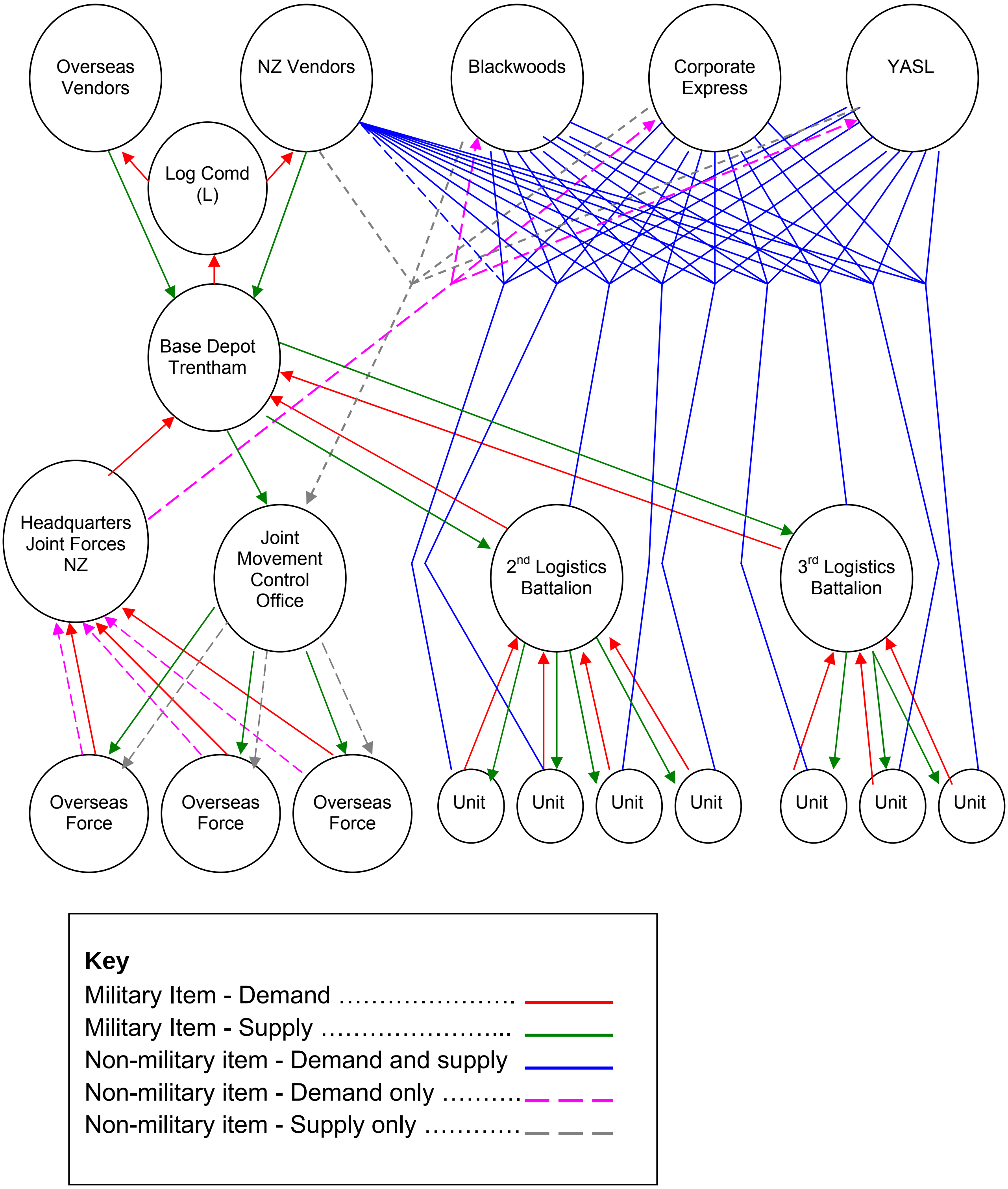
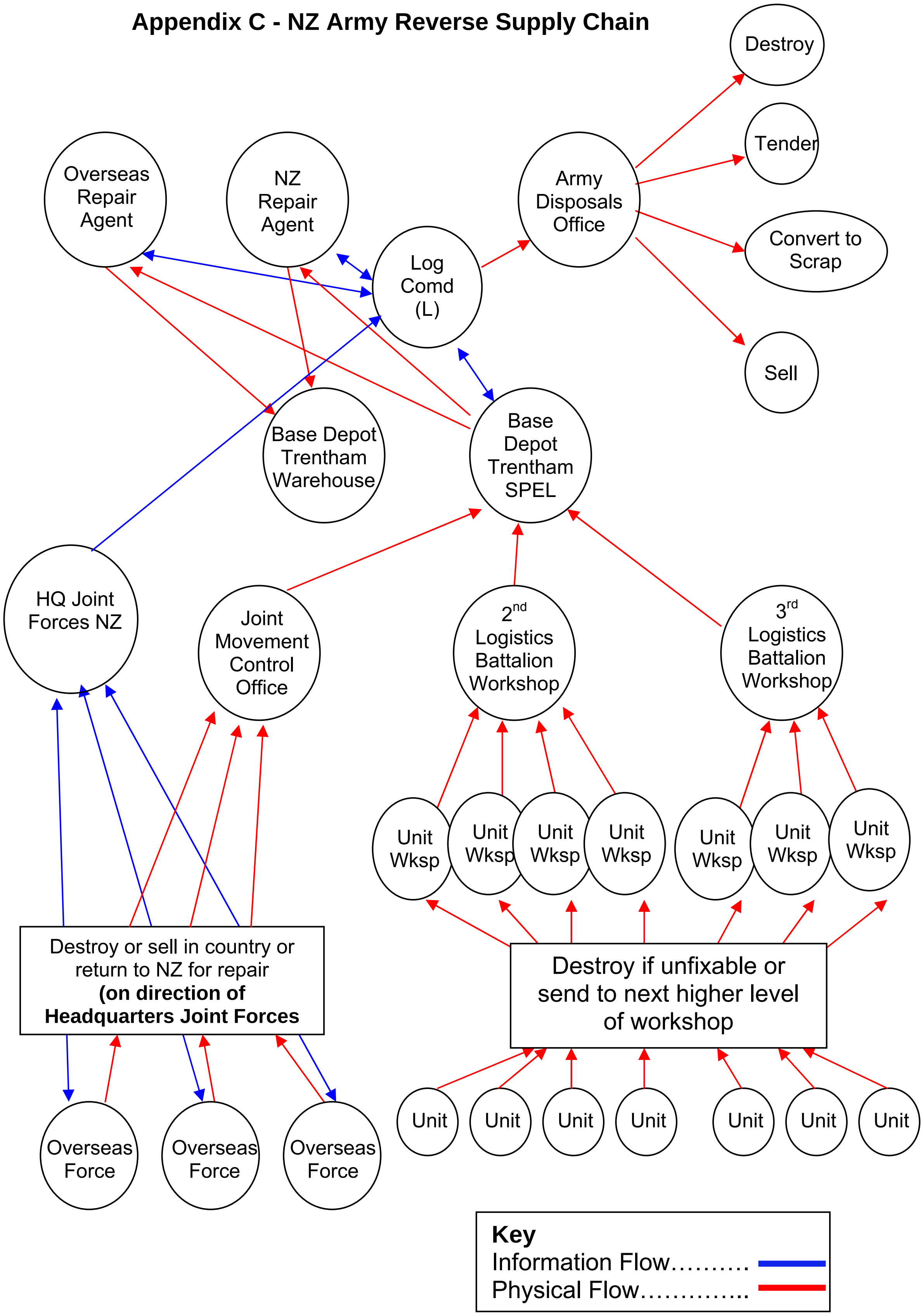
Appendix A - NZ Army Organisation



Appendix B - NZ Army Supply Chain



Appendix C - NZ Army Reverse Supply Chain



Appendix D - Permission Letter – Army

NEW ZEALAND ARMY
3rd Logistics Battalion
MINUTE

4641

15 Feb 10

Commander Logistics (Army)

Through
CO
Comd 3 LFG

PERMISSION TO CONDUCT RESEARCH: T998769 MAJ K.T. COLLINS, RNZALR

Reference:
A. Email Lt Col Taylor/Maj Collins dated 9 Feb 10

1. I am currently conducting a research project for my Thesis in order to complete a Masters in Logistics and Supply Chain Management from Massey University. The subject of my thesis is 'The Applicability of Radio Frequency Identification Device (RFID) to the New Zealand Supply Chain'. The aim of this research is to determine if the application of RFID to the NZ Army supply chain will reduce the workload on our soldiers and increase the efficiency of the supply chain.

2. The research will be achieved by conducting a case study of the NZ Army Supply Chain by examining some of the current processes used, to determine their efficiencies. This case study will be compared to a case study of a civilian supply chain which currently uses RFID, to determine if their processes could be applied to the NZ Army to achieve efficiencies.

3. My intent is to value map the processes of issues, receipts and stocktakes in first and second line supply organisations over a period of two months, to determine the efficiency in these processes. This will be done through interviews with first and second line SupTech pers, observation and through surveys. I would also like to conduct short interviews (up to an hour) with supply staff of varied rank, to assist in developing a picture of the current efficiency of the current processes and generate ideas for improving the processes.

4. Ref A is confirmation that approval can be granted by Comd Log (A) for this research as it is not personnel research and as such is not subject to NZDF provisions concerning research. Therefore I request permission to conduct this research in the following units over the period Mar to Sep 10:

a. Queen Alexandra's Mounted Rifles,

b. 1st Royal New Zealand Infantry Regiment,

c. 2/1st Royal New Zealand Infantry Regiment,

d. 16 Field Regiment,

e. 2nd Logistics Battalion,

f. 3rd Logistics Battalion, and

g. Trentham Regional Support Battalion.

5. I also request permission to use SAP records to gain historical data on the frequency of transactions in the three functions I am researching.

6. The information I gather from my research will be kept secure and only used for the completion of the Thesis. The identity of those individuals interviewed will be kept confidential in the Thesis. On completion of the research all information relating to this research will be destroyed if required. On completion of the research a copy of the Thesis will be provided to the NZ Army.

7. The supervisor for this research project is Dr Norman Marr, Director of the Logistics and Supply Chain department of Massey University. He can be contacted by email at N.E.Marr@massey.ac.nz or by phone on 06 356 0900 extn 81414.

8. No research will commence until the project has been reviewed and approved by the Massey University Human Ethics Committee, this is expected to be completed by mid Mar 10.

9. For your approval.

K. T. COLLINS
MAJ
OC 3 CSC

DtelN 337 7651

Recommended / Not Recommended

J. C. BLISS
LT COL
CO 3 LOG BN

Recommended / Not Recommended

P. B. MCKEE
COL
COMD 3 LFG

Approved / Not Approved

C. LOTT
COL
COMD LOG (A)

Appendix E - Permission Letters – Units

MASSEY UNIVERSITY
COLLEGE OF SCIENCES
TE WĀHANGA PŪTAIAO

MINUTE

4508

25 Jun 10

CO 3 Log Bn

PERMISSION TO CONDUCT SUPPLY CHAIN RESEARCH ON 3 LOG BN

Reference:
A. COMLOG (A) 4508/2 dated 13 May 10 (Encl)

10. In Ref A permission was granted for me to conduct research on the Army supply chain in order to complete my Thesis on 'The Applicability of Radio Frequency Identification Device (RFID) to the New Zealand Supply Chain'. The aim of this research is to determine if the application of RFID to the NZ Army supply chain will reduce the workload on our soldiers and increase the efficiency of the supply chain.

11. I request permission to conduct research on 3 Log Bn
12. supply processes over the pd Jul – Sep 10. My intent is to value map the processes of issues, receipts and stocktakes to determine the efficiency in these processes and the cost, both financial and manpower. This will be done through interviews with some of the snr unit SupTech, observation and through surveys.

13. The information I gather from my research will be kept secure and only used for the completion of the Thesis. The identity of those individuals interviewed will be kept confidential in the Thesis. On completion of the research all information relating to this research will be destroyed if required. On completion of the research a summary of the research will be promulgated.

14. The supervisor for this research project is Dr Norman Marr, Director of the Logistics and Supply Chain department of Massey University. He can be contacted by email at N.E.Marr@massey.ac.nz or by phone on 06 3505226.

15. This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern B, Application 10/05. If you have any concerns about the conduct of this research, please contact Dr Karl Pajo, Chair, Massey University Human Ethics Committee: Southern B, telephone 04 801 5799 x 6929, email humanethicsouthb@massey.ac.nz.

16. For your approval.

K. T. COLLINS
MAJ
OC

DtelN 337 7651

Appendix F - Interview Questions – Army

1. What pers do you have?
2. Is this enough people to do your job?
3. What are your thoughts on the current issue and receipting processes?
4. Can you think of any improvements that can be made to these processes?
5. What are your thoughts on the current stocktaking processes?
6. Is there too much stocktaking done?
7. What are the main issues you encounter with stocktakes?
8. What improvements can be made to the stocktaking process?
9. What do you think of the barcode system?
10. Have you heard of RFID before?
11. How do you think RFID could be applied to the Army?
12. Have you heard of or used Value Stream Mapping?

MASSEY UNIVERSITY
COLLEGE OF SCIENCES
TE WĀHANGA PŪTAIAO

RESEARCH INFORMATION SHEET FOR INTERVIEW

1. I am a part time student at Massey University and am currently conducting a research project for my Thesis in order to complete a Masters in Logistics and Supply Chain Management from Massey University. The subject of my thesis is 'The Applicability of Radio Frequency Identification Device (RFID) to the New Zealand Supply Chain'. The aim of this research is to determine if the application of RFID to the NZ Army supply chain will reduce the workload on our soldiers and increase the efficiency of the supply chain.

2. The research will be achieved by conducting a case study of the NZ Army Supply Chain by examining some of the current processes used, to determine their efficiencies. This case study will be compared to a case study of a civilian supply chain which currently uses RFID, to determine if their processes could be applied to the NZ Army to achieve efficiencies.

3. My intent is to value map the processes of issues, receipts and stocktakes in first and second line supply organisations over a period of two months, to determine the efficiency in these processes. This will be done through interviews with first and second line SupTech pers, observation and through surveys. I would also like to conduct short interviews (up to an hour) with supply staff of varied rank, to assist in developing a picture of the current efficiency of the current processes and generate ideas for improving the processes.

4. The information I gather from my research will be kept secure and only used for the completion of the Thesis. The identity of those individuals interviewed will be kept confidential in the Thesis. On completion of the research all information relating to this research will be destroyed if required. On completion of the research a summary of the research findings will be provided to all participants.

5. Participation in the interview is voluntary. Your name and position details will be recorded to allow follow up questions but your identity will not be disclosed in the published Thesis. The research is looking at organisation efficiency and is not concerned with personnel performance. Individual performance information will not be collected or passed on to any superiors. When participating in this research you have the following rights:

a. To decide not to answer any of the questions.
b. To withdraw from the interview at any time by advising the interviewer.
c. To have any questions regarding the study answered at any time before, during, or after the questionnaire completion.
d. To request that the audio recording is turned off at any time during the interview.
c. To withdraw from the research at any time by advising the researcher.

6. The researcher is Major Kirstine Collins, RNZALR who is currently the Officer Commanding of 3rd Catering and Supply Company. The research is for personal completion of a Masters Degree though the conclusions will be used to support the introduction of RFID if the results indicate it would improve the Army's supply chain.

7. The supervisor for this research project is Dr Norman Marr, Director of the Logistics and Supply Chain department of Massey University. He can be contacted by email at N.E.Marr@massey.ac.nz or by phone on 06 350 5226.

8. This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern B, Application 10/05. If you have any concerns about the conduct of this research, please contact Dr Karl Pajo, Chair, Massey University Human Ethics Committee: Southern B, telephone 04 801 5799 x 6929, email humanethicsouthb@massey.ac.nz.

MASSEY UNIVERSITY
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INTERVIEW CONSENT STATEMENT

I hereby consent to being interviewed by the researcher. I understand that participation in this interview is entirely voluntary. I understand that I may decide not to answer any of the interview questions. I understand that if I have any questions regarding this study or would like additional information it will be provided at any time before, during, or after the interview. I understand that I may withdraw from this interview at any time by advising the interviewer. I understand that the interview will be voice recorded but I have the right to request that this recording is turned off at any time during the interview.

I understand that the information gathered from the interview will be kept secure and only used for the completion of the Thesis. On completion of the research, and grading of the Thesis, all information relating to the interview will be destroyed. I understand that my identity will be kept confidential and not published in the Thesis.

On the completion of the research I would like a copy of the Thesis – YES / NO.

Signed:

Name: Date:

Appendix G - Interview Questions – EastPack Ltd

MASSEY UNIVERSITY
COLLEGE OF SCIENCES
TE WĀHANGA PŪTAIAO

Interview Schedule for Civilian Organisation Participants

(Confirm they have read information sheet and signed consent form)

What is your position within your organisation?

How long have you held this position?

What prompted your organisation to start considering RFID?

What was your implementation plan?

How long did this process take?

How long ago was the implementation of RFID completed?

What were the issues you had with implementation?

What went well with the implementation?

How has RFID changed the way you operate?

What are the benefits or limitations of RFID for Process Time?

What are the benefits or limitations of RFID for Staff Time and quantity?

What are the benefits or limitations of RFID for Inventory accuracy?

What are the benefits or limitations of RFID for Financial savings?

What are the limitations you have found with RFID?

Appendix H - Observation Form

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Create PI for SMI Stocktakes

This questionnaire is part of a research project being conducted into the effectiveness of the NZ Army supply chain with a particular emphasis on the current costs (staff hours and finance) of the current systems. This questionnaire is for the sole use of the researcher and will be destroyed on the completion of the research assessment. The identity of those completing this questionnaire will remain confidential in the completed research Thesis. Further details on the study and the researcher are contained in the attached information sheet.

This survey is for the Create PI process for SMI Stocktakes.

Please fill in the table for each stocktake conducted.

Date	Rank	Trade Band	Time Start	Time Finish	No of PI Docs	Factors influencing time	Comments

Appendix I – Questionnaires

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Questionnaire for Armoury Stocktakes

Please read the Research Information Sheet First.

Where more than one person is completing the armoury stocktake please provide answers for both individuals.

What is your Rank? _______________ / _______________

How long have you been in this rank? ________ years / ________ years

What Trade are you? ___________________ / ____________________

What Trade Band are you? _______________ / _______________

How many times have you conducted an Armoury stocktake before?

_______________ / _______________

What type of stocktake is this? *Please circle appropriate response*

Barrel Count – only counting number of weapons

Serial Number Count – checking serial number for each weapon.

Time stocktake started? *DTG* **(date time group)** ______________

Time stocktake finished? *DTG* ______________

Total number of weapons/equipment counted? ______________

Were there any factors that affected the time it took you? Yes / No
Please circle appropriate response

If Yes how much time did these factors add, or take away, from the process time?
________min.

Thank you for completing this questionnaire. Please hand this in to the Q Store with your stocktake documentation.

Appendix J - Description of Stocktake Process

Process	Unit F	Unit E	Unit C
Create PI	• Log Into SAP • Double Click on "Last PI Count" • Enter Plant and SLOC info • Select 'Enter" • Export to Exel • Sort by "Date last counted" • Select target items Material Numbers and copy them • Return to SAP homepage • Double click on 'Create PI' • Paste Material Numbers • Enter the Unit Register Number and name of stocktake • Press ' execute' • Write down PI Doc number	• Log Into SAP • Double Click on "Last PI Count" • Enter Plant and SLOC info • Select 'Enter" • Export to Excel • Sort by "Date last counted" • Remove newly receipted items • Select target items Material information and copy them • Create MD 738 manual Stocktake • Open MD 738 Template • Paste material information into MD738 (usually approx. 5 items) • Ammend remainder of MD738 information • Print MD738 • Assign MD738 Stocktake (see conduct count process) • Enter Ledger balances into MD738 • Show MD738 to QM to decide if PI go ahead or investigation of discrepancies required. • Log onto SAP • Select NIIN from MD738 • Log onto SAP • Double click on 'Create PI' • Paste Material Numbers • Enter the Unit Register Number and name of stocktake • Press ' execute' • Write down PI Doc number	• Log Into SAP • Select Phys Inv/Phys. Inventory doc/Sessions/Create phys.inv docs/W/o special stock or use shortcut code M101 • Enter Material Number or range of Material Numbers • Enter Plant and SLOC • Double click "Create dcmts directly" button • Change "Max. No Items/Doc" to 300 • Click "Acc. To Stk" button • Select "Only Material w/o Zero Stock" • Select "Unrestricted", "Quality Inspection" and "Blocked" • Select "Incl. Matls Subj. to Phys. Inv" • Select "Incl. Btchs Subj. to PhysInv" • Enter PI number (fm unit PI Register) • Enter name of stocktake eg D009 100% • Press ' execute' • Write down PI Doc number
Print PI	• Return to SAP home screen • Double click on 'Print PI' • Enter PI Doc number • Remove plant and SLOC information • Press 'execute' • Press 'Select Print"	• Return to SAP home screen • Double click on 'Print PI' • Enter PI Doc number • Remove plant and SLOC information • Press 'execute' • Press 'Select Print"	• Return to SAP home screen • Select Phys Inv/Phys. Inventory doc/Print or use shortcut code ZL43 • Enter PI Doc number • Enter plant and SLOC information • Enter Printer number in "output device" • Press 'execute' • Press 'Print"
Conduct Count	• Give Printed PI Doc to counter • Brief counter on conduct of PI • Give 7 day deadline to counter (for CQ stocktakes, less for Weekly 10 item. • Conduct of Count (by min of two pers) • Physically check serial numbers (3 for wpns) • Circle or Tick on PI Doc for each sighted serial number • Count all items • Enter total number on PI Doc • Sign each PI Doc page • Return completed PI Doc to ARQMS or Ledger NCO	• This process done before opening SAP PI doc • Give Printed MD738 to counter • Brief counter on conduct of PI • Conduct of MD 738 Count (by min of two pers) • Physically check serial numbers (3 for wpns) • Count all items • Enter total number and serial numbers on MD738 • Sign MD738 • Return completed MD738 to Ledger Clk • Next process is actual create PI Doc step 23-32 and print 33-38 • PI Doc filled in based off MD738 info and signed by Stm	• Give Printed PI Doc to counter • Brief counter on conduct of PI • Give deadline to counter. • Conduct of Count (by min of two pers) • Physically check serial numbers (3 for wpns) • Circle or Tick on PI Doc for each sighted serial number • Count all items • Enter total number on PI Doc • Sign each PI Doc page • Return completed PI Doc to ARQMS or Ledger NCO

Appendix J Continued

Process	Unit F	Unit E	Unit C
Enter Count	• Log onto SAP • Double click on "Enter PI Count' • Enter PI Number • Enter Count Date (if different from default date) • Press 'execute' • Click 'okay' on warning window • Enter counts • Click 'tick' to see serial numbers • Tick against each serial number counted or click 'select all' • Press 'save' • Click 'okay' on warning box confirming count entered	• Log onto SAP • Double click on "Enter PI Count' • Enter PI Number • Enter Count Date (if different from default date) • Press 'execute' • Click 'okay' on warning window • Enter counts • Click 'tick' to see serial numbers • Tick against each serial number counted or click 'select all' • Press 'save' • Click 'okay' on warning box confirming count entered	• Log onto SAP • Select Phys Inv/Inventory count/Enter or use shortcut code M104 • Enter PI Number • Enter Count Date (if different from default date) • Press 'execute' • Click 'okay' on warning window • Enter counts • Click 'tick' to see serial numbers • Tick against each serial number counted or click 'select all' • Press 'save' • Click 'okay' on warning box confirming count entered
Create Differences Report	• Go to SAP home page • Double click on 'Print Differences Report' • Clear Material Number box • Enter PI Doc number • Change layout to "\ 3LFG' • Click 'execute' • Select ' Print Differences Report" • Tick beside PI Doc number • Select 'list\print' or click 'print symbol' • Tick 'Print' box • Tick 'Okay' on spool request advisory box • When Count Correct • Stamp Differences Report with 'Posted with/without differences' • Stamp Differences Report with 'Posted and Checked' stamp • Give to AO to check. • AO to check and sign Differences Report	• Go to SAP home page • Double click on 'Print Differences Report' • Clear Material Number box • Enter PI Doc number • Change layout to "\ 3LFG' • Click 'execute' • Select ' Print Differences Report" • Tick beside PI Doc number • Select 'list\print' or click 'print symbol' • Tick 'Print' box • Tick 'Okay' on spool request advisory box	• Go to SAP home page • Select Phys Inv/Difference/Print or use shortcut code M120 • Enter PI Doc number • Click "Select All" • Click "Print" • Ensure printer is correct (LN31) • Click the tick. • Tick 'Okay' on spool request advisory box
Post PI	• Log onto SAP • Double click on 'Post PI Doc' • Enter PI Doc No • Click 'save' • Sign Differences Report in 'posted' box • File Differences Report	• Log onto SAP • Double click on 'Change PI Document' • Enter PI Doc number • Click 'Enter' • Tick "del" against items to be deleted • Click 'Deletion Indicator' • Select "Post" so PI posted less item which is deleted.	• Log onto SAP • Select Phys Inv/Difference/Print or use shortcut code M120 • Enter PI Doc No • Click "Select All" • Click "Post Differences" • Click 'save' • File Differences Report

Appendix K - Description of Receipts Process

Process	Unit F	Unit E	Unit E (Barcode)	Unit B
Uplift Freight	• Item delivered to central freight • Central freight processes • Q Store per go to Central Freight (2 times per day) • Q Store per checks package for damage • If correct continue with next step • If incorrect advises Central Freight per • Open package and check contents • If contents undamaged continue with next step • If contents damaged Central Freight conducts damaged goods process and insurance. • Q Store per checks correct address on package • Q Store signs for package on Central Freight Freight Register • Q Store per moves package to Q Store	• Item delivered to central freight • Central freight processes • Q Store per go to Central Freight (3-4 times per day) • Q Store per checks correct address on package • Q Store per checks package for damage • If correct continue with next step • If incorrect advises Central Freight per • Open package and check contents • If contents undamaged continue with next step • If contents damaged Central Freight conducts damaged goods process and insurance. • Q Store signs for package in Freight Register or YASL Freight Register • Q Store per moves package to Q Store		• Q Store per go to Central Freight (3-4 times per day) • Q Store per checks correct address on package • Q Store per checks package for damage • If correct continue with next step • If incorrect advises Central Freight per • Open package and check contents • If contents undamaged continue with next step • If contents damaged Central Freight conducts damaged goods process and insurance. • Q Store signs for package in Freight Register or YASL Freight Register • Q Store per moves package to Q Store
Check Contents	• Open package • Find Packing Slip • Check contents against packing slip • If correct sign packing slip certifying check completed • If incorrect note discrepancy on packing slip	• Open package • Find Packing Slip • Check contents against packing slip. If incorrect advise ARQMS • If correct sign packing slip certifying check completed		• Open package • Find Packing Slip • Check contents against packing slip • If correct sign packing slip certifying check completed • If incorrect note discrepancy on packing slip

Appendix K Continued

Process	Unit F	Unit E	Unit E (Barcode)	Unit B
SAP Receipt		• Completed after putaway • Ledger Office to determine if receipt action required by type of order (YASL and SRM automatic receipt so no action required) • Log onto SAP • Go into 'Inventory Management/Receipts/Receipt from CC/to unrestricted" • Type in PO Number from packing slip • Enter Plant and SLOC location • Click "Print" if needed to be signed for eg MD502 item • Enter Cost Center and Order (SPC) number • Against each item enter number to be receipted • Enter text • Click "Execute"	• Barcode Scanner • Log into SAP • Log into the Barcode Scanner • On Scanner select "Start" then "TTS Tracking" • Enter Regimental Number and Passwork • Select 'Login" • Scan the STO voucher • On the scanner select "Finished" and "File Export" • Return Barcode Scanner to cradle • Wait for information to be uploaded – up to 10 min • Go to SAP homepage • Select "Inventory management/Transfers" • Enter PO Number • Conduct transfer.	• Log onto SAP • Go into 'Inventory Management/Receipts/Receipt from STO" • Type in PO No • Click 'Enter" • Highlight received items • Enter text "exercise and unit reference no" • Click 'Post' • Write SAP Receipt No on STO Doc/Packing Slip
Put Away	• Stm places package in relevant pickup area (if unknown checks with Ledger NCO) • Stm hand packing slip to Ledger Office	• Find order in Demands Folder (Printed PO or NZ10 put in there when items ordered) • Place stock in relevant uplift location • Hand packing slip to Ledger Office		
Ledger Action	• Ledger NCO check packing slip has checked signature • Search through 'Demand Folder' for matching demand (search by PO number)	• If no receipt action required • If order complete attach packing slip with original order and file in completed folder • If order not complete attach packing slip with original order and return to Demands Folder.		

Appendix L - Description of Issues Process

<table>
<tr><th colspan="2">Conduct SAP Issue</th><th rowspan="2">Select and Check Stock</th><th rowspan="2">Customer Uplift</th><th rowspan="2">Ledger Action</th></tr>
<tr><th>Unit F</th><th>Unit E</th></tr>
<tr>
<td>• Log Onto SAP
• Double Click on “Inventory Management” ZO66
• Click on “Issues”
• Select Type of issue eg normal – consumption update
• Enter Plant and SLOC
• Select “Print”
• For multiple items tick
• For one item click “new item”
• Enter CC, SPC and item text
• Enter material number and Qty
• Select “Enter”
• Type text details
• Select “Post”</td>
<td>• Select demand voucher or screendump from PO
• Log onto SAP
• Double Click on “SAP SLOC Workbench” ZP96
• Enter SLOC
• Select ‘Enter”
• Highlight relevant item
• Tick ‘Goods Issue”
• Select relevant issue eg to consumption or to new SLOC
• Enter CC, SPC and item text
• Select “Enter”
• Check Qty Correct
• Select “Post”
• Stamp document original dmd req & PO or SRM order,
• Write down Document Number, circle received and issued, sign and date.</td>
<td>• Check Location on Issue Voucher
• Select Items
• Check item incl serial number or batch number and sign issue voucher as selected.
• Have another person check items and sign issue voucher as checked</td>
<td>• Customer checks item and signs on issue voucher</td>
<td>• Voucher returned to Ledger Office for filing.</td>
</tr>
</table>

Appendix M - Description of EastPack Supply Chain

Picking

- Picking teams move between orchards, picking according to a requested quantity of bins per variety.
- Picking teams stick pre-printed barcodes on bins. Additional information is manually written on labels eg picking team and date, maturity changes.
- Picked Kiwifruit are placed in bins, bins are loaded onto trucks.

Receiving

- Bins are received on trucks, 24 bins per truck, bins stacked 4 high. The bins are put on the truck with the barcode labels facing outward.
- Trucks are received one at a time (only one receiving platform).
- The barcodes are scanned manually and the bins are unloaded from the truck and put down next to the truck. While scanning the barcode, additional information is manually entered into the system.
- The truck is loaded with empty bins and returned to the orchard.
- The unloaded bins are moved to the curing bay.

Curing and Controlled Atmosphere Storage

- After unloading the bins from the truck, bins are stored in the curing bay (under a canopy) for about 24-48 hours. The forklift driver ensures that bins from the same batch (variety/orchard/maturity) are put together.
- Certain types of kiwifruit will be stored in a controlled atmosphere for a period of time. These types of kiwifruit are picked into CA Bins.
- CA bins are moved from the curing bay into the CA coolstores where they are packed 14 high.
- The forklift driver manually records the location of the bins (paper based).
- This data is entered into the system manually.

Grading and Packaging

- Forklift driver moves bins from curing bay/CA Store and transfers to the bin-feed conveyor (pack run) ensuring bins from the same batch are moved together.
- Every bin is barcode scanned (manually). The system notifies the operator of errors, in case bins are from different variety/maturity.
- The bin is weighed and the bin is tipped over and the empty bin is weighted to determine the net weight of fruit.
- The Kiwifruit are graded and packed into trays.
- Each tray has an EAN Barcode label attached at the end of the packing lines.
- Trays are packed onto pallets. Pallets are always homogenous. A full pallet is approx. 2 m high.

Appendix M Continued

Receiving (pallets)

- Build pallets receive temporary pallet numbers.
- Pallets move to Tally Clerk Office and assigned a Zespri Managed pallet number.
- The Pallet card is printed and peel off stickers with the pallet number attached to all sides of the pallet. RFID label stuck to pallet label (+15 sec)

Storage (pallets)

- The pallet is moved to EDI section where the pallet build is then checked, the link between case labels and pallet label is verified.
- EDI attach card showing destination location by coolstore.
- The forklift moves the labelled pallets to their location.
- On drop off the forklift driver barcode scans the pallet card.
- Forklift driver records the location of the pallet either by writing onto form or by scanning once for location and once for lane number from a sheet of barcodes representing coolstores and lanes. RFID automatically changes pallet location on KiwiPlus (-15 sec).
- Data processing updates storage location on Kiwi Plus (not reqd – 3 min)

Picking

- When Zespri prompts an order, the system (KiwiPlus) provides a list of pallets that would match the criteria of the order (variety, size etc).
- ~~The coolstore manager decides which pallets will be picked to fulfil the order.~~
- ~~Forklift drivers are told what pallet to uplift by what location~~.
- As order is received a picking list is printed and given to Coolstore Forklift Driver. They uplift pallet and move to the Load-Out Coolstore (RFID automatically changes pallet location on KiwiPlus). This is done 24 hr prior to expected uplift of order. (-4min)
- Pallets are moved to a marshelling area for order consolidation.
- Forklift driver records location of pallet. Automatic (-15 sec)
- ~~Each pallet is registered by peeling off one of the SSCC barcode stickers and sticking it on a separate sheet of paper.~~
- ~~This sheet of paper is transferred to the dispatching office, where the pallet barcodes are scanned into the system, matched against the corresponding order~~, and the bill-of-lading is created.
- A sample of pallets is checked for quality.

Loading

- IM Office print Loadout Note and picking list and give to Load-Out Forklift Drivers.
- 30 min prior to arrival of truck Load-Out Forklift Drivers select pallets and line up in loading bay.
- Once all in location they scan (barcode hand scanner attached to forklift) the Loadout Note and then manually barcode scan the pallets. Green circle appears on Forklift Screen Unit if correct pallet and red circle if incorrect or if they accidentally scan case barcode instead of pallet barcode. Once all pallets scanned Screen advises if order is complete.
- ~~Each pallet is checked off the pallet checklist (prepared by dispatch office) as it is loaded onto the truck.~~
- When trucks arrive forklift loads them. When pallets raised above knee hight RFID system updates to say they pallets have been loaded onto trucks. (- 20 sec)
- ~~After loading the order is confirmed and the corresponding pallets are checked out of inventory~~
- Load-Out Forklift Drivers measure temperature of case and fills in Load-Out Note with time of uplift, truck number, temperature and hand this form to IM Office who load information into KiwiPlus.

Glossary

CLM	Council of Logistics Management
CRM	Customer Relationship Management
CSCMP	Council of Supply Chain Management Professionals
DIFOTUS	Delivered in full and on time
DoD	Department of Defence
EDI	Electronic Data Interchange
EPC	Electronic Product Code
ERP	Electronic Resource Planning
HF	High Frequency
HQ	Headquarters
IT	Information Technology
LF	Low Frequency
Log Com (L)	Logistics Command Land
MRP	Materials Requirement Planning
Non Regular Force	Part Time Soldiers
NZ	New Zealand
NZDF	New Zealand Defence Force
PI	Physical Inventory – Stocktake on SAP
Regular Force	Full time personnel
RFID	Radio Frequency Identification Device
RNZALR	Royal New Zealand Army Logistic Regiment
ROI	Return on Investment
SAP	Systems, Applications & Processes – commercial ERP system
SCM	Supplier Customer Management
SMI	Specially Managed Items
SRM	Supplier Relationship Management
SupTech	Supply Technician
TOC	Theory of Constraints
UHF	Ultra High Frequency