

The impact of RFID technology on warehouse process innovation: A pilot project in the TPL industry

Samuel Fosso Wamba · Akemi Takeoka Chatfield

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Abstract Using the value chain model which provides a process view, this longitudinal case study and simulation modeling analysis of a Canadian third-party logistics (TPL) supply chain provides some empirical support for the enabling role of RFID technology in effecting warehouse process innovation and optimization for the focal TPL firm. However, the findings of our study also reveal the RFID technology implementation costs as the key inhibitor of RFID widespread adoption and usage among suppliers. This, in turn, precluded the focal TPL firm from implementing the best optimum RFID solution to create better business value from the RFID project.

Keywords RFID technology · Warehouse · Business process innovation · Modeling · Optimization

1 Introduction

Defined as a wireless automatic identification and data capture (AIDC) technology (Fosso Wamba et al. 2008), radio frequency identification (RFID) is emerging as a new interorganizational system (IOS) that will transform supply

chain business processes and practices (Curtin et al. 2007; Geng and Sirkka 2005; Gogan et al. 2007). Despite the high potential of RFID as an enabler of supply chain process innovation, the literature shows a lack of empirical studies that provide support for the enabling impact of RFID technology in improving outbound logistics activities such as warehousing, order fulfillment, transportation, and distribution, which are increasingly outsourced and executed by third-party logistics (TPL) firms in supply chain management. This study intends to bridge this knowledge gap, by drawing on an earlier study on the RFID research agenda (Curtin et al. 2007), as well as on a longitudinal case study in a TPL supply chain. In this regard, this study examines the following three research questions:

1. How are business processes and work systems changed due to RFID at all points in the value chain?
2. To what extent should the initiators encourage the process redesign in their trading partner facilities?
3. How does RFID change the job descriptions and work roles? (p. 99)

The rest of this paper is structured as follows. Section 2 presents a review of the literature on the value chain model for value creation through an integrated flow of materials and information, the importance of information technology in the value chain, the importance of outbound logistics in the TPL industry and the role of RFID technology as an enabler of warehouse process innovation. Section 3 presents the research methodology and a Canadian TPL supply chain studied. Section 4 presents our results and discusses our lessons learned. Finally, Section 5 provides our conclusion including our research limitations and future research directions.

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S. Fosso Wamba (✉) · A. Takeoka Chatfield
University of Wollongong,
Wollongong, NSW 2522, Australia
e-mail: samuel@uow.edu.au

A. Takeoka Chatfield
e-mail: akemi@uow.edu.au

2 Background and context of the study

2.1 The value chain model

The value chain model was proposed by Michael Porter in his book, *Competitive advantage: Creating and sustaining superior performance*, as a means to analyze and describe all activities conducted within a company to create the value and competitive advantage that will support its competitive position in the industry (Porter 1985). The model's *process view* shows the existing task interdependency and implies that an integrated flow of materials and information is the key to value creation within the enterprise value chain.

The model identifies five primary activities: inbound logistics, operations, outbound logistics, marketing and sales, and service, as well as four supporting activities: corporate infrastructure (i.e., leadership), human resources management (i.e., education and training), technology development (i.e., IT to support the value chain activities), and procurement (Fig. 1).

The focus of our paper -warehousing- is an integral part of Outbound Logistics, which performs essential activities such as inventory management, order fulfillment and transportation that are required to get the finished product -an output of Operations- to the end customers. Primary activities are thought to contribute directly to the creation or delivery of a product or service, and hence to business value creation, while secondary activities are mainly used to support and enhance effectiveness and efficiency of the primary activities (Porter 1985). To the firm, the costs of realizing the product or service, and, therefore, profits, depend on the activities to be carried out within the value chain (Porter 1985). More importantly, realizing a profit margin and a competitive advantage will depend on the level of optimization and coordination of all

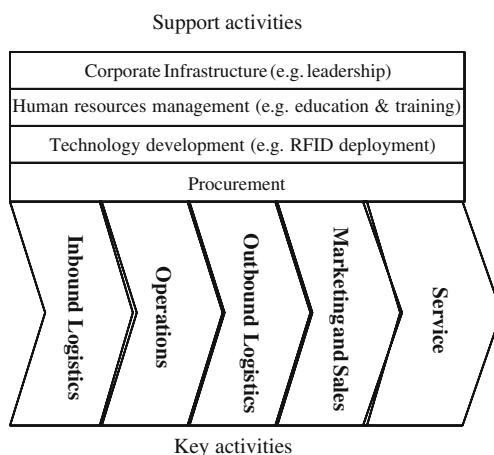


Fig. 1 The value chain model

interdependent activities in the value chain (Porter 1985). In the literature, it is commonly assumed that the use of network information technologies, such as electronic data interchange (EDI) and RFID, can help the firms achieve these value chain objectives. However, the literature fails to provide empirical support for the commonly held assumptions.

2.2 The value chain model and information technology

The value chain model is a useful tool that allows managers not only to analyze, redesign intra- and inter-organizational business processes to improve firm efficiency and effectiveness (Papazoglou and Ribbers 2006), but also to understand how Information Technology (IT) may affect the firm's competitiveness (Karakostas et al. 2005). To Porter (1985) "technology is embodied in every value activity in a firm, and technological change can affect competition through its impact on virtually any activity" (p. 166).

Several ITs have been used to support value chain primary and supporting activities and linkages with external suppliers and buyers. For example, e-commerce technologies are used as a means for integrating the value chain in order to reduce costs and to respond more rapidly to changes in an unstable market (Dedrick and Kraemer 2005), to facilitate intra- and inter-organizational business process reengineering, and thus improving information sharing (Wu and Wu 2006), the coordination of decision making (Asoo 2002), and enhancing the organization's comparative efficiency (Johnston and Vitale 1988) and benefits (Curtin et al. 2007). However, the level of IT adoption and usage within the value chain depends on various factors such as IT characteristics (e.g., technological complexity, relative advantage), firm characteristics (e.g., firm size and readiness) and environmental characteristics (e.g., competitive pressure) (Rogers 1995; Zhu et al. 2006), the level of organizational change to leverage the IT capabilities (Riggins and Mukhopadhyay 1994) and the level of intra- and inter-organizational business processes reengineering, standardization and alignment with the IT (Brousseau 1994; Riggins and Mukhopadhyay 1994).

With regard to RFID technology, its characteristics, such as multiple tags items reading, more data storage capability, and data read/write capabilities, and no line of sight, may serve as facilitators of its widespread adoption and usage, while its perceived complexity and actual cost may constitute inhibitors (Fosso Wamba and Chatfield 2009).

2.3 Outbound logistics and TPL industry

A TPL service provision is defined as "a relationship between a shipper and a third party which, compared with the basic services, has more customized offerings, encom-

passes a broad number of service functions and is characterized by a long-term, more mutually beneficial relationship” (p. 35) (Murphy and Poist 1998). Today the TPL industry appears as a viable solution to the market globalization, increased competition, cost pressures and an increasing use of outsourcing (Power et al. 2007). The growing importance of the TPL industry is highlighted by the results of multiple survey studies. Langley et al. (2005) found that, among more than 1,500 logistics and supply chain executives, almost 82% of the respondents were using TPL services. Similarly, in a more recent study, Langley (2008) found that 70% of firms in North America, 73% of firms in Europe, and 75% of firms in Asia Pacific were using TPL services for their warehousing activities. In addition, TPL is increasingly considered as a strategic tool for the IT-enabled supply chain to reduce environmental uncertainty and improve logistics management efficiency. Indeed, IT capabilities play a vital role in achieving the integration of logistics services provided by TPLs. For example, Langley (2008) found that 91% of TPL users will outsource their web-enabled communications and visibility tools, while 83% of them will do the same with regard to warehouse/distribution center management (p. 14). Finally, the TPL industry is considered as a lead user of RFID technology (Gartner 2008).

2.4 Warehousing processes and RFID technology potential

In an economic context where the growing development of information technologies has been generating unprecedented repercussions on the management of activities within warehouses, it goes without saying that the use of a centralized inventory management, for example, could lead to an increased productivity and short response times of the warehousing systems, and that “shorter product life cycles will impose a financial risk on high inventories and, therefore, on the purchase of capital intensive high-performance warehousing systems” (p. 519) (Van Den Berg and Zijm 1999).

To categorize warehouses, there are three main perspectives to be considered: the processes, the resources, and the organization (Rouwenhorst et al. 2000, p. 516). The processes are the different steps through which a product will pass through in the warehouse; they can be divided in four distinct phases: (i) *the receiving process*, which is the first step the products go through in a warehouse. This stage usually involve the checking and/or the repackaging of the products in the various storage units before they are moved to the next process; (ii) *the put-away process*, which consists in moving and placing the products into their specific storage location so as to make it easy for the picking clerk to retrieve them; (iii) *the picking process*, which involves the retrieval of the products from their

storage locations in order to consolidate a customer order. This process is considered as the most “labour-intensive and costly activity for almost every warehouse” and could account for up to 55% of the total warehouse operating cost (De Koster et al. 2007); (iv) *the shipping process*, which involves the checking, packing and loading of the products in the transportation unit in order to bring them to the customer facilities. The effectiveness and efficiency of these processes will heavily depend on both the better management of the interdependency between them, the available resources, and the organization of the warehouse. More precisely, the resources involve all means, that is, equipment such as the storage unit (e.g., pallets, boxes), the storage system (e.g., simple shelves, automated systems, automated cranes or conveyors, pick equipment), a warehouse management system (WMS) (for control of the processes within the warehouse), a material handling equipment to prepare the retrieved items (e.g., sorter systems), and the personnel needed to operate the warehouse. Finally, the warehouse organization involves all the planning and control procedures that are used to run the system. For example, during the picking process, a routing policy may describe the sequence of retrievals and the road to visit the retrieval locations within the warehouse (Rouwenhorst et al. 2000).

Recently, researchers have increasingly demonstrated that RFID could have important impacts on the four warehouse processes than any other technology. For example, Capone et al. (2004) argued that RFID technology could reduce the put-away labor cost by 20 to 30% and the picking labor cost by some 30 to 50%. Lefebvre et al. (2005), through a pilot study, also demonstrated that RFID could transform the warehouse processes—which may, in turn, facilitate collaboration practices in the supply chain such as collaborative planning, forecasting and replenishment and vendor managed inventory. In other words, RFID technology may automate the verification activities involved in the shipping process, thus reducing potential errors. Fosso Wamba et al. (2006) argued that the impacts of RFID on the warehouse processes would facilitate an “intelligent supply chain management” through the emergence of the so-called “intelligent processes”—processes that can be automatically triggered without any human intervention. Finally, García et al. (2007) showed that RFID enables the automatic input of receipt in the supply chain system during the receiving process, allowing real-time checking of bin availability during the put-away and picking processes and reduces the process time. Despite the high potential of the RFID demonstrated in these studies, however, the literature is yet to provide real-world longitudinal studies to test these assumptions. The RFID literature shows that there is a knowledge gap to bridge and that this research is urgently required.

3 Methodology

This paper is part of a larger study conducted in Canada to improve our understanding of the impacts of integrating RFID technology in a TPL supply chain. A value chain perspective (Porter 1985) is adopted since RFID adoption and usage is mainly product-driven (Bendavid et al. 2009) and involves the study of the impacts of RFID on the interdependent activities related to the management of telecommunications stationary batteries of a specific TPL supply chain (Fig. 2).

3.1 Research design and data collection methods

As the main objective of this study is to improve our theoretical and practical understanding of the impact of RFID technology in real-life contexts over a period of time, the appropriate research design requires a longitudinal case study. Eisenhardt (1989) defined the case study as “a research strategy which focuses on understanding the dynamics present within single settings” (p. 534). This research strategy allows to focus on emerging phenomena and eventually induce theories (Benbasat et al. 1987). It is recognized by many researchers as a suitable approach to answer research questions such as “why” and “how” things are done (Yin 1994), and is therefore appropriate to study the impact of RFID technology on the warehouse processes of a TPL industry, where research and theory are at their early and formative stages (Benbasat et al. 1987).

A longitudinal case study was conducted between September 2007 and April 2008 in a TPL supply chain, which consists of two main phases. *In the first phase*, which is to explore RFID technology opportunities, both qualitative and quantitative data were collected through multiple sources such as several interviews, three focus

groups, multiple on-site observations, RFID workshops, organizational documents and RFID technical papers in order to understand the dynamics within the supply chain. For example, on-site observations allowed us to map existing processes. Interviews with operational staff and managers on “how and why things are done?” provided more comprehensive information that can help to solve possible inaccuracies in our mapping. Furthermore, a business process modeling and analysis tool called “ARIS Tools”, which is based on the Event-driven Process Chains (EPC) formalism (Dreiling et al. 2006; Scheer et al. 2002), was used to understand, represent, and “map” the existing intra- and inter-organizational processes into a current model (as-is). The modeling of the current processes, therefore, enables us to identify bottlenecks and areas of opportunities when using RFID technology. Using this current model as a guide, we worked together with key stakeholders involved in the warehouse project to perform an analysis of business and technological information requirements.

In addition, the business process analysis tool was very effective in enabling the managers to make better decisions about the management of RFID-enabled business processes, by exploring and evaluating the impact of RFID on resource utilization, IS integration, and information flows. The overall analysis enabled us to generate various plausible scenarios for business process innovation. These optimization scenarios were discussed with the stakeholders during RFID workshops. In fact, “ARIS Toolset” allows a global definition, mapping, analysis, optimization and implementation of business processes. This formalism offers a logic representation of activities in a network of multiple organizations through the alternative use of events, functions and connectors to specify the routing logic based on the required decision rule (Dreiling et al. 2006) (Table 1).

Fig. 2 TPL supply chain

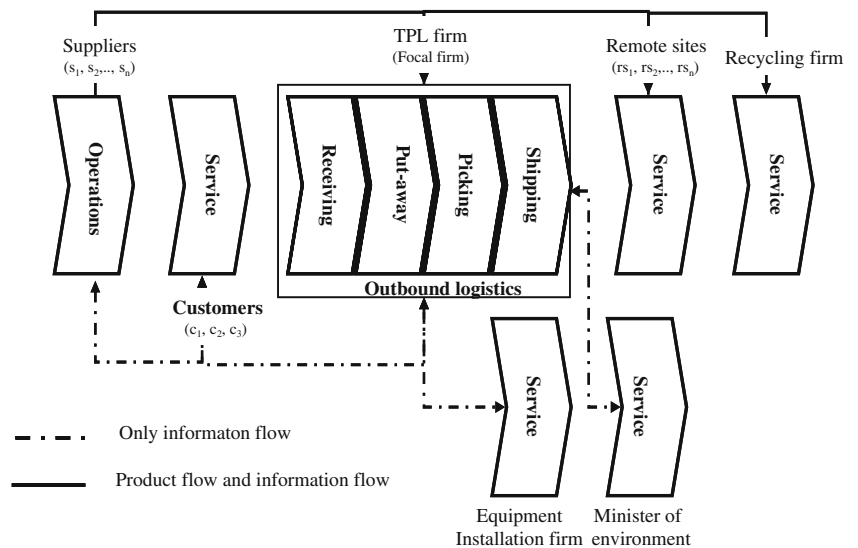







Table 1 Elements of EPC model (Bevilacqua et al. 2009)

Element	Description
	An “event” describes the situation before and/or after a function is executed, and may correspond to the post-condition of one function and act as a pre-condition of another function.
	A function corresponds to an activity (e.g., task and process step), which needs to be executed.
	The “AND” connector allows (i) the flow of the process branches into two or more parallel paths; and (ii) all the events must occur in order to trigger the following function.
	With the “OR” connector (i) one or more paths may be followed as a result of the decision; (ii) each event, or combination of events, will give rise to the function.
	With the “XOR” connector (i) one, and only one, of the possible paths will be followed; (ii) one, and only one, of the possible events will give rise to the function

Moreover, the EPC formalism is considered as a viable means to study a collaborative e-business process (Hoyer et al. 2008), open source online shopping solutions (Saka 2008), and more recently, the impacts of RFID technology on supply chain-enabled business process transformation (Fosso Wamba and Bendavid 2008).

In the second phase, two most plausible scenarios of RFID-enabled supply chain were being chosen and assessed in the RFID solution provider laboratory through the “Living Laboratory” approach. In this approach a given scenario is retained to be implemented and monitored during a pilot project in the focal firm warehouse. In fact, “Living Laboratory” approach was intended to support diverse research settings, including the simulation of business experiments and the use of the laboratory over a prolonged period by all key RFID project stakeholders for “self-trial” learning (Loeh 2005), joint problem solving, interaction, knowledge generation and exchange among all key project stakeholders (Bergvall-Kareborn et al. 2009; Eriksson et al. 2007; Følstad 2008).

In this project, the “Living Laboratory” was mainly used to simulate the impact of RFID technology on intra- and inter-organizational processes, intra- and inter-organizational IS integration, and information flow between the key supply chain players. The simulation enabled them to consider, for example, the best location in the supply chain where RFID tagging should be done, the level of tagging (e.g., single battery vs. case of batteries), and the level of inter-firm information sharing.

3.2 A Canadian TPL supply chain

The TPL supply chain studied in Canada is involved in the management of telecommunications stationary batteries (Fig. 2). The focal firm is a Canadian owned medium-size TPL service provider, with annual revenue of nearly US\$23 million and 52 full-time employees and owns a large distribution centre in Canada and warehouse facilities in the United States of America (USA).

The company provides a variety of services such as storage, transport and customs clearance fees. Its Canada-based distribution centre, where the study was conducted, is used to store telecommunications batteries from various suppliers. The TPL has three major customers for this value chain: a telecommunication company, a communication provider, and a utility company. The company is in charge of (i) shipping new batteries to different customers’ remote sites based on their needs, (ii) collecting used batteries, and (iii) bringing them to the recycling plant. It relies on set of IT systems to conduct its intra- and inter-organizational business processes—which range from the very basic practices (e-mail, fax, and paper-based system) to the sophisticated ones (bar code systems, in-house warehouse management system, RFID-enabled transport management system, B2B Web portal). In addition, the firm often uses the Canadian postal services to communicate with its supply chain stakeholders. Importantly, however, the firm primarily uses its paper based system to track and trace batteries analyzed in this study. Nevertheless, the TLP firm is already using RFID technology in other areas. Indeed, in 2005, the firm had its first experience with the RFID technology when it started providing a “Slap & Ship” RFID solution service to its customers in order to meet RFID mandates from their trading partners. Later in the same year, the firm started deploying a RFID-enabled truck tracking solution so as to have better visibility on its “truck in transit”. Therefore, this TPL organization can be considered as an early adopter of RFID technology. Indeed, in a recent study Langley (2008) found that only 13% of 3PL service providers were using RFID technology. Furthermore, according to the management board of the TPL Company, the use of RFID technology as an enabler of telecommunications stationary batteries management is a “logical next step” in their IT innovation process for value creation.

4 Results

We now present and discuss the results of the RFID implementation in relation to the TPL warehouse process innovation and the future RFID-enabled warehouse optimization that is plausible, but has not been implemented largely because of the lack of stakeholder investment.

4.1 RFID-enabled warehouse process innovation

The first scenario of the RFID-enabled warehouse process innovation (Section 4.1.1) required the RFID tagging of products in the TPL warehouse. As for the next phase, it assumes that this tagging activity is conducted in each supplier’s facilities, and represents, from the TPL firm perspective, *the best scenario of RFID adoption in the TPL supply chain* (Section 4.1.2). However, the suppliers were

unwilling to make the initial RFID investment required. In consequence, the best scenario for the warehouse process innovation and radical transformation could not be chosen for implementation. Instead, the second scenario for incremental change was implemented and monitored in the pilot project at the TPL warehouse.

4.1.1 Current RFID implementation focus: RFID as enabler of incremental change on the picking and shipping processes (s1)

Figure 3 presents the current picking process (“as-is”), while Fig. 4 presents the incremental redesign process of the same process when using RFID technology (“to-be”). Figure 5 presents the current (“as-is”) shipping process and Fig. 6 the incremental redesign of the shipping process integrating RFID technology (“to-be”).

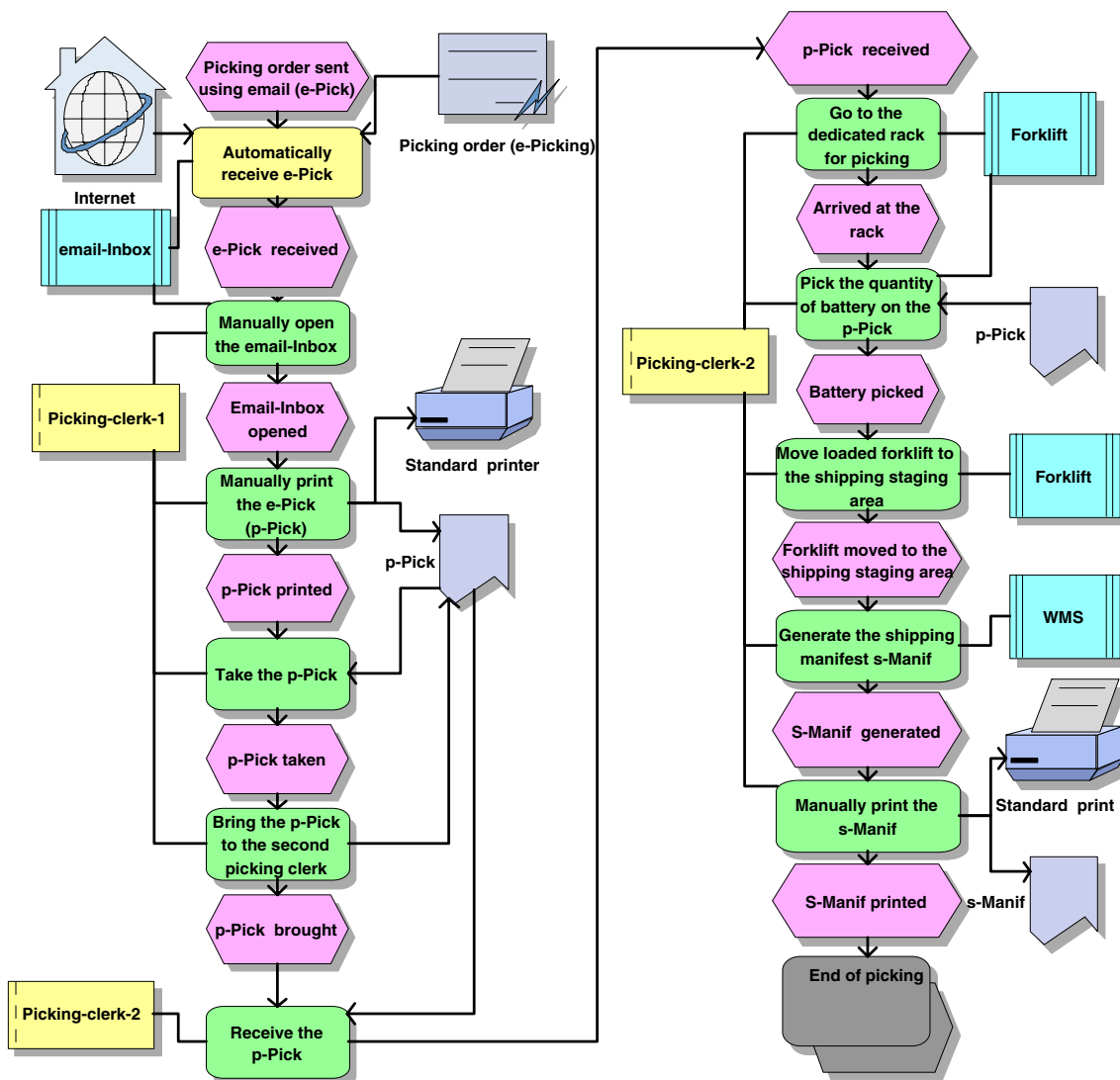
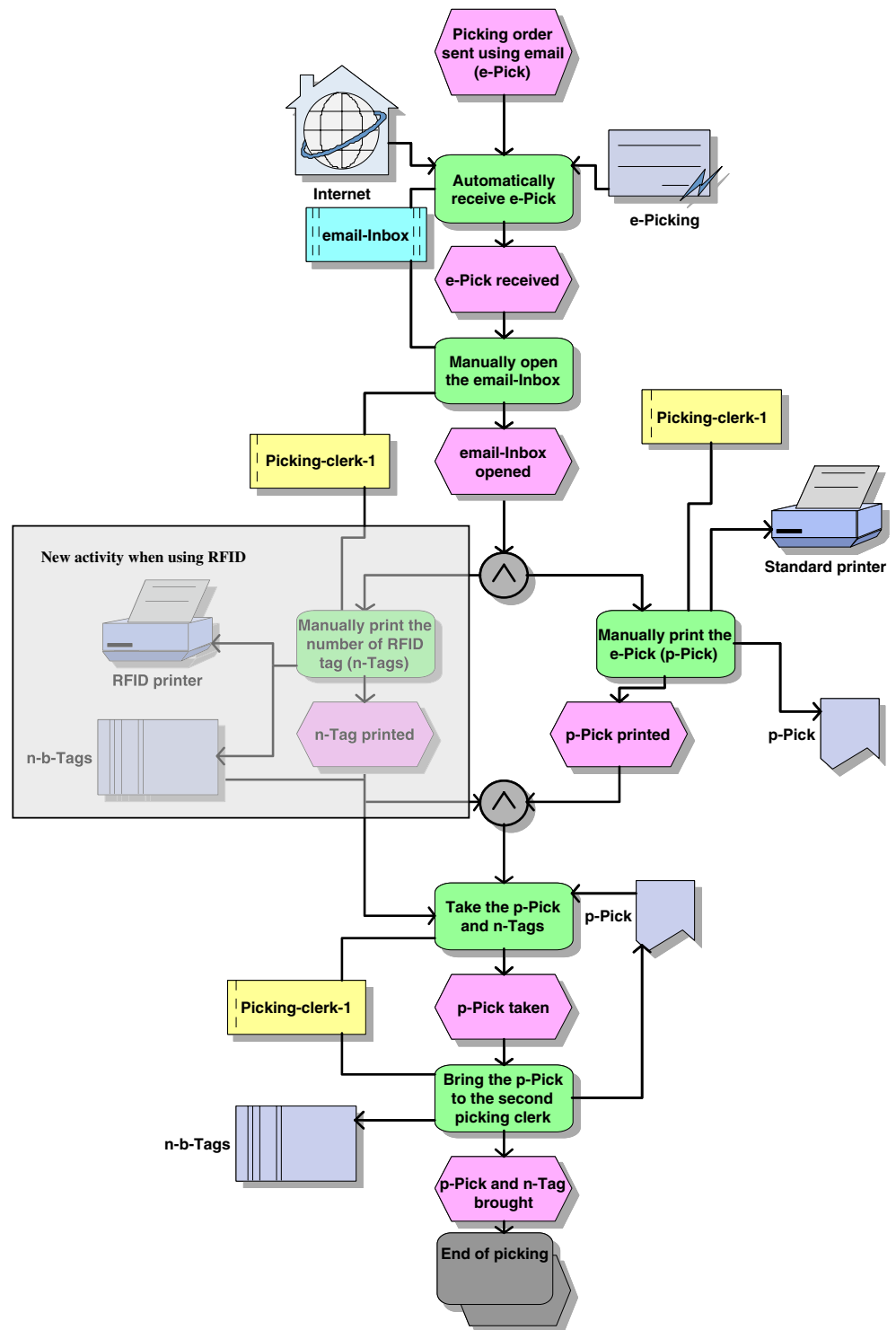


Fig. 3 The current picking process

Fig. 4 The picking process with incremental change when using RFID



Based on the analysis of the current processes (“as-is” picking process in the Fig. 3 and “as-is” shipping process in Fig. 5) and on the incremental change when using RFID (“to-be” picking process in Fig. 4 and “to-be” shipping process Fig. 6), the following observations are made: (i) the picking process involves two human resources (HR) and the shipping process one human resource; (ii) the

main activities of the HR in the picking process (Picking-clerk-1) include the processing of information (e.g., manually print the picking order (e-Pick) that is used in this process, while the second HR deals with physical activities in the process (e.g., Picking the quantity of battery on the p-Pick), and generates and prints the manifesto (s-Manif) marking the end of the process. This



Fig. 5 The current shipping process

manifesto constitutes the link between the picking process and the shipping process.

In the shipping process, a single HR needs to manage all physical activities (e.g., Drop battery into the truck) and informational (e.g., Take the s-Manif) activities in the process. In both cases, the information used is mostly paper-based. On the other hand, there is no means to verify that the type of batteries that is being picked corresponds to the one being ordered. The smooth running of these processes heavily depends on the judgment of the HR involved. For example, there is no mechanism to know for sure that the batteries that are being shipped are those specified in the manifesto. This often leads to a shipment mismatch, and thus results in the

increased transportation costs as the truck driver needs to bring back the shipment and reschedule a new one, which also affects customer service delivery. Resolving this situation is one of the goals of RFID technology adoption, by the TPL management board, for more effective batteries management.

The new picking process with the RFID-enabled incremental change from RFID technology is similar to the current (“as-is”) picking process. With a new no-value activity, which is “manually print the number of RFID tags (n-Tags)” — the first picking clerk (Picking-clerk 1) needs to pick the order using a RFID printer. It must be noted that the TPL needs to conduct the tagging process because the suppliers of the TPL firm are not yet involved in the

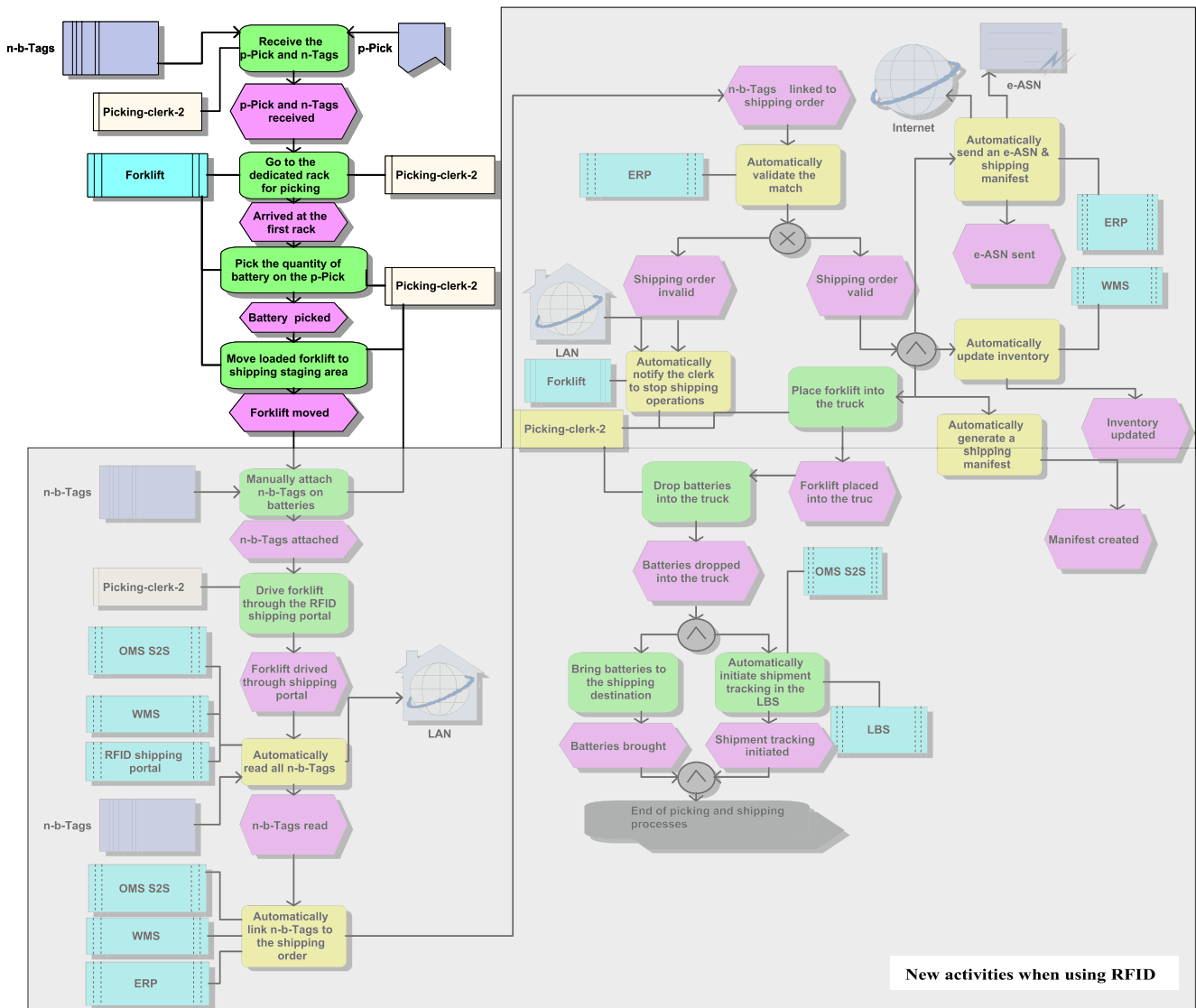


Fig. 6 The shipping process with incremental change when using RFID

project. Now, not only is the second picking clerk responsible for picking the quantity of battery on the p-Pick to bring them in the shipping staging area, but he is also in charge of all shipping activities.

The new picking process increased the level of electronic integration. Indeed, it resulted in the integration of the RFID infrastructure with the firm’s ERP and WMS. This allows the automatic validation and generation of the manifesto, and all picking activities related the manifesto are now transferred to the shipping process and are automated all together, and thus increasing the level of electronic integration between the picking and the shipping process. One implication of this new level of electronic integration is that the picking and the shipping processes should henceforth be carried out when the truck is ready to

carry the shipment to the remote sites. It effectively results in the better use of the warehouse staging area.

In this scenario, the workflow of the second picking clerk radically changed as a result of the adoption and use of RFID technology. Now he has to perform not only his traditional responsibilities but also those of the shipping clerk. This resulted in labor cost savings, although a proper training to update his skills is required to enable him perform his new responsibilities. Moreover, the shipping clerk can now be reassigned to other duties within the warehouse.

In the “as-is” shipping process, the process is triggered by the shipping manifesto, and followed by the physical picking of the batteries from the shipping staging to the truck by the shipping clerk.

In the case of the shipping process with incremental change when using RFID, the following four steps can summarize the new process (Fig. 6):

- (1) When the p-Pick (paper-based picking list) and the n-Tags (number of RFID tags required in the picking list) are received by the second picking clerk (Picking-clerk-2), a picking clerk drives the forklift to the dedicated picking rack so as to pick the requested number of batteries and move the loaded forklift to the shipping staging area where he manually attaches the RFID tags to the batteries (Fig. 7a). Once the tagging process is finished, he drives the forklift through the shipping dock equipped with an RFID reader (RFID portal) (Fig. 7b).
- (2) As soon as the picking clerk drives through the shipping dock equipped with an RFID reader (RFID portal), an automatic reading of all RFID tags is performed, followed by a linking of the data collected from the tags to the shipping order for automatic match validation (Fig. 7c).

- (3) If there is a mismatch, owing to the business rules that are configured in the RFID middleware, an automatic message is sent to the clerk to stop the process for further verification. Otherwise, a set of operations are performed in parallel (e.g., automatically send an e-ASN, automatically update inventory into the WMS, automatically generate and send the manifesto.) while placing the forklift into the truck to drop the batteries.
- (4) Once the batteries are dropped into the truck, the truck driver leaves the TPL facility to bring the batteries to the shipping destination while the location-based system (LBS) is automatically initiated for “in-transit” visibility.

4.1.2 Future plausible RFID implementation: RFID-enabled process innovation and radical transformation by merging the existing picking and shipping processes (s2)

Figure 8 presents the case of a merge of the picking and shipping processes when using RFID technology.

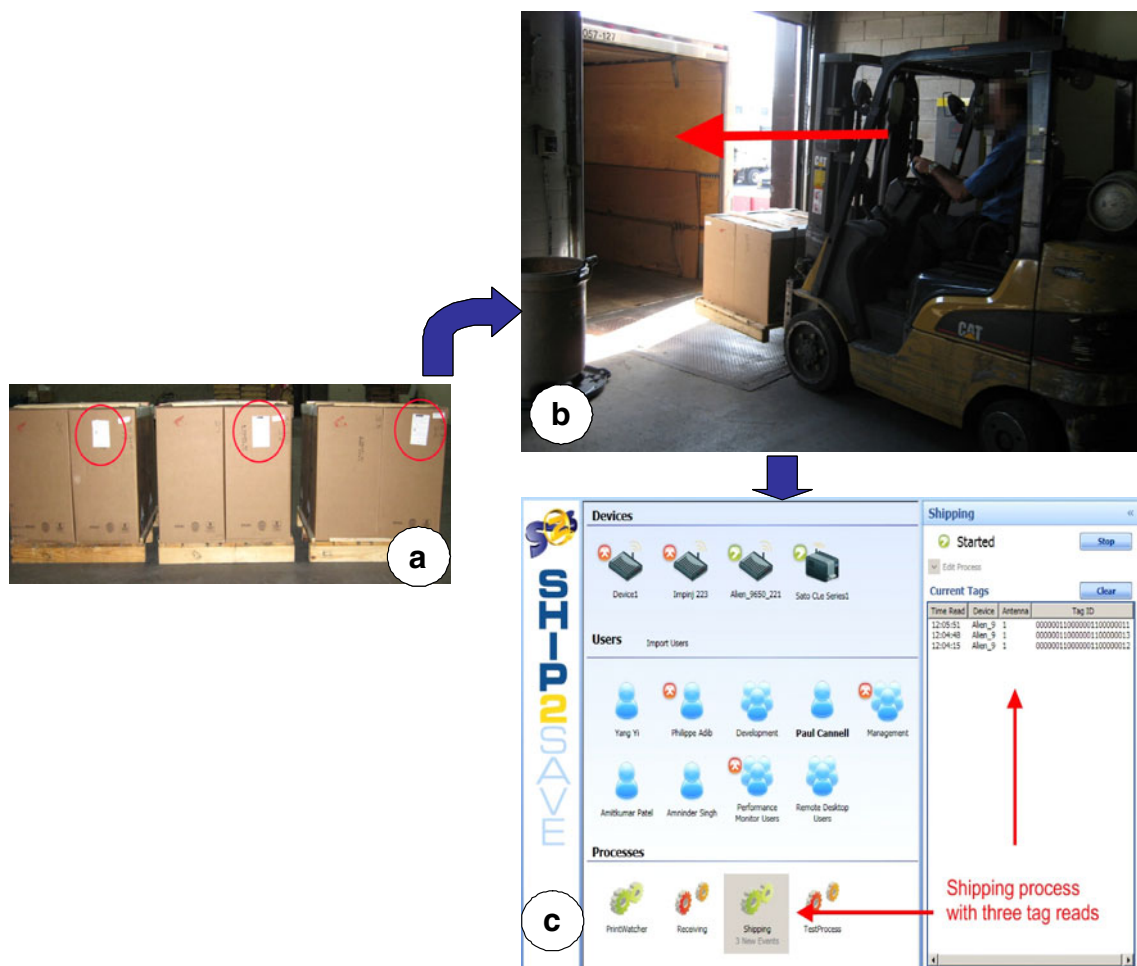


Fig. 7 Steps related to automated picking and shipping processes

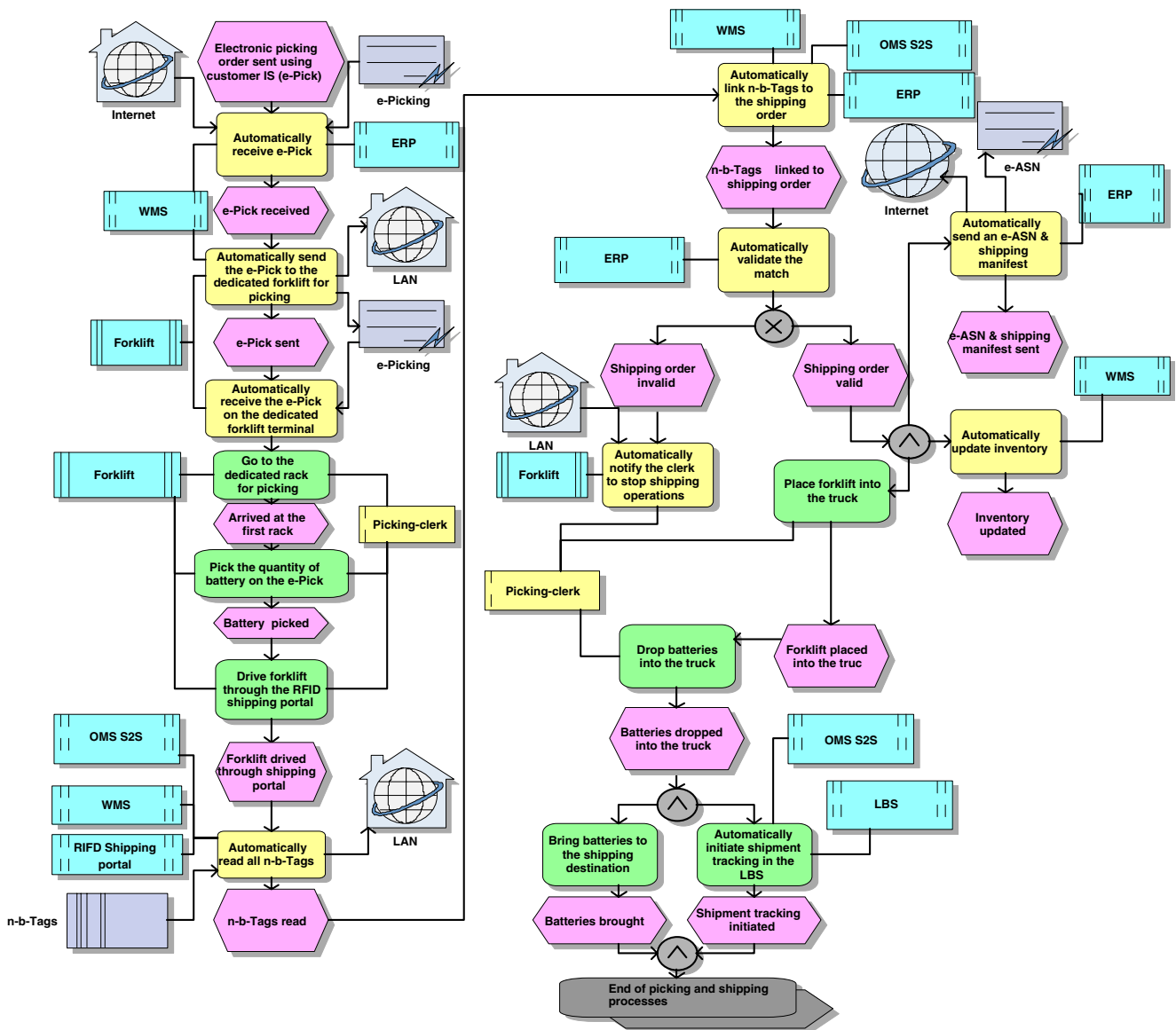


Fig. 8 Merge of the picking and shipping processes using RFID

In this scenario, which is considered as *the best RFID implementation scenario by the TPL firm*, the RFID baseline infrastructure is built in the suppliers facilities (e.g., for the product tagging, RFID information exchange, etc.), which is then gradually extended to the rest of the supply chain stakeholders. With this scenario, all batteries are now RFID-enabled *prior to* their shipment to the TPL focal firm warehouse and the rest of the supply chain, and thus increasing the level of supply chain electronic integration and the positive RFID network externalities.

By comparing and contrasting this scenario with the current picking process (Fig. 3) and shipping process (Fig. 5), we have the following observations to analyze the impact and understand the likely opportunities in the future:

Under the future plausible scenario, the picking and shipping processes are performed jointly as a single process

and involve only one HR (in opposition to 3 HRs before), and thus leading to labor cost savings. In other words, all paper-based activities can be eliminated, redesigned or automated. This single process is triggered by an electronic picking order (e-Pick) sent by the customer IS to the TPL WMS and ERP (this is the case of inter-organization process and IS integration). In summary, the following five steps can illustrate the process innovation and radical transformation:

- (1) When the e-Pick is received by the TPL WMS, based on business rules in the system, an automatic message with the e-Pick is sent to the dedicated forklift terminal for picking.
- (2) When the message is received, the picking clerk goes to the dedicated rack display on the forklift terminal to pick the requested number of batteries.

- (3) As soon as the picking clerk drives through the shipping dock equipped with an RFID reader (RFID portal), an automatic reading of all RFID tags is performed, followed by a linking of the data collected from the tags to the shipping order for automatic match validation.
- (4) If there is a mismatch, owing to the business rules that are configured in the RFID middleware, an automatic message is sent to the clerk to stop the process for further verification. Otherwise, a set of operations are performed in parallel (e.g., automatically send an e-ASN, automatically update inventory into the WMS, etc.) while placing the forklift into the truck to drop the batteries.
- (5) Once the batteries are placed into the truck, the truck driver leaves the TPL facility to deliver the batteries to the shipping destination while the location-based system (LBS) is automatically initiated for the “in-transit” visibility.

Moreover, an analysis of time required to perform activities related to the tracking and tracing of batteries in the picking and shipping processes shows that in the case of incremental change scenario (s1), the total time of the picking and shipping processes is decreased by 17% compared to current situation (“as-is”). However, there is a trade-off; an increase of around 133% for the picking process mainly due to the introduction of no value added activities, such as manually printing the number of RFID tags and manually applying them to the batteries. On the other hand, in the second scenario of process innovation and radical transformation (s2), we have an improvement of 83% in comparison to the “as-is” situation. Table 2 below shows the current time savings and the future potential time savings in tracking and tracing batteries. However, the simulation modeling analysis results from the “Living Laboratory” show that this high level of the future potential time savings under s2 can only be achieved *only when* RFID tagging is done by the upstream supplier rather than by the TPL firm. This analysis result highlights the importance of the adoption and use of RFID technology by a critical mass of stakeholders in the supply chain. More importantly, when RFID tagging is achieved at the supplier facilities and the required level of intra- and inter-

organizational business processes reengineering is realized, the operational and strategic benefits of RFID technology are increased and have “positive network externalities on supply chain logistics optimization, inter-firm information sharing, and inter-firm knowledge and technology transfer” (p. 615–616) (Fosso Wamba and Chatfield 2009).

In addition to the efficiency gains in time savings, the TPL firm can now have *better visibility* of all batteries moving from the warehouse to the recycling plant.

5 Conclusion

In this paper, we have drawn on the value chain model (Porter 1985) and have presented the preliminary results of a longitudinal pilot project of the RFID-enabled warehouse process innovation. From the TPL firm’s perspective, one of the important research results is that the suppliers were reluctant to adopt the RFID mainly because their initial investment cost, required by the TPL firm, has produced the minimum level benefits for themselves, which, in turn, has a cascading effect on the minimum level business benefits realized by the TPL firm. The first scenario discussed in this paper explains these insights, which were presented in Figs. 4 and 6. These research findings provide support for the important negative impact of the cost issue on supplier RFID adoption, and are consistent with the results of prior research by (Schmitt and Michahelles 2009; Fosso Wamba and Chatfield 2009). Like other networks technologies, the study demonstrated the importance of increasing the positive RFID network externality effects by promoting the buy-in for wider RFID adoption and use among all TPL supply chain stakeholders (Robey et al. 2008). Moreover, our results are consistent with prior studies on the importance of a process view during IT implementation (Riggins and Mukhopadhyay 1994; Scheepers and Scheepers 2008; Vathanophas 2007), and recent studies on RFID technology (Fosso Wamba et al. 2008). In fact, Vathanophas (2007) observes the value of the process view, by stating that the main organizational issues, which may emerge during the implementation of IS projects, are better understood and managed as “they often enact as a set of critical factors in project dynamics, and

Table 2 Current time savings and future potential time savings for information related activities for tracking & tracing batteries

Process (Time in seconds)	“as-is”	Actual RFID implementation (s1)	Future plausible RFID implementation (s2)
Picking per delivery	360	840	120
Shipping per delivery	720	60	60
Number of annual delivery	800	800	800
Total annual time	864000	720000	144000
% Annual time savings		17%	83%

ultimately lead to a project success or failure” (p. 434). Finally, the study confirms the capabilities of RFID technology as an enabler of transforming the existing picking and the shipping processes in real-world setting, which is consistent with prior studies on RFID technology (Lefebvre et al. 2005; Loebbecke 2007). Using RFID technology, the TPL firm improved the internal control of its warehouse. For example, the real-time verification of shipments reduced the existing shipments mismatch during the execution of the shipping process which resulted in the reduced transport costs which are traditionally associated with shipment mismatch. This benefit realization by the TPL firm through RFID use is consistent with prior studies on improved organizational coordination and control mechanisms due to the technology (Curtin et al. 2007). However, this study presents a limitation in that it only focuses on the impacts of RFID on the narrowly focused picking and the shipping outbound logistics processes in a single warehouse. Further studies are needed to assess the impact of technology in the supply chain in a wider context and to develop tools and frameworks to calculate the return on investment of RFID projects at organizational and supply chain levels.

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Dr. Samuel Fosso Wamba is a senior lecturer in IT, University of Wollongong, Australia. He earned an MSc in mathematics, from the University of Sherbrooke in Canada, an MSc in e-commerce from HEC Montreal, Canada, and a Ph.D. in industrial engineering for his work on RFID technology, from the Polytechnic School of Montreal, Canada. His current research focuses on business value of IT, inter-organisational system (e.g., RFID technology) adoption and use, supply chain management, electronic commerce and mobile commerce. He has published papers in a number of international journals and conferences including: *European Journal of Information Systems*, *International Journal of Production Economics*, *Information Systems Frontiers*, *Journal of Theoretical and Applied Electronic Commerce Research*, *Hawaii International Conference on Systems Science (HICSS)* and *Americas Conference on Information Systems (AMCIS)*. Dr. Wamba is organizing special issues on RFID for the *Business Process Management Journal* and *Pacific Asia Journal of the Association for Information Systems*. He has been served as mini-track organizer and chair on the same topic for the 15th *Americas Conference on Information Systems (AMCIS)*, The 6th, 7th and 8th *Workshops on e-Business*, A *Pre-ICIS Workshop Sponsored by AIS SIGeBIZ*. He is *CompTIA RFID+ Certified Professional* and *Founder and CEO of e-m-RFID*.

Dr. Akemi Takeoka Chatfield is a senior lecturer in IT and head of E-Government and E-Governance Research Group at University of Wollongong. She serves as a member of organization committees for 2011 *HICSS E-Government Mini-Track* and *E-Government One-day Workshop*. Her research interests include IT benefits realization, e-government impact, and RFID/GIS-enabled government-community collaboration in disaster management. She published her work in *Journal of Management Information Systems*, *European Journal of Information Systems Communications of the ACM*, *Information Technology for Development Journal*, *Information Systems Frontiers* and *Electronic Journal of E-Government*.