Understanding the Impact of Emerging Technologies on Process Optimization: The Case of RFID Technology

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Abstract

This paper examines the case of one supply chain in the electricity sector where RFID technology integrated with firm's information systems acts as an enabler of process optimization. Using a business process approach and laboratory simulation, we explain how the implementation of RFID technology can increase the visibility of information at various layers of the supply chain, allowing members to gather precise information on real demand and improve replenishment processes. On the other hand, while RFID technology has the potential to automate some processes, human intervention is still required. Therefore, use case scenarios and sensitivity analysis should be carefully considered when selecting the proper design (architecture options) for the virtual and hardware components of RFID systems. The choice of the appropriate configuration needs to be integrated in the firm's strategies and supply chain partner's vision.

1. Introduction

Over the past, RFID technology (Radio-Frequency Identification) has attracted the attention of the scientific community. This increasing interest can be ascertained through various special issues on the topic in academic journals such as International Journal of Production Economics, Production and Operations Management, IEEE Transactions on Automation Science and Engineering, International Journal of Electronic Business and Journal of Theoretical and Applied Electronic Commerce Research. Following this trend, this paper addresses the case of one supply chain in the electricity sector with emphasis on internal customers in charge of the power grid maintenance and operation. The main objective of the paper is to explain how RFID technology integrated with firm's information systems can act as an enabler of process optimization and enhance the efficiency of a supply chain.

Section 2 presents RFID technology. In section 3, a literature review is presented with regards to supply chain optimization integrating RFID technology, followed in section 4 by an evaluation of the business value of information technology. In Section 5, the context of the study is presented followed in section 6, by the research design where the business process approach and laboratory simulation are presented. In section 7, selected RFID-enabled scenarios are discussed in terms of process optimization. Lastly, the conclusion and future research are presented in section 8.

2. RFID Technology

RFID technology is a wireless automatic identification and data capture (AIDC) technology (see [16]). A basic RFID system is composed of a tag containing a microprocessor, a reader and its antennas, and a computer equipped with a middleware program, in which business rules are configured to automate some decisions [2]. The tag, which is generally attached to a product, communicates through radio frequencies with the reader's antennas. The reader sends the location and unique identification of the product to a computer. When this information is routed to specific enterprise information systems (e.g. Enterprise Resource Planning Systems-ERP, Warehouse Management Systems-WMS), automated transactions can be performed such as reject unplanned receipts, directly enter receipt into computers, compare ASN (Advance Shipping Notice) for inbound deliveries, etc.

Beside some standards and technological limitations such as the read rate, data reliability, lack of unified standards, high costs associated to the technology (hardware and software), security issues (i.e. data access, privacy and legislation) [4], RFID technology presents many advantages over other AIDC (Automatic Identification and Data Capture) technologies such as (i) simultaneous multiple readings, (ii) no line of sight requirements, (iii) read and write capabilities, longer read range, etc. While RFID technology is considered promising, there are still many questions concerning its adoption [8], specifically in the ways its real potential can be delivered. Therefore, the objective of this paper is to demonstrate "how business processes can be optimized using RFID technology".

3. Literature Review on RFID Impact in the Supply Chain

Previous works on RFID impacts in supply chain context is still scarce, but represent a burgeoning area of research. Most recent papers can be classified in four main areas: conceptual papers, simulation modeling and mathematical papers, articles with empirical results from laboratory and from field studies.

For instance, among the conceptual papers, [18] suggest that RFID may facilitate the development of emerging supply chain configuration by acting as an enabler of a build-to-order supply chain management strategy. In the same vein, [25] and [31] suggest that RFID may facilitate supply chain collaboration practices and may constitute a link to more collaborative approaches such as CPFR (collaborative planning, forecasting and replenishment). [23] examine how RFID technology can act as an enabler of traceability in the food supply chain. The authors also outline an "information data model" for supporting traceability information modeling and an EPC (Electronic Product Code) based system architecture to indicate how to deploy the solution across a supply chain. While exploring the impacts of RFID in a retail supply chain, [25] and [15] also identify the emergence of "intelligent processes" to support RFID enabled B-to-B e-commerce applications.

When considering simulation modeling and mathematical papers, authors have used various models to assess the impact of RFID on supply chain performance. For instance, [17] developed some "mathematical frameworks" to evaluate quantitatively the impact of RFID technology in various aspects of supply chain management. Indeed the author looks at (i) the costs and incentive issues in a supply chain implementation (ii) the added value of information visibility in the supply chain, and (iii) the benefits of implementing RFID technology in an assembly environment. For instance, when considering the improvement of inventory control policies through the use of RFID, the author found that replenishment decisions "overall cost improvement is in the range of 2.8 to 4.5% with product progress information accounting for 47% to 65% of the cost savings" [17, p. 68]. Based on the six "fundamental operation (business) models" found in the Taiwan's printing industry [21] carried out a quantitative benefit analysis for RFID applications in different supply chain activities and presented the impact at various supply chain levels. For example, when considering quantitative cost and benefit analysis at the retailer level, the proposed item tagging mechanism can save multiple working days per year, and stock checking could be accomplished within one hour instead of several days when compared with bare codes. [14] used simulation as research method to study the impact of several factors that cause inventory inaccuracy (e.g. theft, unsaleables, misplaced items, incorrect deliveries) on a number of monetary (e.g. cost components that are affected by the factors that cause inventory inaccuracy) and non monetary (i.e. inventory inaccuracy, out-of-stock) supply chain performance measures within a retail supply chain. Their results indicate that eliminating inventory inaccuracy can reduce supply chain cost as well as the level of out-of-stock, and that RFID technology could greatly contribute to this issue.

With respect to articles with empirical results from laboratory studies, [16] explore the impact of RFID technology and the EPC Network on mobile B2B e-commerce in a retail supply chain. The authors point out some major impacts in terms of (i) business and operational process reengineering, (ii) IT infrastructure requirements, (iii) information sharing/synchronization between SC members, (iv) human and physical resource utilization, and finally, (v) strategy redefinition. [4] explore the impact of RFID technology in a five layer supply chain in the utility industry. The authors indicate that "open loop RFID implementation" could drastically benefit to all supply chain members. Based on selected RFID-enabled scenarios, they suggest multiples areas of impacts such as (i) a better "asset utilization" (e.g. fleet management by the transportation company, assembling lines at the supplier level), without compromising (ii) the "quality of service" provided by the operators, (iii) major benefits in terms of "inventory management" at all the supply chain levels, with the possibility to be provided with real time inventory updates that was translated in terms of millions, etc.

Finally, among articles with empirical results from field studies, other recent studies such as those proposed by [27] and [20] examine the influence on RFID technology on emerging applications in the retail supply chains. More specifically, [27] investigated the pilots conducted at the Metro group in Germany, and found that the RFID technology contributed to a reduction in out-of-stock by 9 to 14%, as compared to the preceding year, while optimizing store space by about 11%. [20] conducted an independent study at "Wal-Mart RFID-enabled stores" over a period of 29 weeks. They found similar impacts with RFID enabled stores being 63% more effective in replenishing out-of-stocks than stores without RFID, which can be translated into a reduction of out-of-stocks by 16%. [26] also examine the results of a joint RFID pilot project conducted between Kaufhof Department Stores, a leading European retailer and Gerry Weber, a fashion merchandise manufacturer. Following the pilot, the companies could observe time savings in moving merchandise through the supply chain, lower labor costs in existing processes, higher data quality and new service offering possibilities. The authors also lay emphasis on "data, about processes, product movement, and even customer behaviour (…) that can be used for proprietary and distinctive capabilities to gain competitive advantage (if) turned into understandable and usable 'content'".

Again, previous studies suggest that RFID technology is part of a broader system where automated data capture has little value unless translated into business intelligence.

4. Evaluating the Business Value of Information Technology

According to comparative analysis of worldwide IT spending that have been aggregated by eMarketer, analysts indicate a steady increase from 4% to 8% over the years with sharpest growth is Eastern Europe and other developing countries [11]. The global ICT spending was expected to reach $2.86 trillion in 2005 with the US market alone accounting for 39.6% of the worldwide market spending. In the specific case of RFID technology, analysts predict a $5.29 billion RFID market in 2008, with an increase of almost 7.3% over the previous years. Forecasts indicate that RFID spending will double before 2012 [22]. Other sources evaluate RFID annual growth rates are over 23% [7]. These growing investments in IT are pressuring many academics and practitioners to seek for economic justification as "more than ever IT executives encounter the justification issue due to senior management's insistence that the investment be properly utilized" [9, p. 273]. The literature on the evaluation of business value of IT can be classified into two main categories, namely the production-economics based approach and the process-oriented approach [33].

Respectively, studies in the first category use production functions to study the relationship between IT investments and productivity at the firm level, while studies in the second category try to assess the impact of IT investments on specific processes [30]. For instance, by adopting a production-economics based approach [5], showed considerable return in IT investments at the firm level in terms of cost savings, quality of service improvement and better customer service. However, as noted by [30, p. 200] the impacts of IT investments are "perhaps better observed at the process level (versus the firm level)". Indeed, when the process approach is used to assess the impacts of IT investments, other factors that affect the translation of these investments into impacts are investigated more obviously [24]. The process-oriented approach has been used by various researchers to assess the impact of IT (e.g. [13][25]), and it has been considered as the best approach to study the impact of IT at a more exhaustive level [6].

5. Context of the Study

In the utility context, the adoption of RFID technology is still at its early stages and the use of this technology are under preliminary investigation, mainly due to the "technology push" from technology suppliers, as well as competitive market conditions that create pressure toward supply chain optimization solutions. In fact, today, the world energy production is driven by demand with the global energy consumption that has been rising over the past three years at an annual average rate of 4.2% and is expecting to rise in the years to come, with Asia and Australasia (excluding Japan) which are expected to consume almost as much energy as North America by 2009 [10]. In Canada, the energy sector accounts for nearly 6% of GDP, which represents 1.9% of the labor force (327,000 jobs) and has been a major engine of growth in recent years). Beside crude oil, natural gas, coal and uranium, Canada is a major producer of electricity in the world (the fifth largest producer of energy in the world), which accounts for 9% of its total energy output. In this sector, the country benefits from low-price electricity as hydroelectric generation is the most important source of electricity supply, accounting for 60% of the total electricity output [10]. Owing to the abundance of energy, the size of its territory, the rigor of its climate and the high level of industrialization of its economy, Canada ranks among the most intensive consumers of energy. Nevertheless, Canada's energy output exceeds domestic needs from far, and the surpluses are exported in the US which is its major client [12].

Since 1997, following a restructuring of the North American market initiated by a deregulation opening the markets to competition, utility industry has undergone significant changes, with the entrance of important competitors specializing in the production and trading of electricity and other forms of energy. This phenomenon has pushed industry members to rethink some of their strategies and revise their business practices. In this context, while supply chain applications at a strategic level (e.g. strategy definition, supplier relationship management, contractual logistic management) have been considered as a rich area of opportunity for cost reduction [19], this article focuses more on the operational aspects of supply chain management. For instance, activities such as power grid maintenance and mobile field service have also been identified as having important effect on cost savings and level of service improvement [32]. It is along this continuum of electronic platforms (e.g. ERP, electronic marketplaces) and IOS adoption, that utilities are now looking toward emerging technologies such as RFID to drive transaction cost reductions.

6. Methodology

This paper is part of a larger study conducted to improve our understanding of RFID technology in a supply chain context. The business process approach and laboratory simulation are selected as they proved to be relevant in order to assess the impacts and potential benefits of RFID technology (e.g. [25][16]).

6.1 Research Sites

The investigated utility supply chain consists of: (i) a focal firm (Firm A), one of its strategic first-tier suppliers (Firm B), and one of its internal customers (Firm C). Firm A is a major player in the utility industry (electricity) in North America. As managers from Firm A indicated, among their primary motivation toward RFID technology adoption, the power grid maintenance and operations (repair) were key areas of potential improvements. Firm A owns two major distribution centers (DCs) and receives thousands of products (namely overhead distribution transformers) every year, of which 15 thousand are considered strategic components of its power supply infrastructure. These products which were selected in the study are distributed in 90 stores disseminated in a vast territory. Following a power outage, missing one product could have a serious impact on network down time. Therefore, optimizing product replenishment at specific stores (level) and automating the picking process at the store location were identified as critical activities.

6.2 Data Collection

For this study, both qualitative and quantitative data were collected using (i) on-site observations, (ii) interviews and (iii) joint working session with industrial partners in laboratory settings.

1. On-site observations were conducted in all research sites involved in this study. The main objective of on-site observations was to map the current intra- and inter-organizational business processes (As-Is) related to the chosen product value chain. This was done using a Business Process Analysis tool (ARIS Toolset) at various stages of the research. The ARIS Toolset is a Business Process Analysis (BPA) tool used for global definition, mapping, analysis, optimization and implementation of business processes. It helps to make "quick decisions about the management of e-business processes, by providing realistic simulations of resource utilisation, activity-based cost calculations, as well as web-based communication of modelled and optimised company processes" [1, p. 1].
2. Interviews were conducted with a semi-structured questionnaire to complement to observations and gather more information on specific business processes.
3. Joint working sessions where conducted with key respondents from each firms to identify critical processes to be redesigned while integrating RFID technology The resulting RFID-enabled B2B e-commerce scenarios, therefore, had to be validated by ERP consultants and RFID solution providers and, most importantly, by a middleware provider in order to ensure their technical feasibility. This iterative approach allowed refining the scope of the simulation in laboratory settings (see the RFID laboratory in Figure 1).

6.3 RFID Laboratory

The laboratory where RFID-enabled B2B e-commerce scenarios were simulated is presented in Figure 1.

On the left side, an RFID portal represents the supplier's shipping dock including:

- Photo eye (1) for automatic product detection and trigger to activate two fixed antennas (2). This procedure allows the antennas to be awakened and transmits radio waves only where necessary.
- These two antennas are connected to a fixed reader (3) that captures the information written on the tags (4).
- A stack light (5) linked to this reader allows the confirmation of the status of the readings as the products (or boxes) are passing on the conveyor belts (6).
- On the right side of figure 1 of an RFID portal represents a customer's receiving dock (7) with technical consideration similar to that of the shipping dock.
- Based on each specific business cases, other technological options could be considered such as mounted RFID fork lift or handheld RFID gun.
- The third part of the laboratory is composed of the ERP and middleware servers where all the business rules are configured (8). While the new generations of readers allow "built in intelligence", in the case of these pre-pilot experiments, business rules where configured in the middleware.
- For the purpose of the demo, OMS from Ship2save was used at the supplier location (simulated environment), and Catamaran (provided by Hewlett Packard and Shipcom Wireless) was used at the client location (simulated environment). The integration of these two middleware was facilitated with pre-configured bridges. Because of the scope of this paper, our discussion will only emphasize on the results obtained within Catamaran.
- Ultimately, the last components are the three screens on the walls (9), where all the information resulting from transactions is projected, allowing participants to follow the information flow in real time, as each transaction is automatically performed.
- Moreover, complementary devices such as mobile RFID reader (i.e. RFID gun) were used, to allow real time access to the middleware in order to take action while being on the move.

7. RFID-Enabled Scenarios

In this study, we have adopted a "store" perspective in conformity with the indication of firms A managers on targeted critical activities. This focus enables researchers to understand HOW the work would be carried out within one store as a power grid operator would handle an electronic working order (e-WO) in order to fix a power outage.

The EPC (Event-driven Process Chains) formalism was used as a common language between all the project stakeholders for the participants to fully understand the impacts of implementing RFID technology on selected processes. The EPC formalism allows a logic representation of activities within and between processes. An interesting aspect of the EPC formalism is that it highlights all the events that trigger the activities and the resulting sequence of events; suggesting that a process can be seen as a chain of events and functions (i.e. an activity which needs to be performed). Moreover, the modeling of a business process using EPC formalism uses three types of logical connectors to indicate the workflow between activities and events, mainly the "^" (i.e. and), "v"(i.e. or) "XOR" (i.e. exclusive or). In addition to the basic representation of a process using EPC formalism, it is possible to assign responsibilities (i.e. employee) to a specific function, allocate a system which is used to perform the function (e.g. ERP, RFID middleware), indicate information inputs and outputs (e.g. RFID data) specify some business rules, assign them to logical connectors and quantify their probabilities of occurrence.

7.1 Simulated Scenarios in the Laboratory

Today, when a power outage occurs, the operators have to call a maintenance center for identifying the closest remote store where required products (e.g. transformers) are available in order to proceed with their picking before to go on the site for repairing the power grid. However, because of store management issues, a store manager has to be assigned for opening the store, providing operators with the products and filling up the documentation. An alternative approach being used is a permanent store manager assigned to a specific store.

Indeed, if multiple stores can constitute critical inventory buffer areas between remote locations and distribution centers, the current situation is rather costly and inefficient. Therefore, a redesigned process integrating RFID technology was proposed and validated in laboratory settings. The simulated scenario represents the automatic "access" to a remote store for the "automatic picking" of a "specific product" in order to fix a power outage that just occurred (Figure 2).

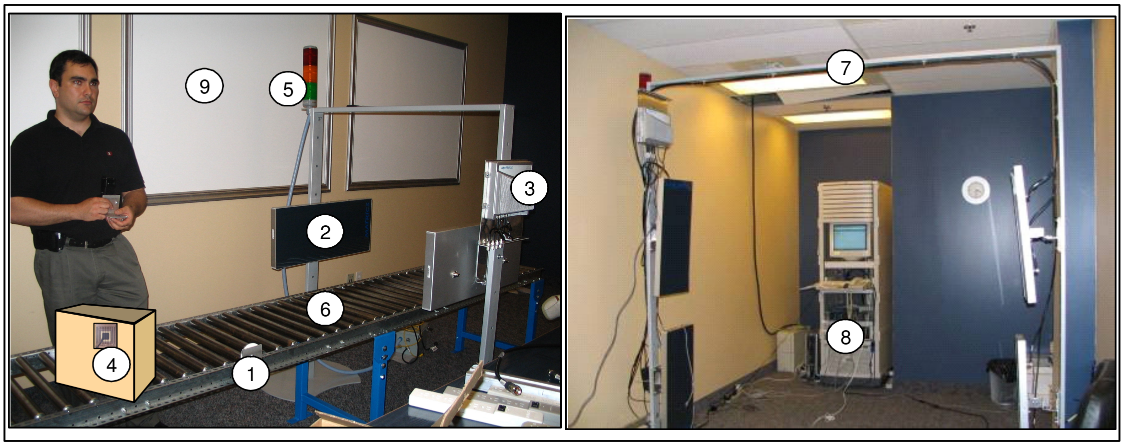

Figure 1: ePoly RFID –ERP Laboratory

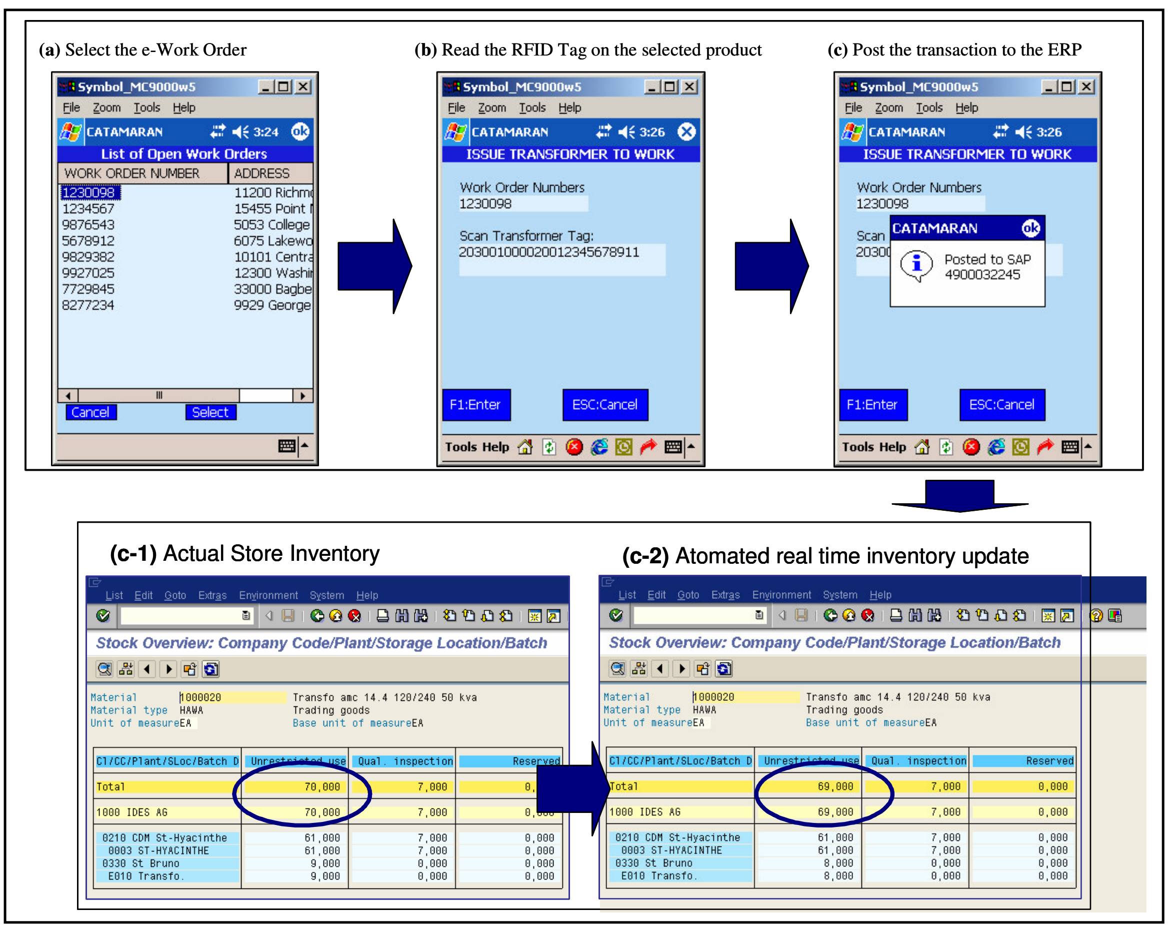

Figure 3: Steps related to automated picking in a store

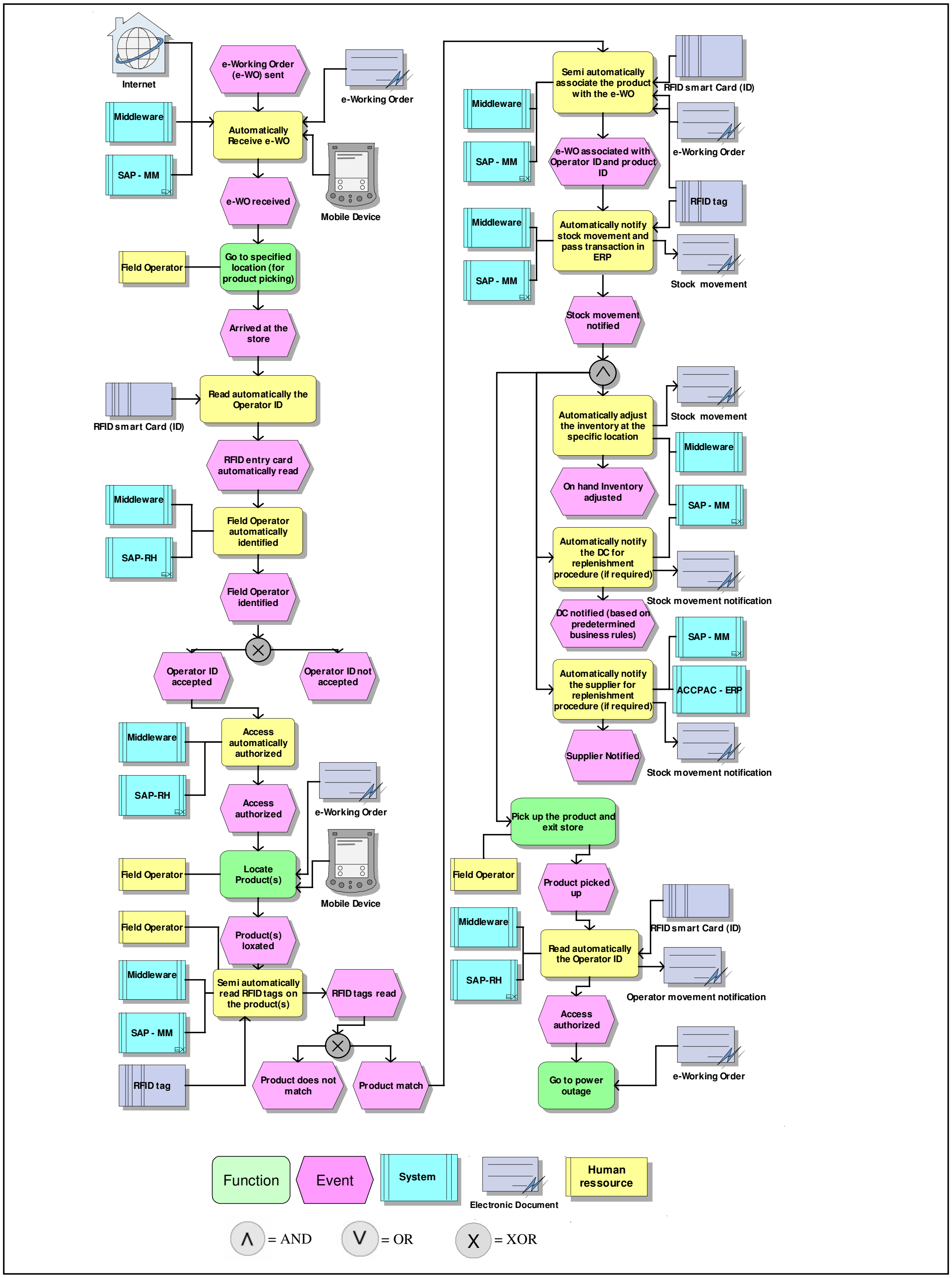

Figure 2: Simulated RFID-enabled scenario

7.2 Discussion

The following course of actions is triggered by an electronic working order (e-WO) sent to an operator in order to fix a power outage that has just occurred.

More precisely, the following steps can summarize the scenario simulated (Figure 2) in laboratory:

1. When the e-WO is received, the operator can directly access the ERP from the field, using a wireless device (i.e. PDA), check product availability in the inventory and reserve the required product at the closest store.
2. When the product arrives at the store, by automating its identification (i.e. RFID employee smart card), the operator automatically access the store, locate the reserved product, scan the product to confirm the matching with a specific e-WO before picking it up (i.e. operator equipped with RFID reader with embedded middleware functionalities and products equipped with RFID tags) (Figure 3, part (a)).
3. Once the verification is performed, the operator semi automatically validates the transaction by associating a specific e-WO with this specific product (Figure 3, part (b)) and posts the transaction into the ERP (Figure 3, part (c)).
4. As this transaction is posted, this triggers other functions such as the automatic inventory adjustment in the ERP in real time (Figure 3, part (c-1, c-2)). This could in turn trigger more events such as sending a notification to specific supply chain members on the stock movements.
5. Finally, as the operator exits the store, a notification is sent to the ERP to notify the status of the employee.

The same logic could be used to follow the whole process from power outage to reparation, giving the organisation a better visibility on its mobile workforce performance.

8. Conclusion

This study attempts to improve our understanding of the impact of RFID technology on business processes by trying to answer the following question: “How business processes can be optimized using RFID technology?” In terms of practical implications, it is in line with recent questions raised by [29] and [8] about RFID while these authors are asking for models, theories, concepts, frameworks, methods, techniques, and tools that are being applied in practice, raising the importance on RFID research to meet the needs of practitioners and managers.

Our results suggest that, when implementing RFID technology at the store level, the visibility could allow supply chain members to gather precise information on real demand, thus enabling lean assembling at the supplier’s level and optimizing the replenishment procedures at the distribution center and at the store levels. Also, in critical situations, as power outage minimum downtime is a key issue, RFID technology seems to be a relevant technology to increase the responsivess of organization managing emergency situations. Moreover, RFID technology still requires human intervention for some activities. For example, the operator still has to select the exact working order to match the specific product for the billing of a project. More intelligent business rules could have been configured in the middleware to avoid this human intervention, but is it worth it? Indeed, each scenario could lead to many possible configurations, suggesting that use case scenarios and sensitivity analysis should be carefully considered when selecting the proper design (architecture options) for the virtual and hardware components of RFID systems.

In reality, the exercise can be highly complicated, when considering all the options for selecting (i) the proper RFID systems vs. other AIDC systems (ii) the type of wireless network, (iii) the level of integration with various enterprise information systems modules, and with eCommerce intra and inter organizational systems. Moreover, beside trade off on functionality vs. costs consideration, the selected configuration will heavily depend on the decisions of different managers at the supply chain level. This raises the issue of the identification and selection of performance measurement that needs to be shared among supply chain members in order to evaluate the implementation of the retained scenario [3]. Indeed, when building RFID-enabled scenarios, such performance measures would enable managers to (i) evaluate and control the performance of their resources, (ii) communicate these performance, and (iii) improve their supply chain processes [28] by identifying gaps (between "As-Is" situation and expectation) and point out at action for improvements. Also, the integration of RFID infrastructure with the existing enterprise information systems at focal firm level and between supply chain members could be a very challenging task and require a high level of collaboration. The next logical step of this research could be the investigation of the impact of RFID on the supply chain members’ relationship.

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