Process integration for paperless delivery using EPC compliance technology

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Abstract

Purpose – The purpose of this paper is to outline the research work of managing returnable assets such as pallets by radio frequency identification (RFID) methods on a national scale.

Design/methodology/approach – The project is an extension of an earlier project which tracks pallets and cartons through a fast moving consumer goods (FMCG) supply chain. This extension project investigates how RFID information can be applied for integrating business processes. The project team developed a national business information network with electronic product code (EPC) compliance devices and systems. To implement an effective pallet management business process, the project team carried out detailed process modelling study of the effect of RFID processes and measured the improvement in performance and efficiency.

Findings – The key to success in the extension project is the adoption of EPC compliance technology that enables efficient communication of business data across platforms and companies. The project found that there is an average 18 per cent improvement in system efficiency should an EPC compliance technology be adopted for supporting paperless proof of delivery. There are also additional administrative and unquantifiable savings in support systems and services.

Research limitations/implications – The research is related to the FMCG industry sector. The business processes in this sector can vary significantly. The project is conducted under a controlled business environment on the condition that the changes would not affect main business activities of the partners. The system efficiency improvement and savings estimated from the project findings should be taken as reference figures only.

Originality/value – The combination of process modelling approach and validation of system performance data by simulation in this paper provide a basis for generalisation of the methodology in similar national scale research studies. The estimated data could be used as reference for preliminary feasibility studies of similar EPC applications.

Keywords Materials management, Tracking, Process efficiency, Modelling, Systems analysis

Paper type Research paper

1. Introduction

Modern supply chain management depends heavily on the capture and processing of information. To make traceability feasible and easily deployable across a supply chain, the development of supply network information systems should be built on well-designed information data models (Kelepouris *et al.*, 2007). Success of these data

The two national projects, NDP and NDP Extension, were supported by the Australian Government through two research grants from the Information Technology Online Program managed by the Department of Communications, Information Technology, and the Arts.

Journal of Manufacturing Technology Management
Vol. 20 No. 6, 2009
pp. 866-886

1741-038X
DOI 10.1108/17410380910975122

models depends on the quality of information that can be captured. In this context, barcodes are the basic data source in supporting the supply chain information system (Manthou and Vlachopoulou, 2001; GS1 Australia, 2008).

Although barcodes have been used for decades, the technology shows deficiency in meeting the demands of technological developments, speed of automation and reduction in manual work. Radio frequency identification (RFID) is a new generation of the object identification technology using electromagnetic radio frequency (RF) signals to communicate identification information. Xiao *et al.* (2007) surveyed RFID systems and applications and discussed five critical research issues: cost control, energy efficiency, privacy issues, multiple readers' interference and security. They concluded that RFID technology is better than barcodes in many ways and will replace barcodes in the future if requirements such as low cost and protection of personal privacy can be met.

RFID systems typically use tags (or transponders) to store identity data and readers (or interrogators) to extract information from the tags. There are three basic RFID systems in use: passive, active and battery-assisted (sometime called semi-passive or semi-active). In passive RFID systems, readers send data or commands by emitting and modulating RF energy. Passive tags, that are small in size and can be as thin as a piece of paper, are commonly used in applications where the tags can be a one-off disposable attachment to a consumer product (Myerson, 2006). This means passive tags must be very low cost. If ordered in large quantities, RFID tags can cost as little as US 12 cents each. Tags respond by backscattering the incident RF energy, in accordance with their stored data. Active tags are battery powered and actively transmit a response, and have greater range than passive systems (some vendors report up to 800 metres). Battery-assisted tags are similar to passive tags but have a battery to either support a sensor (e.g. temperature sensor) or to facilitate a greater read range, but the response mechanism is by backscattering and not an active transmitter. RFID tags can be scanned from a distance with faster data transfer between tags and reader than is possible with barcodes. There is no need for line of sight and the communication protocol allows for multiple tags to be read almost simultaneously. RFID tags can also store data and provide "real time" information about the item.

In a recent Australian RFID pilot project, the National Demonstrator Project (NDP) used electronic product code (EPC) technology to demonstrate how large-scale and distributed RFID enabled supply chains could be implemented (GS1 Australia, CSIRO, 2006). EPC is an identifier that uniquely identifies any product in the supply chain. In its simplest form, EPC comprises a 96 bit code (EPCglobal Inc., 2007). EPCglobal's Ultra High Frequency Class 1 Generation 2 protocol standard defines the protocol to enable a unique item identification (known as item serialization) to be communicated between tags and readers (EPCglobal Inc., 2005). The protocol standard is the latest development of the RFID technology containing advanced features such as Read/Write, password protection (for access to memory), locking of memory areas, data encryption and a kill function (used to disable the tag once the item has been purchased). These advanced features provide the identity data of the tag; enable storage of product information such as time of manufacture; and tracking data such as time of last read if the system supports writing of data to tags.

The NDP successfully tracked pallets and cartons through a fast moving consumer goods (FMCG) supply chain. This was the first attempt in the world to explore the use of EPC standards to achieve inter-enterprise transactions. The NDP demonstrated the feasibility of EPC Networks enabling visibility of goods across company boundaries. However, the project was designed to be exploratory and did not address the issue of how EPC data should be linked to and exploited by business functions, for example, triggering further action on RFID shipment information to send invoices to the customer. Integration of the EPC system to business functions is particularly important enabling the FMCG industry to improve efficiency and achieve cost savings within the supply chain.

Some NDP consortium members continued the work with an extension of the project addressing the issue of EPC data integrating with business information system. The NDP – Business Information Integration (NDP Extension) concentrated on tracking assets, in this case pallets (GS1 Australia, RMIT University, 2007). Managing and tracking assets throughout the supply chain is a labour-intensive and a surprisingly complex task. As assets move between trading partners, any irregularities are hard to spot at the time they are created, and are difficult to reconcile at a later date. Often, discrepancies in quantities sent and received are not spotted until a statement is received several weeks later. The discrepancy must then be resolved by negotiation between trading partners, each of whom will have its own version of events and supporting paperwork that may or may not prove who is responsible. Since there are more than ten million pallets in circulation throughout Australia, the potential for loss is enormous and effort spent managing assets is extremely costly.

This paper uses the NDP Extension case to illustrate how EPC technology could be integrated into the business processes of real time asset management in logistics industry, and describes the benefits quantitatively. The rest of the paper will be organised in the following sections. Section 2 reviews the application of RFID and EPC technologies to business environments. Section 3 outlines the design of the NDP Extension including network configuration, system design, process models, performance of different hardware, and RFID devices. Section 4 presents the process models showing how the business processes were changed when EPC was applied. Section 5 describes an assessment of the impact of the NDP Extension using several key performance indicators. The productivity gain due to EPC-enabled supply chain is measured. Section 6 outlines a way forward, based on the findings in the NDP Extension, for companies to benefit from implementation of EPC in their supply chain.

2. RFID applications

RFID is an identification device for individual items. The ability to identify items individually will substantially improve system efficiency in situations such as accuracy of delivery, quality control, product recalls, customer services, etc. are important. Kärkkäinen and Holmström (2002) presented the idea of wireless product identification as a generic enabler of improved efficiency, customisation, and information sharing in single organisations and supply chains. A system for managing single-item level information was later proposed (Kärkkäinen *et al.*, 2003). Sarma *et al.* (2001) predicted the potential benefits of linking RFID systems directly to the internet as the cost of RFID was declining. Evaluation tools are now available to help organisations identify opportunities in processes where RFID can either add values or reduce wastes (Brintrup *et al.*, 2008).

Chawathe *et al.* (2004) noted that there are still significant challenges in developing and deploying large-scale and distributed applications that impacted nation-wide supply chain management. A solution is to use standard RFID system and components in these applications to ensure system interoperability and seamless data exchange. Schmitt and Michahelles (2008) studied the economic impact of RFID technology in Europe. While some important factors (perceived benefits, costs, compatibility, complexity, top management support, standards and the size of an organization) influencing the adoption and diffusion of RFID are well-known, it is very difficult to quantify or prove RFID's economic impact.

This section reviews the most common industrial applications of RFID and examines current RFID issues meriting research.

2.1 RFID in manufacturing

As early as 1984, General Motors first implemented RFID to track cars and parts through production (Twist, 2005). Brewer *et al.* (1999) analysed the information requirement for supporting dynamic scheduling and concluded that the success of dynamic scheduling would depend on real-time information. They described intelligent tracking technologies that provided the real-time information needed for logistics planning and execution. RFID's important advantage improving inventory accuracy and hence delivery in full on time, thus increasing inventory turnover ratios, as demonstrated by the automated tracking process developed by Song *et al.* (2006).

McFarlane *et al.* (2003) investigated the use of automated identification information to assist decision making and controls relevant to the item that had an RFID tag attached to it. They examined the way in which both conventional and distributed control methods could be enhanced by the availability of accurate, timely information. Extending this idea, Parlikad and McFarlane (2007) demonstrated qualitatively that availability of product information has a positive impact on product recovery decisions. They showed how RFID-based product identification technologies could be employed to provide the necessary information for end of life operations. In the printing industry, Hou and Huang (2006) investigated the business operation requirements and concluded that the ideal approach for RFID applications was the item-tagging mechanism.

2.2 RFID in supply chains

James *et al.* (2004) designed a mobile information system allowing a large supplier of herbs and spices to supermarkets to manage its merchandiser supply chain more effectively. The system used the internet as a low cost communication platform and identified significant cost savings and additional functionality. Prater and Frazier (2005) studied RFID applications in the grocery industry and outlined the market drivers that affected the way the grocery industry approaches RFID. They provided a theoretical framework for future applied research on RFID implementation. They developed a research framework that included research using modelling techniques, RFID implementation and the impact of RFID on daily operational issues.

Sellitto *et al.* (2007) proposed an RFID information value chain that mapped benefits and information attributes across the supply chain. The work was also one of the first that attempted to relate RFID-derived information with aspects of organisational decision making. Chow *et al.* (2006) designed a knowledge-based logistics management system to support logistic service providers in making decisions during the stage of logistics planning and operations by extracting, sharing and storing real-time logistics knowledge. The system was used to manage a number of business processes in a warehouse operating environment.

Fleisch and Tellkamp (2005) examined the relationship between inventory inaccuracy and performance in a retail supply chain using a three echelon supply chain with one product in which end-customer demand is exchanged between the echelons. The model showed that without alignment of physical inventory and information system inventory, inventory information became inaccurate due to low process quality, theft, and items becoming unsalable. They then modified the model with automatic identification technology and found that elimination of inventory inaccuracy could reduce supply chain costs as well as the incidence of stockouts.

Management of RFID data has been a major challenge to industry adoption of the technology. Attaran (2007) found that while RFID was the most prolific technology supporting collaboration and visibility, its adoption was impeded by a variety of issues outside the technology itself: marketing problems, false promises, security and privacy considerations, and a lack of standards.

2.3 EPC and business

EPCglobal (2004) claimed that the EPCglobal Network and the global data synchronization network each provide significant benefits in their own right: the EPCglobal Network provides access to dynamic information about the movement of individual items as they pass through the supply chain while the GDSN ensures the quality of static information about commercial entities and product/service groups among partners for collaborative trading. To apply these standards, each company must evaluate its own goals and information needs to determine if data synchronization can optimise its operations.

Because of the novelty of RFID adoption in the logistics context and to the lack of real case examples, Bottani (2008) used a discrete event simulation model to analyse the effect/potential of adoption of RFID technology on the optimal management of common logistics processes of a FMCG warehouse. In this study, the model replicated both the reengineered RFID logistics processes and the flows of EPC data generated by such processes. The study provided a proof-of-concept case: an EPC compliant data warehouse could help optimise the FMCG industry's logistics processes.

In a related study, Bottani and Rizzi (2008) used a three-echelon supply chain model to quantitatively assess the impact of EPC system on the processes of the FMCG supply chain. The three-echelon supply chain, comprised manufacturers, distributors and retailers of FMCG. The study showed that EPC implementation with pallet-level tagging provides positive revenues for all supply-chain players, whereas adopting case-level tagging created substantial extra costs for manufacturers.

Asset management is one of EPC's potential applications that has substantial business benefits. GS1 France, BRIDGE WP9 partners (2007a, b) analysed the market size of returnable transport item (RTI) and provided a first description of business requirements for RTI management. The specification described the basic requirements in terms of functionality, technology and change management, but the analysis was limited to pooling and exchange models for pallets and crates.

At about the same time, the NDP Extension was developed to explore how EPC technology enhanced the effectiveness of business functions, in particular, enabling electronic paper proof of delivery. This paper describes the NDP Extension more elaborately, illustrates how EPC technology was applied, and summarises the lessons learnt.

3. System development

Development of the EPC system for the NDP extension project was a slow and iterative process. In order to test the idea that the future EPC Network with business information integration should accommodate the wide range of RFID readers used by different trading partners, the consortium used several brands of readers. A number of reader suppliers invited to meet specified reader requirements. Three suppliers, Symbol (later purchased by Motorola), Alien Technology, and Intermec were finally chosen to supply the reader hardware. The suppliers had good records in Australia and guaranteed to provide the EPC compliant readers within the project's tight time frame.

Selection of the test sites was also a problem. The sites should not be so busy so that the tests could disrupt partners' normal business processes, and yet they should have sufficient local support, to maintain and operate the readers, including staff, infrastructure and space. Some development work was severely delayed by key personnel changing employment.

3.1 Development of an end-to-end EPC service

Management of partner expectations was one of the major issues. Some partners were keen to implement every bit of the EPC system themselves. Others provided only minimal on site support. Fortunately, the presence of a large telecommunication partner helped the EPC Network design enormously. The EPC Network was an end-to-end service model meeting the following on-site specifications (Figure 1):

- A Cisco AON router which required three static global IP address to enable network engineers to monitor and control its operations.
- Each RFID reader had a fixed local IP address to enable the AON router to communicate for capturing and filtering RFID read information.

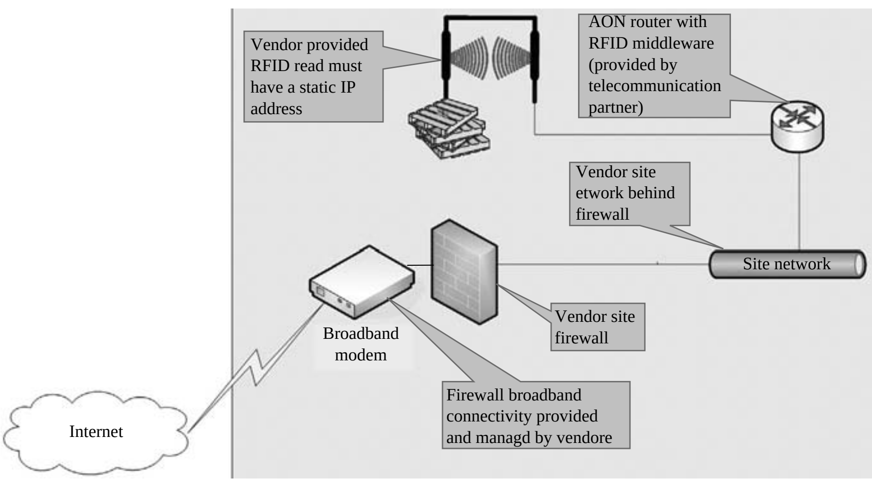

Figure 1. EPC network design

To access the end-to-end service, the on site network configuration required:

- Firewall rules to allow inbound HTTP traffic from the internet to dedicated ports on the Cisco AON router were set up.
- The on site systems should be operating (power on) at all times. Keeping the system on ensured uninterrupted connectivity to the global system. However, some site managers were trained to switch off everything prior to a weekend shutdown.

Some partners were reluctant to agree to these requirements but after intense consultations, all sites conformed to these specifications.

3.2 Quality assurance of tags

The RFID tags used were sourced in USA. It was found that the tags were tuned for attaching to plastic containers only. When the tags were applied to the wooden pallets used in this project, the dielectric property of the wood material de-tuned the tag, which compromised RFID reads.

A second batch of tags was ordered from USA (sample shown in Figure 2). These were supposed to be tuned for attaching to a wooden backing. Their performance was better but still unsatisfactory for this project, especially when multiple stacked pallets containing 15-20 tags were passed by the readers.

It was later found that the tag performance could be made satisfactory by leaving a gap between the tag and the pallet. A 3 mm foam material was subsequently used for this purpose.

3.3 RFID reading configuration

The consortium decided that the main objective of this extension project was to investigate how EPC enabled transactions and data could be used for real business information system integration. The decision to investigate the tracking and business integration for pallets only simplified the hardware setup greatly. However, one of the consortium's main concerns was the ability of the reader to read all tags in its field when the tags were presented. The site owners were also concerned that since this was an investigative research and development project, the installation of EPC

(a) Front **(b)** Back

Figure 2.
CHEP tags used in the project

hardware should be designed such that the system would have minimum impact on their normal business activities on site.

In order to improve the readability of the system, the hardware design was required to read a high stack of pallets (the height varied between 1.8 and 2.2 metre). This means the reading portal design should concentrate all available antennas on the readers to a one-sided configuration. Most RFID readers could drive up to four antennas. Therefore, all four antennas were located at one side of the portal and the pallets were arranged so that all their tags were on the same side. An extra operational procedure had been implemented at the test sites to ensure that all tags were presented to the reader properly. A sturdy but portable stand was designed to accommodate all antennas on one side. The portable stand provided flexibility in operating the read points without obstructing the warehouses' normal working environments.

Different brands of RFID readers operated differently. As an example, the antenna configuration and operating pattern for one of the brand is shown in Figure 3. The antennas were configured to operate in pairs and spaced appropriately on the stand to minimize potential RF interference.

4. Process modelling

Process models were developed to determine what benefits could be obtained from collecting and analysing RFID data. The process models were created using acceptable modelling convention (Standards Association of Australia, 1987). When a process model is available, analysis on the model can be done on a series of "what-if" scenarios. By comparing the costs and benefits, the optimal operating strategies, parameters and conditions can be identified.

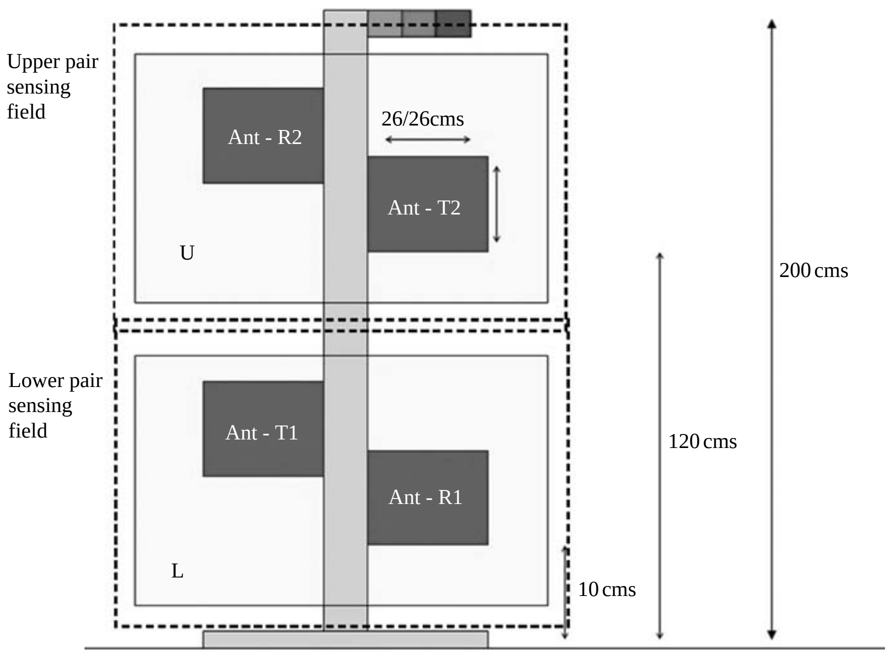

Figure 3. Antenna array operating in pairs on the supporting pole

In the NDP Extension project, industry partners such as Masterfoods, P&G, ACCO, Linfox and Westgate Logistics hired pallets from CHEP. The pallets were shipped out to customers from several manufacturing locations around Australia. The consortium decided to use a Melbourne and a Sydney depot for pallets handling. The business process of interest in the pilot was the transactions of delivery and receipt between the supplier (CHEP) and user (other partners) sites. For each site, two process maps were drawn:

(1) The current (existing) process as employed at the respective company.

(2) The future EPC enabled process.

4.1 Pallet receiving process (manual)

The pallet receiving process entailed a company receiving pallets from a CHEP depot. The current process was totally manual and relied on the associated delivery documents. Tracking and processing of these documents required a lot of manual activity distributed amongst several staff of CHEP and the receiving companies. A similar pallet receiving process existed for both Masterfoods and P&G. There were minor variations amongst companies but in general, the process started with a purchase order (PO) from the initiating company to CHEP. Once the pallets were ready, they were shipped to the ordering company. Appropriate PO numbers and transaction information were recorded on these documents. Figure 4 shows the pallet receiving process for one of the partners.

To support the current process, CHEP's truck drivers and Service Centre staff all used rugged Personal digital assistant PDAs running an application developed by retriever communications (one of the partners). The PDAs communicated with a server at CHEP's head office (known as Retriever server) for issuing, delivering and returning pallets. Hence, these transactions were in fact completed in a system that has minimised handling of paper documents.

4.2 Pallet receiving process (EPC enabled)

One of the objectives of the project was to assess the level of improvement achievable if a paperless system was implemented. After examining the current process maps, the project team modified the processes with a provision that some of the activities would not exist should a full scale EPC system be implemented in the future. The modified process map is shown in Figure 5.

Under the new process, a Business Information Service (BIS) was set-up at the Retriever server. When a forklift load of pallets was driven past the fixed readers at the CHEP Service Centre, the tag information was delivered to the EPC Information Service (EPCIS) system on site. As the EPCIS had no reference information for the PO and therefore could not tell if the correct number of pallets was read, it sent the tag information to the BIS. Using its own database, the BIS paired the tag read to the original order information and the tag count to the truck driver's PDA where a traffic light display indicated that the order had been completely loaded. The tag count was also displayed so that the truck driver could see precisely how many pallets had been read and loaded.

Since the information exchanged between the servers comprise the pallets' identities, the BIS was able to identify any unpaired pallets in the process thereby eliminating the possibility of miscounting or unaccounted for pallet exchanges. Development of the BIS represented a crucial step integrating the EPC data with the PO.

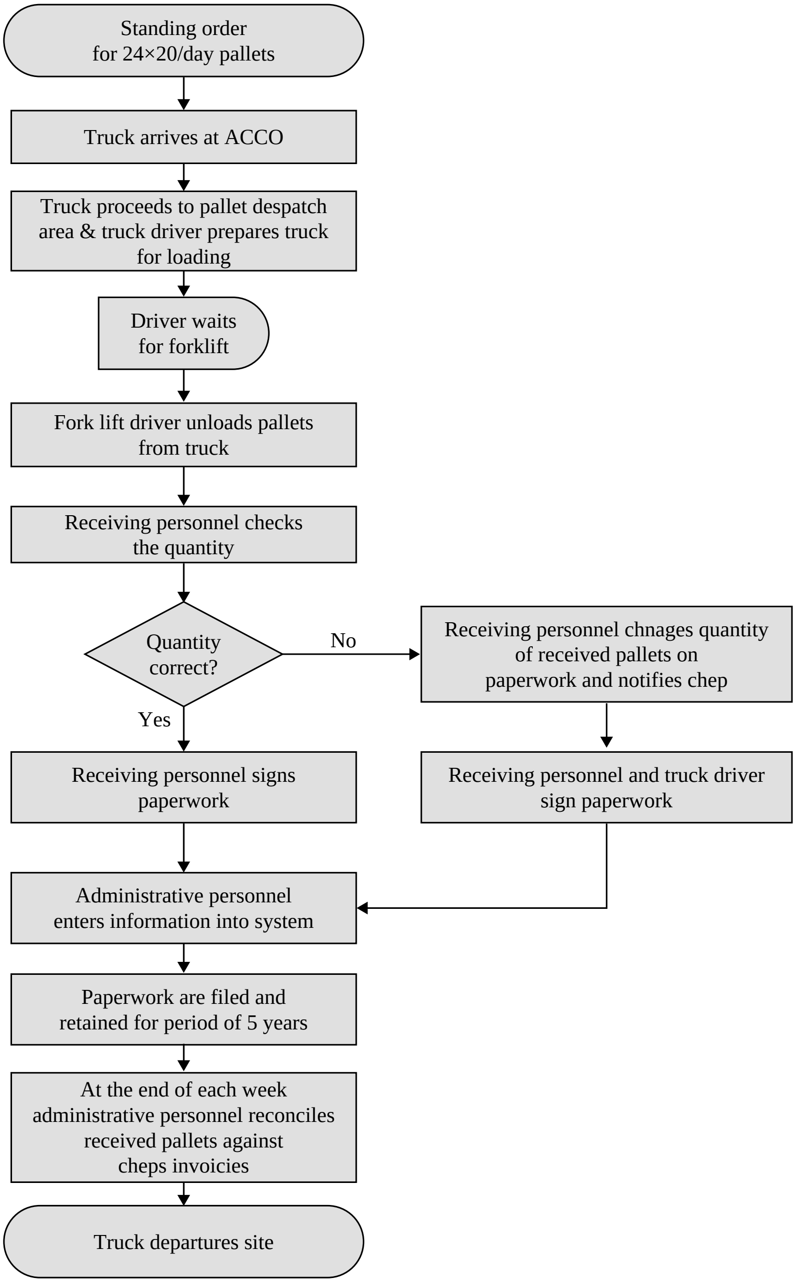

Figure 4.
Pallet issuing process
(manual)

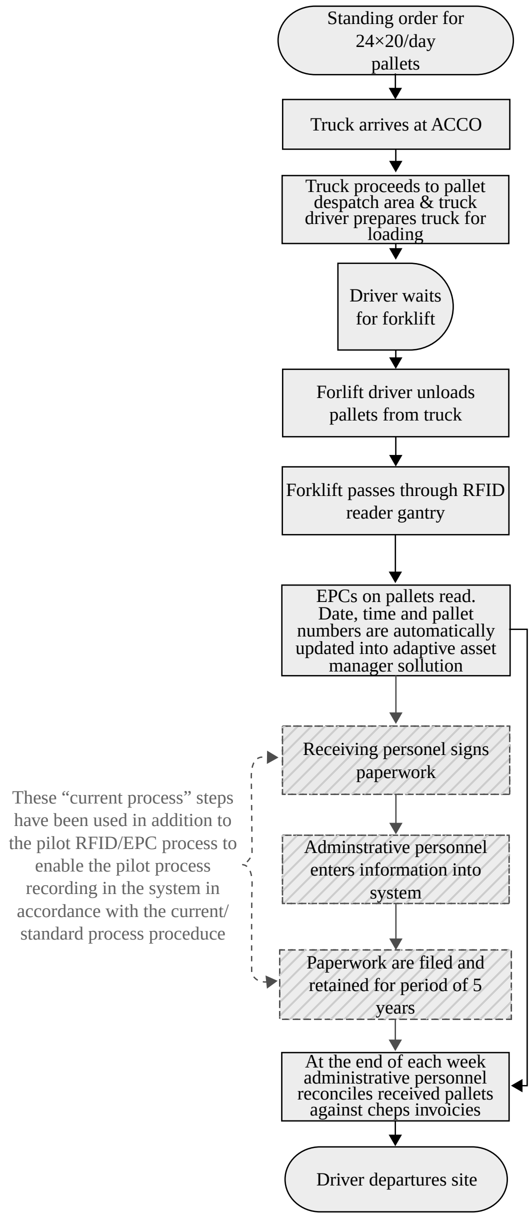

Figure 5.
Pallet receiving process (EPC-enabled)

4.3 Pallet de-hiring process (manual)

The NDP Extension not only examined the flow of pallets from the CHEP manufacturing or repair facilities to customer sites, but could also process customers' returns of pallets to maintenance. The pallet de-hiring process at Westgate Logistics was to return the pallets from the supply chain back to CHEP. Figure 6 shows the current manual pallet de-hiring process.

4.4 Pallet de-hiring process (EPC enabled)

Similar to the EPC enabled pallet receiving process, the EPC enabled pallet de-hiring process has created significant changes in the activities of pallet verification and recording. The main process simplification was the elimination of the need for the yard supervisor and the truck driver to check and confirm the number of pallets going onto the truck. Figure 7 shows the new pallet de-hiring process.

4.5 Global data repository

The NDP Extension web site was set up on the Telstra global server for the partners' information. Users could access the system to see the details on each site down to the level of individual pallets handled. In Figure 8, all the pallets that passed through the Erskine Park gate were recorded on the screen.

5. Assessment of the EPC-enabled system

The process models helped to establish a common understanding of the processes and procedures whereby stacks of pallets were counted, then compared with the accompanying documentation. Generally, the process maps showed the differences within the process of the receiving or issue pallets between parties in the supply chain, and they could be used for standardisation of the process of pallet's delivery verification. Three key performance indicators (KPIs) were developed to assess the performance of the new EPC-enabled system.

5.1 KPI-1 – inventory management/delivery accuracy

Although the inaccuracies of pallets issued against pallets received were small with respect of total volume of pallets, a discrepancy was found due to human error during manual processing of dispatch and receipt documentation. The pallet receiving process required manual docket printing as proof of delivery and manual recording of data into a system. If the quantity on dispatch docket was incorrect for any reason, the inventory stock on hand would also be incorrect.

Since, errors in recording shipments are probabilistic, evaluating this KPI requires accumulating data over a long period. This was not practical under the specified project plan. This KPI was therefore assessed by on site observations and interviews with staff. It was found that on average, site staff spent 190 minutes per day on administrative work, including documentation filing and error identification and rectification. Based on the principle that CHEP staff needed to work with the customers, the total time the customers spent would be approximately the same as reported by CHEP. Individual customers might spend lesser amount of time, due to smaller numbers of pallets, but the more significant process improvement opportunities for them would be in other areas, such as production, product movement, raw material consumption, etc.

On the other hand, the EPC system in the new pallet delivery processes had the ability to match the identity EPC of individual pallet shipped out against the EPC of pallets received. This means any discrepancy in the shipment could be traced to individual pallets and the possibility of error in quantity is eliminated.

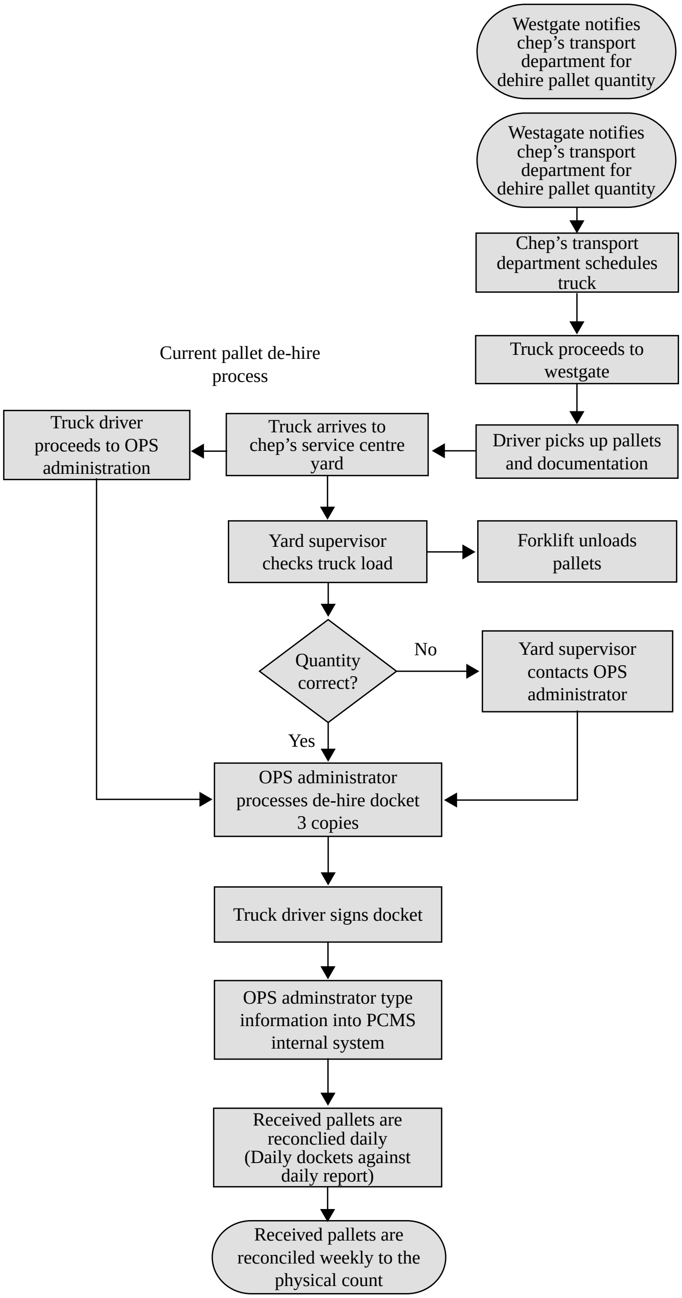

Figure 6.
Pallet de-hiring process (manual)

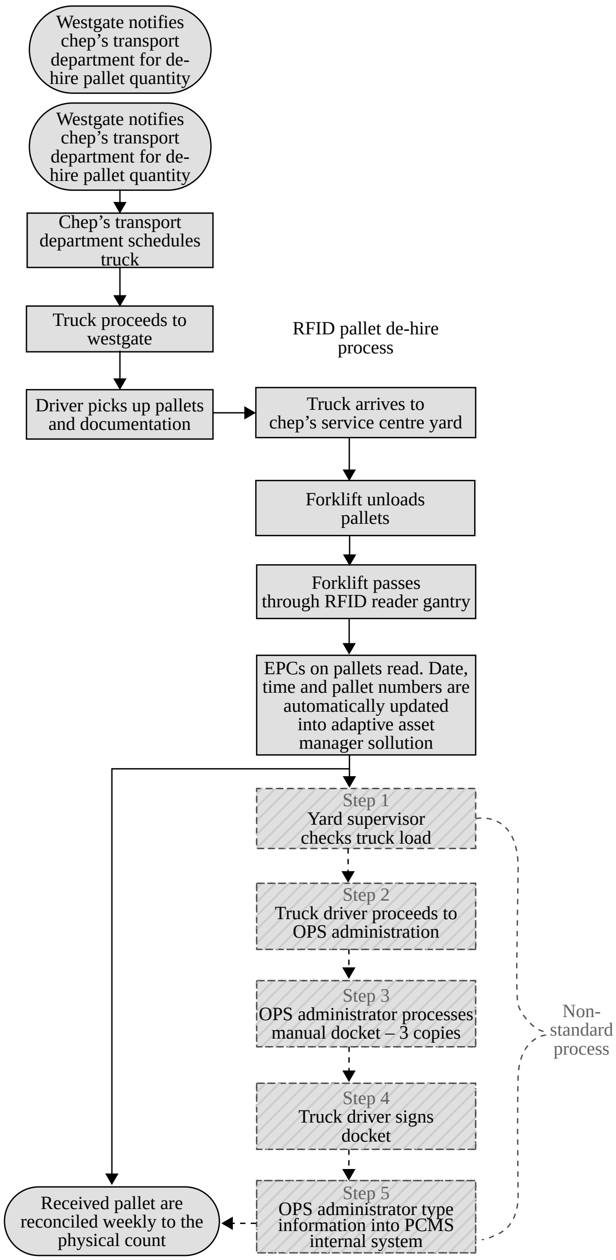

Figure 7.
Pallet de-hiring process (EPC enabled)

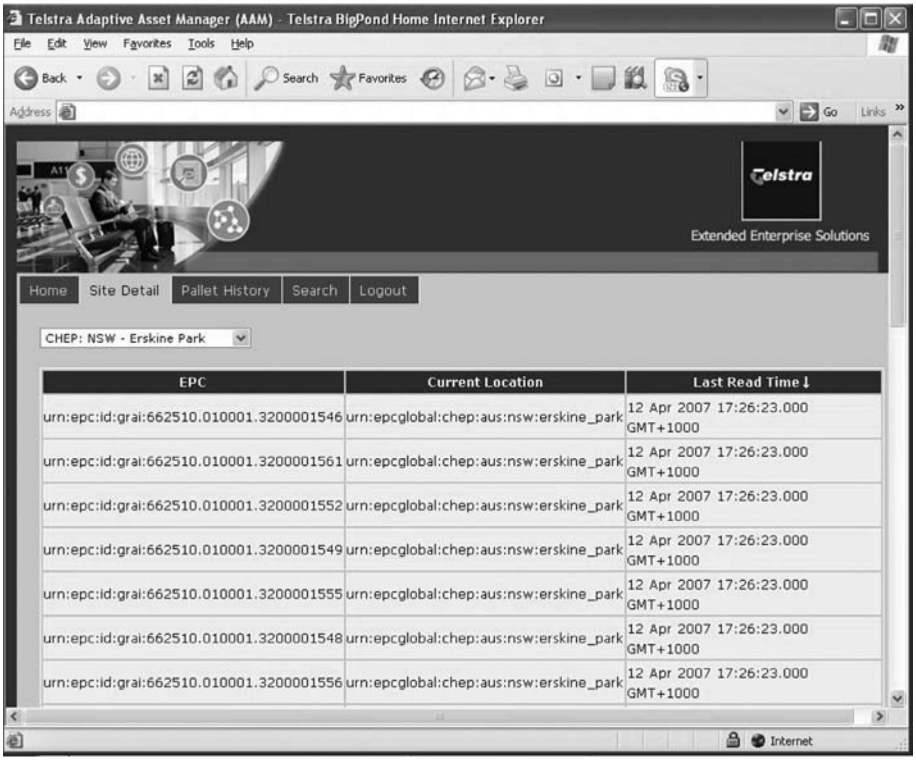

Figure 8.
EPC network demonstrator extension project web portal

5.2 KPI-2 – process efficiency gain

The process efficiency gain was obtained by a time measurement taken by the project team for each step in the process maps. The average time required for the processes in each site is recorded in Table I. Under the existing (manual) process, the staff at each site spent on average, approximately 37 minutes per transaction.

By comparing the existing process time to the EPC-enabled process time in the NDP Extension tests, it was found that there was an average 18 per cent improvement in system efficiency as shown in Table II.

Table I.
Improvement in process efficiency

Site	Standard/current process time (minutes/delivery)	Pilot EPC process time (minutes/delivery)	Gained productivity (minutes/delivery)	Process efficiency gain (%)
Erskine Park	35	23	12	34.3
Ballarat	35	30	5	14.3
Scoresby	38	36	2	5.3
Arndell Park	35	30	5	14.3
Yennora	45	35	10	22.2
Average	37.6	30.8	7.5	18.1

5.3 KPI-3 – cost savings

Improvement in process efficiency can be converted to a dollar value by using each site's hourly labour cost. Overhead costs associated with the processes include printing card/docket, receipts, printer maintenance, filing and retaining receipt of deliveries must be included. The direct value gain per delivery is computed using the productivity gains from Table I and summarised in Table II.

For the NDP Extension, there were ten deliveries per day (one delivery per client site and six deliveries for supplier site), the average total savings per year for all sites is of the order $15,000. There are 480 pallets in one delivery. Hence, if the process is rolled out to service the ten million pallets in circulation, the potential benefit should be quantified albeit with caveats.

Significant cost savings could also be achieved by eliminating the following manual processes:

- Time spent identifying and rectifying errors due to manual data entry processing.
- The time dispatch personnel spend on verification of quantity of pallets.
- Associated administrative costs.

The results for each of the site owners have been summarized in three ways of savings. These are listed in Table III.

Note that the above saving calculations do not include overhead costs of the companies.

5.4 Other process performance improvement indicators

Apart from the productivity improvements described, further productivity gains were achieved in improved inventory accuracy and improved quality, (e.g. transparency of information, customer interaction and job satisfaction). Quality improvement in supply chain operations can have beneficial impact on other system functions such as planning and forecasting. A major benefit is reliable identification of each pallet. Inter alia, this enables tracking of each pallet's maintenance.

There were difficulties in measuring these performance parameters. The data was assessed qualitatively using a questionnaire to the project participants. A total of 38 anonymous questionnaires were sent out with about half of them returned. The responses are summarized in Table IV. The questions are designed to solicit opinions of whether the new process improved aspects of business processes.

Site	Gained productivity (minutes/delivery)	Gained labour productivity ($/delivery)[a]
Erskine Park	12	6.4
Ballarat	5	2.3
Scoresby	2	0.8
Arndell Park	5	1.9
Yennora	10	5.2
Average	7.5	3.5

Note: [a]Labour cost per hour differs by sites

Table II.
Cost savings per delivery

The responses showed that communication among internal and external customers was significantly enhanced. There were also significant improvements in resource planning, preventive maintenance and pallet replacement time. The survey strongly suggested that these intangible effects were more important than the tangible effects.

6. Business models for EPC-enabled supply chains

The NDP showed that companies implementing the system had to have strong IT support and resources to exploit the exchange of data on the internet. The NDPs' experience, unfortunately suggested that companies would have to spend over A$100,000 on any meaningful implementation. This capital outlay cost comprises:

- Installation of a dedicated network on site for EPC data transfer.
- On site IT equipment including a separate server as EPCIS.
- Registration and EPC assignment with EPCglobal.
- Establishment of EPC services at the global EPCIS administrator.
- Configuration or network enhancement for connecting on site EPC Network to the internet.
- Training and development of staff capability to handle new network and process requirements.

Table III. Reduction of error reconciliation and administrative costs

Site	Time spent on verification of pallets filing (minutes/delivery)	Time spent to identify and rectify errors (hour/year)	Administrative cost ($/year)[a]	Total cost ($/year)
Erskine Park	20	23	$3,000	$10,667
Ballarat	12	16	$2,500	$4,068
Scoresby	15	21	$1,900	$3,675
Arndell Park	5	12	$200	$859
Yennora	10	28	$1,800	$3,501
Total				$22,770

Note: [a]Labour cost per hour differs by sites

Table IV. Questionnaire results consolidated

Question	Average response
Dealing with internal customer	67%
Dealing with external customer	67%
Resource planning	60%
Other areas (not one of above)	80%
Saving in time to search errors (week)	22.5 minutes
Saving in time to rectify errors (week)	7.5 minutes
Effect on error searching and rectification on job	Some improvement
Effect on job performance	Little effect
Effect on business performance	No difference
Error proof process effect on job improvement	Little effect
Effect on preventive maintenance	Considerable
Effect on pallet replacement time	Considerable

The tangible savings estimated from the pilot study were not sufficient to substantiate the project. One of the project objectives was to develop independent pathways of EPC standards implementation and explore the potential of commercialising these solutions for general industry use. There were two findings in this project that were considered to be exploited by the commercial partners:

(1) The end-to-end EPC Network service described in Section 3.1 could be provided by the telecommunication partner to the public.

(2) BIS described in Section 4.2 could be provided as an add-on to existing company servers as licensed software by Retriever, the software developer partner.

The end-to-end EPC Network service eliminates the aforementioned outlay commitment of companies. It can be provided as a "service product" that replaces the capital outlay of system implementation (CAPEX) by an affordable operating expenditure (OPEX). A technology that can be financed as an OPEX significantly increased the opportunity for small and medium enterprises (SME) to adopt it.

The integration of data depended on the careful design of processes and related data models. The BIS had successfully demonstrated the capability of a message oriented data link that allowed business transactions between EPCIS and a pallet management control server to be verified electronically. Adding the EPC pairing function to the BIS allowed despatch and receipt processes to be finalised on the spot seamlessly.

7. Conclusion

The NDP Extension was an investigative R&D project exploring how EPC data could be used to support business transactions. The ability of the EPCIS to provide individual pallet identity was critical to the key task of eliminating any mis-counting or errors caused by off line activities such as arbitrary exchange of pallets.

This project also provided several key lessons for implementing EPC-enabled supply chains. Development of the EPC compliant system often requires good technical support with relevant competencies, e.g. understanding the operating characteristics of the RFID system and quality assurance of RFID tags. The complexity of EPCglobal Network implies the need for strong IT design and support, or alternatively, seeks the type of end-to-end EPC service described in Section 3.1, if it is available commercially.

The tangible benefits of an EPC system are generally not sufficient to justify on the ground of return on investment only. However, the partners found that intangible benefits such as improvements in customer relations and asset maintenance were significant. These benefits were measured quantitatively (using process maps) and qualitatively (using questionnaires). The use of process modelling method to analyse the pallet delivery and receiving processes in Section 4 helped identify the changes that could be made to reduce errors, rationalise work flow and improve information flow.

The NDP Extension provides a learning platform the partners to investigate application requirements of the EPC technology for integrating product movement information captured at the reading points to the management of PO. The new business information system still needs further development to be offered as an affordable standard package for SMEs so that they can obtain significant business benefits from this technology.

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