

A Framework for the Implementation of RFID Systems

Invited Paper

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Abstract There are an increasing number of organizations planning to implement Radio Frequency Identification (RFID) systems to enhance their competitiveness. Due to the novelty of the technology, many managerial challenges exist in determining and planning for the implementation of such systems. These challenges often lead to wasted efforts and resources, as well as to failed implementations. This paper presents a systematic and holistic RFID implementation framework which has been validated by both users and experts. The framework outlines the important tasks to be performed in each step of the implementation process. To enable practitioners to make informed go/no-go decisions, essential considerations of implementation are also discussed in this paper. Furthermore, the critical success factors for the deployment of such systems are also elaborated.

Keywords RFID, RFID Implementation, Critical Success Factors, Implementation Framework, Deployment And Management Issues

1. Introduction

Radio Frequency Identification (RFID) - a cutting-edge technology in the Auto-ID industry - has been around for

more than 50 years. It was first used in military applications for identifying enemy aircraft (Fanberg, 2004). Nowadays, RFID has become one of our partners in daily-life (Smart 2004; Garter, 2005; Stuart 2006). In many industries, a growing number of organizations around the world are considering introducing RFID systems as a means to improve their business and operational processes. RFID has revealed its potential to revolutionize existing systems, and it is undoubtedly a highly versatile technology that can serve the needs of diverse industries.

RFID is a technology that uses radio waves to transmit information. This kind of system usually consists of tags, readers and a data processing system. Such a system allows computers to acquire information about the identities of physical objects. It is more than a substitute technology of barcode systems. An RFID tag can hold much more information than a barcode, to the extent that it is possible to identify individual tagged items in a supply chain. RFID is superior to a barcode as it does not require line of sight for automatic data capturing, which is a definite advantage in numerous applications (Chowdhury et al., 2007). It also has a faster response time and process time when it is used to identify objects remotely.

An important application of RFID is its use as a tool to enhance the visibility of objects in a supply chain. This allows the organization to achieve better material management so as to improve a supply chain's efficiency and effectiveness. It enables organizations to track product information, allowing for greater control and flexibility in managing goods as they move through the supply chain. It will also significantly reduce the manpower needed and minimize human errors when compared with the existing technology. More importantly, the use of RFID technology improves supply chain efficiency by streamlining the stocktaking operations. As a result, it strengthens customer relationships by providing better services, facilitating promotional activities and allowing retailers to allocate resources more effectively (Angeles, 2005).

Although RFID is recognized as a revolutionary innovation that has the potential to change the way of managing businesses and supply chains, and even though it has captured the attention of many organizations, the adoption of RFID solutions in businesses has been slow (Wu et al., 2006). Many organizations are only "interested" in this technology, waiting for others to take the plunge and see if it bears fruit. Due to the lack of standards in relation to the technology and uncertainties about the return on investment (ROI), organizations usually take the wait-and-see approach in taking a decision to adopt it (Reyes, 2007).

It has been mentioned that implementing RFID brings about lot of potential benefits. In order to convert these potential benefits of RFID into positive ROI, it is very important for the organization using it to pay attention to the pitfalls of RFID's implementation.

A lack of worldwide standards for RFID tags, the security of the data stored in the RFID tags, as well as the costs and risks of the early implementation of RFID technology comprise the major concerns of managers (Paul, 2007). Somehow, the largest difficulty confronting managers is the huge amount of investment required for the implementation of RFID systems together with the unpredictable payback period and the time needed to break even. The pace of implementing RFID from its introduction to a project's completion is determined by the perceived potential and limitations of the RFID system, as well as the way in which they are managed and exploited. The speed of adoption will then affect the benefits that the organization will receive and the risks to which it will be exposed.

Many RFID implementation and evaluation frameworks for various industries have been suggested (Soylemezoglu, 2006; Reyes and Jaska, 2007; Ngai et al., 2010). Kim and Garrison (2010) have introduced the key

organizational characteristics that drive the evaluation of RFID, whereas Angeles (2009) has investigated the ability of the components of IT infrastructure integration and supply chain process integration in predicting RFID deployment outcomes. With the process of technological innovation, Matta et al. (2012) examined the key antecedents that may influence the initiation, experimentation and implementation stages of a RFID system. However, a systematic framework that helps managers to understand how RFID should be implemented along with the activities and issues that need to be considered in implementing RFID solutions in specific business and operational settings is yet to be developed. Without such a framework, managers will need to spend a lot of time looking for useful references.

Managers find it difficult to make decisions on the implementation of RFID systems due to a lack of knowledge about RFID technology. Unfamiliarity with the system leads to myth creation and an erroneous perception about the benefits that an RFID system can produce. In such a situation, managers will have improper perceptions and expectations of RFID technology. They are curious about when the right time to adopt an RFID solution might be. Although there are lots of successful cases, they remain doubtful about the benefits and the ROI of such costly investments. This is particularly true in relation to the high initial investment costs for realizing the potential benefits, in which there is no concrete resource commitment to pilot studies or implementation (Brown and Russell, 2007). As discussed in Leimeister et al. (2009), many IT decision-makers have heard about and taken an interest in RFID, but are still far from considering implementation. They need clear guidance that will help them to analyse and identify the benefits and pitfalls of any system's deployment.

This paper presents a methodology to address the above mentioned issues in deciding RFID's implementation. Suggestions on how and when to implement an RFID system that will bring benefits to the whole company will be offered. The critical success factors for RFID's implementation will also be discussed.

2. Current Expectations Towards RFID Deployment

Figures 1 and 2 show the major reasons against deploying an RFID system and those in favour of deploying one in an organization, respectively (Osyk et al., 2012).

A common expectation as to RFID deployment is the enhanced visibility of the supply chain (Angeles, 2005). Improved efficiency in item-tracking and reduced item location uncertainty can result in cost reductions after the deployment of RFID systems (Lee et al., 2008). The real-time exchange of data provides logistics networks with a better and more accurate information flow (Saygin et al.,

2007). Information on locations, inventory levels and demands can be easily collected from a more transparent network - this facilitates managers' decision-making and it can assist the implementation of new business processes (Saygin et al., 2007). When a rewriteable tag is attached to an object, transactional data stored in the tag can be updated as it moves along the supply chain (Mills-Harris et al., 2006). By enhancing the visibility of the supply chain, stock uncertainty can be reduced and operational efficiency can be improved, thereby achieving the overall goal of cost reduction upon successful implementation of the system (Lee et al., 2008).

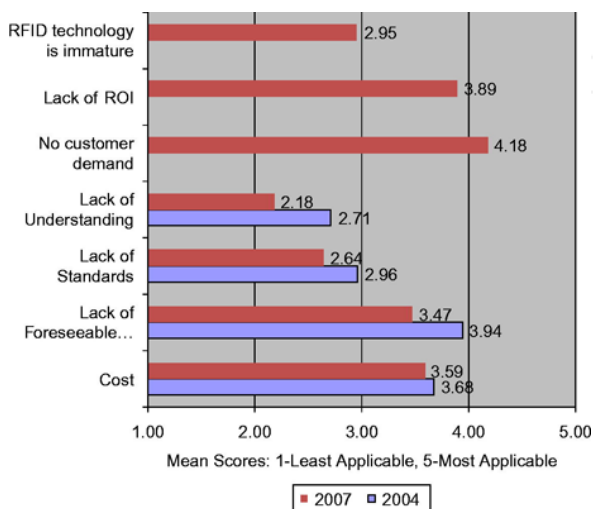


Figure 1. Reasons for not implementing RFID (Osyk et al., 2012)

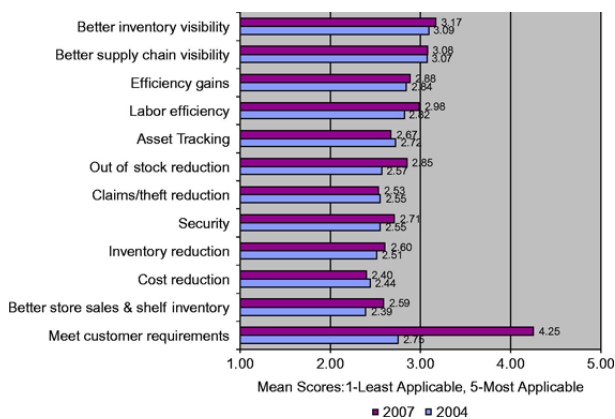


Figure 2. Reasons for deploying RFID (Osyk et al., 2012)

Another expectation is the more effective use of labour. After the implementation of an RFID system, an organization will expect that all the repetitive tasks will be performed by the system, releasing labour to do other tasks that can be more knowledge-based (Harvey et al., 1997; Mills-Harris et al., 2006). Since all data entries are instantaneous and operator-free, supply chain transactions that used to be labour-intensive can be automated to increase the efficiency of the whole supply chain. This can also help to automate workflow and avoid the business's interruption in the manufacturing process (Chowdhury et al., 2008). Thus, RFID systems are a

breakthrough for business in relation to automation (Cheong and Kim, 2005). With information being more readily available, the picking and put-away accuracy of warehouse operators can be enhanced (Bhuptani and Moradpour, 2005).

Since RFID technology can help to provide information about the object being tagged, organizations could make use of this to minimize inventories by deciding upon the right time to place the right product at the right place so as to maximize sales and profits (Chowdhury et al., 2008). As businesses could obtain more accurate and timely information about their products, the product inventory across the supply chain can be managed better, such as by reducing the inventory turns and the risk of stock-out (Cheong and Kim, 2005; Doerr et al., 2006).

It is also claimed that RFID systems can produce higher quality and more information (Bergeron et al., 2005). Information is collected automatically without human intervention. Thus, the gathered information is more precise and free of human errors that often exist in data collected manually. Since data entry is no longer needed and labour is saved, the automation could result in the reduced cost of data collection, improved data quality and providing for the easier manipulation of information (Joglekar and Rosenthal, 2005). Moreover, information is validated and transmitted to other operational systems without delay, thereby enhancing the timeliness of information that might facilitate contact with customers (Lee et al., 2008). With higher quality information that is easily accessible, RFID systems can assist in various management tasks, such as event management, business action management, task management and scheduling, exception handling, interface management, authentication and authorization (Chen, 2005). It is also thought that it can help organizations to learn more about customer behaviour (Wang et al., 2006).

The other expected benefits of RFID technology are the reduced risk of counterfeiting (Lee et al., 2008) and theft prevention (Chowdhury et al., 2008). These benefits can be realized because of the technology's ability to authenticate and track products. This can lead to increased customer satisfaction and loyalty, contributing to revenue growth and increased profits, as the products are more reliable and customers will receive better service (Heskett et al., 1994; Lee et al., 2008). As RFID systems will also enable the identification of items, it could enhance the security of organizations (Bhuptani and Moradpour, 2005) and might improve patient safety in healthcare services (Ting et al., 2011).

3. Methods

Figure 3 depicts the research methodology of this study. A search of English language articles published in major electronic databases from Jan 1, 2000, to Dec 31, 2010, was

conducted. As the research on this topic is relatively recent, the scope of this investigation is limited to the timeframe 2000 to 2010; nonetheless, this 10-year period is deemed to be representative of the application of RFID. The six international electronic databases listed below were interrogated:

1. Science Direct;
2. IEEE Xplore;
3. InformaworldTM;
4. Emerald;
5. Inderscience;
6. ABI/INFORM

The search was conducted using the keywords "RFID", "RFID implementation", and "RFID application". The authors and ten other RFID experts reviewed each article collected from the search to determine whether it was related to the scope of this study. The review exercise was conducted by the authors and experts individually in the first instance and then collectively. The search focused upon articles that discuss the common and critical procedures of RFID implementation (e.g., the steps for implementing RFID in a medical organization, from the point of a project's initiation to its end). For this reason, numerous articles that discuss the integration of RFID with other technologies (such as barcodes and sensors) were considered to be outside the scope of this review, and they were eliminated from further consideration. The shortlisted articles were classified into various critical procedures on the basis of their contents. Differences in the classifications made by members of the review team were discussed collectively until an agreement was reached. The essential steps of different deployment methods and the critical success factors for implementing RFID solutions were identified from the results of this classification exercise.

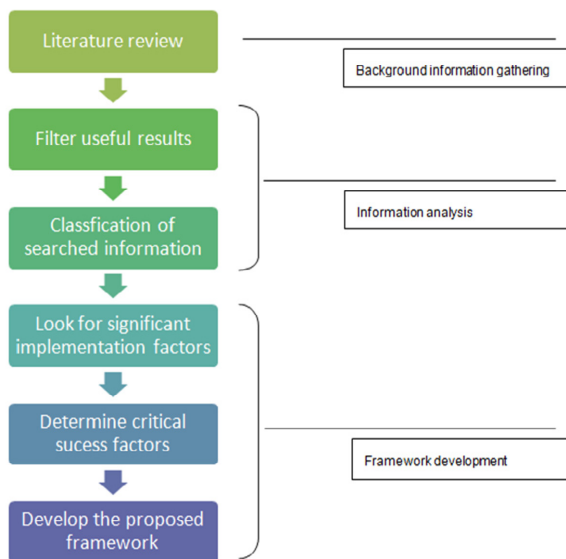


Figure 3. Research Methodology

4. Proposed Implementation Framework

Table 1 summarizes the proposed 6-step generic framework for the implementation of an RFID system. The implementation of RFID solutions is a complex task that involves both technical and human factors. The proposed framework is based upon a synthesis of existing frameworks published in the literature that will make it applicable to most industrial settings.

Steps	Description	Reference(s)
Project Scoping	<ul style="list-style-type: none"> ● Understand the potential and limitations of RFID technology ● Define the project objectives 	Angeles (2005); Vijayaraman and Osyk (2006); Wu et al. (2006); Attaran (2007); Reyes and Jaska (2007); Sellitto et al. (2007); Ngai et al. (2010)
Analysis of the Existing System	<ul style="list-style-type: none"> ● Collect information ● Information analysis 	Soylemezoglu et al. (2006); Attaran (2007); Jaska (2007); Pålsson (2007); Huang and Tang (2008); Hellström (2009); Kim and Garrison (2010); Ngai et al. (2010)
System Design	<ul style="list-style-type: none"> ● Requirement analysis ● Hardware/software selection ● Develop a new process 	Soylemezoglu et al. (2006); Reyes and Jaska (2007); Huang and Tang (2008); Hellström (2009); Ngai et al. (2010)
Prototype Testing	<ul style="list-style-type: none"> ● Debug ● System Adaptation 	Reyes and Jaska (2007); Soylemezoglu et al. (2006); Ngai et al. (2010)
Implementation	<ul style="list-style-type: none"> ● System deployment ● Training 	Soylemezoglu et al. (2006); Spekman and Sweeney II (2006); Attaran (2007); Reyes and Jaska (2007); Ngai et al. (2010)
Continuous Improvement	<ul style="list-style-type: none"> ● Monitoring ● Collect feedback from users 	Ngai et al. (2010)

Table 1. Proposed Framework for RFID Implementation

4.1 Step 1: Project Scoping

The typical tasks in this step are to understand the potential and the limitations of RFID systems and to define a given project's objectives. These are critical tasks that need to be completed during the planning stage. Understanding the potential and limitations of an RFID system can help to avoid unrealistic expectations towards RFID's deployment. Defining the project objectives can give a clear direction to the implementation team.

4.1.1 Understand the Potential and the Limitations of RFID Technology

RFID technology will bring a lot of benefits when it is successfully implemented, but this does not mean that it is a perfect solution that does not have limitations. Organizations should understand what RFID both can and cannot do before the making the decision to implement a system. As discussed by Hardgrave and Miller (2006), organizations tend to create unrealistic expectations and have incorrect perceptions towards the system. Misunderstandings and false expectations about the technology could lead to the formulation of unachievable goals or else the premature rejection of a project. Grasping the technology's limitations would also allow managers to reflect upon the suitability of implementing the solution in their own organizations. For example, data accuracy is one of the common false expectations encountered by the public. Indeed, RFID cannot work properly with metals and liquids; thus, in the case on placing RFID tags directly on a metal surface (such as a truck) for vehicle in under the container terminal environment, managers need to be aware of the risk of getting poor readability results, as metal will reflect radio waves (Ting et al., 2012). To avoid poor reading performance, managers are required to take into consideration the limitations of RFID; they will ultimately adjust the tag's location by placing it away from metal surfaces (i.e., affixing the tag on a windshield). As a result, a better understanding of the technology could assist in formulating a clearer goal and gaining most of the potential benefits.

4.1.2 Define the Project Objectives

After gaining a clear picture about what RFID technology can bring to an organization, it should attempt to identify the areas that need to be improved in the current process. It is essential for the organization to know the reasons and expected outcomes of the implementation. A clear scope and objectives in implementing the system will guide the organization towards a productive programme (Ngai et al., 2010). Establishing the scope of the project could assist decision makers to develop well-defined boundaries for the implementation of the project. The project objectives to be established must be achievable and sensible, and sometimes short-term goals may also be set at this stage. Take a wine cellar as an example - the objectives of its RFID system are identified as functions with regard to: (i) the prevention of counterfeiting, (ii) avoiding the mixing of customer's wines, (iii) enhancing the stock-take accuracy and process, (iv) avoiding theft in shops, and (v) mapping wine products with location information automatically (RFID News, 2011; Swedberg, 2012). Concerning the scope of the work for these objectives, wine cellar managers should divide the project into different phases (i.e., objectives (ii), (iii) and (v) are

achieved in first phase, whereas objectives (i) and (iv) are achieved in the second phase). In this way, achievable goals and objectives will encourage an organization to improve the system continuously and to gain the most benefits from the project. Furthermore, these objectives should also align with the organization's strategies. To earn the support of all stakeholders, the project objectives should be communicated across the whole organization.

The organization should focus on those RFID solutions that will have a significant impact upon the business performance of the company. Setting long-term goals and major milestones is also important. Members of the project team will have a sense of fulfilment when the milestones are met, one by one.

4.2 Step 2: Analysis of the Existing System

During this step, various methods are used to collect information on the existing system which is analysed to evaluate the current system. This helps to identify the vital procedures in the process - i.e., the vital inputs to the subsequent redesign stage.

4.2.1 Collect information

The details of the current process will be collected by various methods, such as conducting interviews with the key individuals and front-line staff who use the present system, collecting comments from stakeholders, and eliciting experts' opinions. Observations should also be made through site visits in order to understand the physical flow of items that may be tagged in the new process. Information about the current process that needs to be collected would include data on the operation, equipment, related documents and forms, as well as the activities performed in the process. It is stressed that only information relevant to the RFID implementation process should be collected. Making reference to the project's scope will help to achieve this. Apart from the physical flow of the process, the information flow of the process should also be studied. It is important to collect information about the daily decision-making processes. For example, Sonoco - a global manufacturer of packaging products - invested in a RFID system upon their customers' request (RFID News, 2008). Sonoco's customers requested better visibility into the company's supply chain. Sonoco and its customers were able to improve inventory management and track their goods in real-time. The company tagged the goods when they were manufactured. Thus, the traceability of product quality could be improved, as the source of defects could be precisely identified. This could help Sonoco to reduce the frequency of lost shipments and reduce waste. More importantly, it increases customers' satisfaction. This example illustrates the implications of collecting information from different kinds of people.

4.2.2 Information Analysis

After collecting information about the operation process, the analysis and evaluation of the current process will follow. This could be performed by using the diagramming techniques and tools that have been agreed upon by the key individuals who are currently using the system. By examining the current process with the aid of workflow diagrams, areas for improvement can be identified. When multiple candidates for improvement exist, they should be prioritized according to their impact upon the organization's business performance. Those candidates that will bring about more potential benefits to the organization will be given higher priority in implementation. For example, in the case of the wine cellar again, the stock-take accuracy and process can be significantly improved, with a 60% time reduction (when compared with manual operation). Therefore, managers will decide to develop the system with this objective first, as it is the most direct and worthwhile benefits of RFID implementation.

4.3 Step 3: System Design

After analysing the current situation and the operation process, the organization should design a new process that is most suitable to matching its needs and requirements. The system design stage should include requirement analysis, hardware and software selection, and the development of the new process.

4.3.1 Requirement Analysis

This task is the follow-up step of information analysis. Upon the completion of information analysis, the major problems and potential steps that need to be modified are identified. The purpose of performing requirement analysis is to thoroughly understand the ways in which RFID technology can address the problems identified. Sometimes, this may suggest a complete redesign of the process in order to optimize the process flow. However, a complete redesign is not always necessary; very often, minor modifications that meet the system's requirements can remarkably improve the process flow. For example, in the case of warehouse operations, the company has developed its own Enterprise Resources Planning (ERP) system to enhance day-to-day management (Ting and Tsang, 2012); however, the company would like to adopt RFID technology in its forklift for automating the product flow within the warehouse (e.g., from Location A in G/F to Location C in 1/F). Therefore, it is suggested that the operator drive slowly when passing through the RFID gate door for the better capture of RFID signals; this constitutes a minor change of operation. However, according to the findings of the detailed analysis of twenty-four businesses conducted by the Grocery Manufacturers of America (GMA), one of the major issues of RFID deployment lies in defining the process that

requires changes (Roberti, 2004). Such an analysis can help to pin-point the specific supply chain management issues that need to be addressed.

4.3.2 Hardware/Software Selection

The performance of an RFID system is easily influenced by the operating environment. Therefore, the careful selection and testing of hardware and software is crucial to the successful implementation of the system. An RFID system comprises hardware items such as RFID tags, antenna and readers; these hardware items should be selected by taking into consideration the environmental factors which are identified in the requirement analysis step. One of the factors to be considered is the material of the tagged object, because it will have a significant effect on the performance of the RFID system. For example, metal absorbs and degrades radio frequency signals; to avoid such problems, the RFID tag attached to such objects should be coated with an insulator (Ngai, et al., 2010). In developing the software, one should study the radio frequency signals that might exist in the environment in which the system is going to be deployed; such signals may have the potential to interfere with the RFID system. Therefore, a suitable radio frequency should be selected to avoid the interference problem. The organization should design the way in which the readers are connected to the network and the software architecture, including the RFID middleware and the application level software.

The selection of hardware and software also involves the process of testing them; this is to understand the characteristics of each element of hardware and software and to decide which option is more suitable for the current environment. The testing of the hardware would give decision-makers a clearer picture of how the hardware and software items function in an integrated system, as well as providing data for measuring the reliability of the system. One should also select the appropriate means of mounting the antenna and the orientation of the tags so as to optimize the readability of the tags. The proper selection of the software could also assist in meeting the data requirements - some software might perform better in handling a special kind of data and some might not; therefore, an organization should select the software that meets its requirements.

4.3.3 Develop the New Process

After information and requirement analysis, the organization should be familiar with the process's needs and the improvements that need to be made. At this stage, the organization should be able to modify the existing process or else develop a brand new one to enhance its performance and meet any project objectives. The new process should be designed based upon the knowledge of the current process and any potential

changes so as to avoid surprises when the system is implemented.

Apart from designing the hardware and software systems, the decision-making and operation processes may also need to be redesigned. The RFID system's implementation may involve the simplification or elimination of existing procedures. For example, the stock in and out process can be automated by capturing the RFID signals when the RFID-tagged objects passed through the reading device (e.g., a RFID gate way). As a result, one should ensure that the decision-making process and the operation process are aligned with the new procedures to be implemented. It could avoid tag collisions and the duplication of efforts, thereby reducing confusions in the early stage of system implementation.

4.4 Step 4: Prototype Testing

Before the actual implementation of the RFID system, it is very important to conduct demo testing so as to ensure that the workflow developed together with the RFID technology will work and that it is ready for deployment. This will also help users to understand the systems. On the successful completion of prototype testing, the implementation of the system in the actual environment can start. Prototype testing may be conducted in the laboratory or in the actual environment. Conducting on-site testing is more reliable, because all the environmental factors can be considered and tested. When it is impossible to conduct the test in the actual environment, demo testing in the laboratory could be an alternative. The simulated environment should be as similar to the actual environment as possible, to ensure that the test results will be useful. Apart from debugging the technical system and eliminating the mistakes in the analyses, this step also includes collecting feedback from users after the demo testing. This is designed as such in order to elicit comments on the various user interfaces and in order to fine tune their design.

4.4.1 Debug

The prototype testing covers both software and hardware tests. Thus, bugs and the collision of systems may be detected. Technical staff should be involved so as to support the testing and in order to resolve (debug) any technical problems detected in the test. Tests under different foreseeable scenarios are conducted to assess the flexibility and capability of the system. For example, proof-of-concept testing on several scenarios is conducted to simulate all the situations to be encountered by the RFID system. As with the case of vehicle tracking, tests on various speed levels (e.g., normal speeds, fast speeds, and over the limit speeds) should be taken into consideration to capture the reading performance of different levels so as to see how to debug the system and help it fit with all situations (Ting et al., 2012).

4.4.2 System Adaptation

The adaptation of processes may be necessary to ensure that the RFID system will deliver the expected performance results. Problems found during the demo testing should be recorded and reviewed so as to fine-tune the system and resolve these problems. Consider the case of Mississippi Blood Services, a non-profit organization that collects more than 60,000 units of blood annually. It faced problems in managing the inventory of blood products that have a short shelf life (Greengard, 2006). The organization would like to know if RFID would help to solve this problem. After consulting some experts, the organization conducted a pilot test on 1,000 units of blood products. The process being tested involved transferring specific blood products from the tray to the cooler. Problems of interference caused by the metal trays and other electronic devices in the operating environment are yet to be addressed. However, after the pilot test, it was found that the high water contents of the blood products together with the metal tray exacerbated the readability problem presented to the auto-identification system. This case shows that, without the actual on-site testing of the system, it would be difficult to identify the full extent of potential problems in a given environment. Therefore, prototype testing is an essential step of any RFID implementation project.

4.5 Step 5: Implementation

Implementation follows the adaptation of the system; it is more than just the installation and commissioning of hardware and software systems. Typically, it also involves change management, training and system deployment. All if the tasks in the implementation step are vital, as they will affect the success of the implementation. Sometimes, implementation might not involve a clean changeover to the new system; the new RFID system may run side-by-side with the original system, and the latter will phase out only when the performance of the new system is assured.

4.5.1 System Deployment

System deployment will include installation and commissioning of hardware and software systems, as well as developing the new procedures. During the process of installing hardware items, care must be given to the placement of the antenna as well as that of the tag on the object to be tracked, because such factors will affect the readability of the tags. The placement of hardware items should have been tested earlier - what needs to be done at this stage is to install these items according to the optimal design determined during the earlier test. Software configuration is the other issue that goes hand-in-hand with hardware installation.

Software configuration involves middleware configuration and deployment. Middleware is used to control the readers' ability to read from and write to the tags; it also filters the tags' data and forwards useful information to other functional applications. It is important to configure the middleware properly to achieve the seamless integration of the current applications and database with the new RFID system. For example, a data interface layer for an application may need to be developed - the database may need to be modified in order to make it possible to accept data collected from the new system. A security system should be set up at this stage as well. RFID applications can be high risk systems when there is no control to protect their security. Therefore, at this stage, it is important to establish control measures for assuring the security of the system, such as formulation and enforcement of access controls that apply to data collected by the system.

In addition, policies and procedures that support the implementation of the new system would be established at this stage. Current policies and procedures may need to be modified to facilitate the adoption of the new system. Sometimes, management practices may need to be changed. However, people tend to resist change because familiar practices will become obsolete - there is anxiety about unknown factors such as the impact of the new system. Management should be sensitive to those problems that threaten the successful implementation of the new system. Myths should be broken before they become perceived truths. New management practices that accompany the implementation of the RFID system may involve new divisions of labour or coordination and communication with multiple stakeholders.

4.5.2 Training

Users need to receive training on technical operations of the system and basic information about the system. The training should include courses that introduce the system and basic knowledge of its operation and shatter the myths about it.

It is also essential to provide users with practical training so that they will have hands-on experience in using the new system and the changed process (Ting, et al., 2011). This will also provide users with opportunities to understand the guidelines and precautions as to system usage. At the same time, the organization should listen to users' comments on the changes, as well as their acceptance of these changes. This will reduce conflicts between users and managers and speed up implementation, thereby turning successful deployment into a reality.

4.6 Step 6: Continuous Improvement

The last step for implementation is continuous improvement. Since no system is perfect upon its

introduction, there is always room for improvement. The organization should continuously evaluate the system's performance and compare it with the preset objectives, enhance the system with emergent technologies, or else adapt it to match the changing needs of the market. This step includes the tasks of system monitoring and the collection of user feedback.

4.6.1 Monitoring

After system deployment, the performance of the RFID solution needs to be closely monitored - especially in the early stage of implementation - so that the project team can quickly respond to the problems encountered. The actual performance of the system should be compared with the targets set during the system design stage. For example, a multi-frequency tag readability test was conducted at United Airline's ticket counter in Tokyo (O'Connor, 2005). In that test, an average of fifteen pieces of dummy baggage per day were tagged with randomly generated numbers that simulated passenger names. The dummy bags would then be dispatched to flights for different destinations via different routes and then sent back to Tokyo flights in the reverse direction. The readability of the tags on these bags was recorded and the results were analysed to monitor the performance of the baggage tagging system.

4.6.2 Collecting Feedback from Users

Feedback from the different stakeholders of the RFID system should be collected and analysed so as to spot potential problems and issues in the newly deployed system. Both technical and operational issues should be covered when comments from users are elicited through interviews.

Apart from monitoring system performance and collecting user feedback, the project team should also keep track of the development of new technology and be sensitive to potential any problems revealed by the findings of the interviews.

4.7 Implementation Considerations

A systematic and holistic framework for the implementation of RFID systems has been proposed above. Specific issues that need to be considered before and during the implementation of RFID have also been discussed briefly and they are further elaborated upon below.

4.7.1 Scoping

Fontanella (2004) states that there are four types of RFID implementation, namely discrete processes, intra-company processes, inter-company processes and information synchronization. They represent different scales of implementation scenarios. Some might only

involve the entities of a company; others may need to create links across the whole supply chain. Before launching the implementation project, the organization should decide upon the boundaries of it so that appropriate objectives and performance targets can be established for the project. For any type of RFID project, consultation and assistance from internal or external RFID experts will be crucial.

4.7.2 Privacy and Security

One of the factors that needs to be considered is privacy, while the security issues associated with the deployment of RFID technology are another important factor to be considered (Stuart and Liu, 2006). Concern has been raised about access rights to information and the related privacy problems across the supply chain. Unauthorized users may intercept communications between the tags and RFID readers in order to capture private or sensitive information that is not supposed to be made available to a third party (Chowdhury, et al., 2008). For example, there is concern about tagging items or patients who do not wish to share their personal information without their prior consent. There are a number of ways to address these problems, including "kill tags", password locks, a cage approach and active-jamming (Boulard, 2005). This is a very important issue that organizations must address so as to ensure that the information written on the tags are securely protected.

4.7.3 Lack of Standards

Unlike barcodes, RFID technology is still evolving. Thus, the standards related to the technology are not yet well-developed, presenting a major obstacle to the implementation of the technology. According to Saygin et al. (2007), there is no standard related to RFID technology that meets the needs of all users. The development of standards has progressed through the formation of the Electronic Product Code (EPC) network, while EPC's operation itself must be backed up by the International Organization of Standards (ISO) to develop a widely accepted standard. Since common standards for the radio frequency and other technical aspects are yet to emerge, it is difficult to develop RFID solutions that will cover the whole supply chain. People tend to stick to the existing barcode system and refuse to get involved in deploying RFID systems. Therefore, the lack of clear standards and policies for RFID technology is an intangible barrier to the deployment of such systems (Floerkemeier and Lampe, 2004).

4.7.4 Interference Issues

RFID technology uses radio frequencies to transmit data. This creates interference problems in a number of environments. It is common to encounter objects and equipment that are covered with metal or have liquid

contents in a supply chain. These items will adversely affect the readability performance of the RFID tags; they will disrupt the RFID signals generated, making it challenging to track the tagged objects. Electronic devices will also affect the read rate of RFID signals (Greengard, 2006). Therefore, RFID readers are not always 100% successful in reading all the tagged items (Lee, 2005). Objects with metal components, glass fibres or nylon may also create noise in the RFID signal, creating an environment that is unfriendly to RF. It is challenging to implement RFID systems in an RF-unfriendly environment, even with precise prototype testing, because the interference problem cannot be completely eliminated in such an environment.

4.7.5 Cost Control

Deploying an RFID system to enhance the performance of a process involves significant investment. This constitutes the common roadblock to the implementation of the technology (Paul, 2007). Investment includes the costs of tagging objects, acquiring and installing hardware devices and application software, system integration, staff training and other expenses, all of which must be taken into consideration before making the decision to implement the technology across the system. During the initial stage of deployment, the cost of infrastructure is high because, given the current state of technology, RFID tags are much more expensive than barcodes and the testing of the new system requires a considerable amount of time. Thus, before the adoption of any new technology, the organization should determine the ROI. The ROI of deploying RFID technology is often slow - being aware of the slow return rate will help organizations to be realistic in estimating the benefits of deploying such systems. For example, a book store that has implemented RFID system will result in savings from faster and more accurate stock receiving operations and better inventory management (Bansode and Desale, 2009). The system also reduced the out-of-stock rate and improved re-ordering effectiveness, producing the potential for increasing sales by five percent.

4.7.6 Motivation of Adoption

The organization should have the appropriate motivation and expectations of RFID systems. As RFID technology is still evolving, it is not as powerful as commonly perceived; decision-makers should gain more knowledge about RFID technology so that they will not have excessive expectations about it. It is advisable to consult the experts to acquire knowledge about the technical issues. If the organization wishes to apply the technology to streamline an inter-company process or to achieve data synchronization, it should note that many supply chain players may be reluctant to invest in RFID (Chowdhury et al., 2008). Moreover, front-line users of the system usually tend to resist changing their practices when necessitated by

the deployment of new technology. This is a critical issue because the success of the implementation will depend upon acceptance of users. The organization should make efforts to eliminate users' concerns and earn their support. It is important not to have unrealistic expectations, because in the end it will lead to disappointment.

5. Critical Success Factors for the Implementation of RFID Systems

The critical success factors for a system's implementation as gleaned from the literature are discussed in this section. These factors are classified according to technological, managerial and social dimensions (Table 2). In addition, each of these factors is associated with a specific step in the implementation framework (Table 3).

Classification	Critical success factors	Reference(s)
Technological Dimension	● Selection of appropriate hardware and software	Angeles (2005); Soylemezoglu et al. (2006); Huang and Tang (2008); Yue et al. (2008); Kwok et al. (2010)
	● Effective testing	Spekman and Sweeney II (2006); Soylemezoglu (2006); Reyes and Jaska (2007); Ngai et al. (2010)
	● Sufficient technical support	Attaran (2007)
	● Clear process, data routing	Yue et al. (2008)
	● Clear performance measures	Kwok et al. (2010)
Managerial Dimension	● Clear vision	Zailani et al. (2010)
	● Good project management skills	Wang et al. (2006); Ngai et al. (2010)
	● Good risk management skills	Luo et al. (2007); Lim and Koh (2009)
Social Dimension	● Teamwork	Ngai et al. (2010)
	● Effective communication	Wang et al. (2006); Ngai et al. (2007); Wang et al. (2010)

Table 2. Classification of Critical Success Factors

5.1 Technological Dimension

Since RFID technology is still evolving, technical knowledge is vital for successful system implementation.

5.1.1 Selection of appropriate hardware and software

To succeed in deploying RFID systems, the organization needs to select the appropriate hardware and software that it purchases or develops. Selecting suitable hardware devices for the system will reduce the chance of system collision and interference (Ngai et al., 2010). Various types of RFID hardware and software are available for

selection, but each type may only be suitable for specific applications. Therefore, the careful evaluation of these items must be made. In many circumstances, price does not reflect suitability (Ting et al., 2011). In selecting the hardware and software to acquire, and apart from the product itself, the vendor should also be evaluated, taking into consideration its attitude towards partnering with customers. Sometimes, it may be more appropriate for the organization to develop its own application software that will be most suitable and fit for use.

Steps	Critical success factors
Project scoping	Clear vision Good project management skills
Analysis of the existing system	Teamwork Support across the organization
System design	Selection of appropriate hardware and software Clear process, data routing
Prototype testing	Effective testing Sufficient technical support
Implementation	Good risk management skills Suitable training
Continuous improvement	Clear performance measures Effective communication

Table 3. Corresponding Critical Success Factors in Each Step

5.1.2 Effective Testing

Since prototype testing is used to assess the availability performance of the system, it is important that effective and reliable testing be conducted so as to expose potential problems in the new process (Saygin et al., 2007). The project team should review and modify, if necessary, the system design in light of the exposed problems.

5.1.3 Sufficient technical support

Since RFID is an evolving technology, it would be very helpful if an expert or technician in that field could support the deployment of the system (Ngai et al., 2010). Organizations typically encounter many technical problems at the early stage of implementation and misunderstand the technology (Smart, 2004). Adequate support from technical staff will effectively assist the whole implementation process, especially during the step of prototype testing. Technical support staff can give objective opinions and comments about the testing results. They can also give constructive advice on the adjustments that need to be made. Inadequate technical support will lead to faults in system design and unrealistic expectations as to performance results. This could also drive up implementation costs and times, as debugging and mistake detection are performed by inexperienced staff.

5.1.4 Clear Process, Data Routing

A clear process of the RFID system and the data routes should be mapped, as such a system is often deployed to

deal with complex tasks and complicated data transfer routes. Well-defined process and data routes will help technical staff to understand and build the system. Furthermore, such information will also facilitate users and operators in appreciating the design of the system. The process and information data routes can be represented by using graphical tools; visualizing the data routes could make profound impressions upon users, thereby enhancing the effectiveness of the process (Fuhrer, et al., 2006). Clear process and data routing is of critical importance during the system design stage because this could enhance the development of the new system so that it will be both efficient and effective. During the system design stage, when processes are developed and designed, a well-defined process flow could also facilitate the subsequent implementation process, as it will make it unnecessary to give a lot of explanations during prototype-testing and the actual implementation of the system.

5.1.5 Clear Performance Measures

During the continuous improvement stage, the organization should measure the achieved performance and compare it with the target to evaluate the effectiveness of the new solution. In order to track performance of the RFID system, it is critical to develop well-defined performance indicators for the system so that users and the project team can closely monitor the progress made and work hard to meet the target. Performance targets must be concrete and specific. For example, the performance target for the read rate of the RFID tags should be an exact percentage - such as 95% - rather than "most of the tags should be read".

5.2 Managerial Dimension

Apart from technical contents, good management will also contribute to success of RFID system implementation. Management plays an important role in coordinating the whole implementation process. The critical success factors in the managerial dimension are discussed in the following section.

5.2.1 Clear vision

As an RFID system could be implemented in a variety of areas in an organization, complex objectives and visions may give rise to confusion. A clear vision can keep a project in focus in order to align with the organization's business goals. This ensures that proper priority will be set while the RFID system is being developed. Resources will be allocated according to the importance of the area, and only those areas that have a leverage effect on the implementation results will be given the required resources (Rao, 2004). A clear vision will also help to set the appropriate project scope. With a clear focus on the aim of a deployment, the pre-set goals can be achieved

more easily. This will make the whole development process more focused. Since money, labour and time are limited in a new technology development project, a clear vision will provide managers with guidelines for making informed decisions on the utilization of limited resources that will produce optimal benefits for the project.

5.2.2 Good Project Management Skills

RFID implementation typically constitutes a huge project, involving a lot of stakeholders. Introducing it into a business also involves huge amounts of money. Good project management skills will streamline integration across the stakeholders and achieve better project cost control. This ensures that the deployment project will be completed within budget and on schedule. The project team should concentrate on results, keep track of the progress made, and review the schedules and budget periodically. To manage a large project, the schedule and milestones of the deployment should be set clearly before implementation so as to provide users, as well as members of the operation and project teams, with a comprehensive roadmap to the project (Saygin, 2007). As such, these stakeholders will have realistic expectations about the timing when the benefits will be realized. A clear schedule will also ensure that adequate levels of appropriate resources are available before the required action takes place.

5.2.3 Good Risk Management Skills

As the standards of RFID technology are not yet established, a certain degree of risk exists when the technology is deployed in an organization. The project team should have good risk management skills to deal with various types of problems and issues that may arise during the implementation process. Contingency plans should be developed and tested in advance so that unforeseen incidents that may emerge can be addressed promptly and efficiently (Bhattacharya et al., 2008).

5.3 Social Dimension

Apart from technological and managerial issues, the organization should also be sensitive to the social issues of a change initiative, such as the introduction of RFID technology. The deployment of RFID systems involves a lot of individuals and the behaviour of these individuals will have various degrees of impact upon the performance of an RFID deployment project.

5.3.1 Teamwork

During the process of developing the RFID system, the success of the project is determined to a significant extent by the level of teamwork within the whole organization. During the analysis stage, data on the current system needs to be collected; members of frontline staff should be interviewed or onsite observations be conducted.

These activities will require the support of the whole organization in order to collect appropriate and accurate information. Moreover, as the implementation of RFID systems involves many individuals, they must share the vision and objectives of the project so that the whole process will be finished effectively. "Islands of RFID applications" developed within departments, and a lack of integration and cooperation inside the company will lead to the waste of resources (Saygin, 2007).

5.3.2 Effective Communication

As a lot of people are involved in the development process, communication is very important for information transfers within an organization. During the stage of continuous improvement, feedback and comments are given by the frontline users, and their opinions should be effectively communicated to the management level so that proper adjustments are made in a responsive manner (Ngai et al., 2010). This could improve the performance of the RFID system and might increase the effectiveness of it. To deal with the fears of staff towards the implementation, it requires the coordination of both stakeholders and users. To resolve fears within the operation team, communication with all the people concerned is substantial and at the same time supporting evidence should be provided to prove its truthfulness.

5.3.3 Suitable Training

As a new technology, implementing adequate and suitable training could provide front-line staff with precise knowledge about the system and break the myths discussed among them. Appropriate training can not only provide theoretical knowledge, but so too should practical things be taught - this could reduce the opposition towards the transition time of the early deployment stage. The newly implemented technology could be rather daunting and difficult; training should be provided to explain the benefits of the system and the changes involved. To gain the buy-in of the users and the operation team, a demonstration of the system and an explanation of its benefits and the changes it would bring about should be done during the training (Ngai et al., 2010).

5.3.4 Support Across the Organization

Gaining support across the organization could ensure that the system is operating in the desired way - if there are staff who do not support the development of the system, they may refuse to use it and stick to the original one. By launching a reward scheme for improvements in process or productivity due to the implementation of the system, the upper management can show their support and confidence towards the implementation. Management support could also convince any lower level

staff or users that the RFID technology could help the organization. Without that buy-in from the management team, it will be difficult to carry out the project within the organization (Ngai et al., 2010). An appropriate culture within an organization could hasten the implementation process, since a good organizational culture will increase staff loyalty and they will be more willing to share their opinions towards the newly developed system. Good staff morale will also increase the level of acceptance from the staff during the implementation process because they will unintentionally believe that the organization only aims at release their burdens from work and doing this kind of automation will not affect their employment.

6. Validation of the Proposed Framework

6.1 Evaluation Methods

In order to validate the usefulness of the proposed implementation methodology, a questionnaire was developed in the spring of 2011. It consisted of the significant procedures and critical elements of success (identified by the authors and RFID experts) and was administered to a number of RFID practitioners, including representatives from manufacturing, garments, food, retailing, logistics, library services and healthcare, in order to gather a number of different perspectives. The responses to each of the steps and the criteria are provided on a 5-point Likert scale, ranging from highly insignificant (1) to highly significant (5) (i.e., 1 = highly insignificant, 2 = insignificant, 3 = no strong view, 4 = significant, 5 = highly significant). The questionnaires were distributed to selected respondents by standard mail in mid-June. A pre-paid, pre-addressed envelope was included to facilitate the return of the completed questionnaires. The anonymity of the respondents was assured by using a unique control number to which only the author had access. The recipients of the questionnaires who did not respond after two weeks were contacted by a follow-up letter. The data collected from the returned questionnaires was analysed using SPSS software.

6.2 Participants

The evaluation included 300 participants, ranging from system specialists to presidents of organizations. All of the participants were at the management level or above (in which they were the target group significantly influencing and participating in the RFID implementation). In order to ascertain the validation results, responses from those who had had 1-3 experiences of the implementation RFID systems were considered in the survey. Of 300 questionnaires distributed in the first instance, 201 valid responses (16% were presidents, 17% were vice-presidents, 20% were directors, 21% were managers, 16% were senior architects and 10% were senior systems specialists) were returned. This represented a response rate of 67%.

Regarding the variety of industries involving in the evaluation, the majority of these responses were from logistics (30%), followed by retailing (20%), manufacturing (19%), healthcare (15%), garments (10%), food (3%) and libraries (2%). This was to be expected, given that most of the applications of RFID are in the logistics/supply chains and manufacturing industries.

6.3 Results

The outcome of the evaluation indicated a medium to high level of user satisfaction with the proposed RFID implementation framework. In particular, 70% of the respondents gave a mean score of at least 3.5 on the five-point scale of all the major steps. This indicates that the steps of the proposed framework identified from the literature match with the prevailing reality. Such a satisfactory result validates the view that the steps in the proposed framework are applicable to most industrial settings (when applying RFID in business). Furthermore, the respondents gave high ratings on both the project scoping step and the implementation step, with a mean score of at least 4.1 on the five-point scale. These results highlight that it is important to identify and inform users' of the limitations of the project during the preparation stage. In addition, training is also an important factor in driving successful implementation. With regard to the critical success factors, most of them have mean scores ranging from 3.8 to 3.9; a few of the respondents suggested that a more in-depth discussion on technical issues would help them to understand the implementation better. To confirm that the mean scores of the system evaluation are significantly different from the neutral values of the scale (i.e., 3 = no strong view), a sample t-test using 3 as the test value was conducted. The results showed that the mean values of all the questionnaire items were significantly larger than the neutral values of the scale at a 5% significance level. This suggests that the proposed RFID implementation framework is able to support a system implementation that starts from the preparation stage and ends at the delivery stage (See Tables 4 and 5 for details).

6.4 Limitations of the Study

The methodology employed in this study has a number of limitations. First, this literature review is based on the results of a keyword search of selected international, refereed academic journals. Thus, only publications registered in the selected databases are considered. Second, non-academic publications, such as news and practical reports, are not included in this study. Third, non-English publications are also not taken into account in this study. As a result, the effects of different cultures on the implementation of RFID and sensor integration systems are not studied. Notwithstanding these limitations, the journals

covered in this review are highly regarded internationally. The fourth possible limitation is the time period, whereby a 10-year time frame was taken to develop the implementation framework in the study. It is assumed to be representative of the RFID research over the past few years because it is believed that a more recent coverage of the major journals would be more appropriate for this analysis. As such, we believe that the results of this review adequately reflect the recent trend of RFID development and implementation.

Steps	Description	Mean Rating	Standard Deviation
Project Scoping	● Understand the potential and limitations of RFID technology	4.5	0.5
	● Define the project objectives	4.1	0.2
Analysis of the Existing System	● Collect information	3.6	0.4
	● Information analysis	3.9	0.7
System Design	● Requirements analysis	3.9	0.3
	● Hardware/software selection	4.5	0.2
	● Develop the new process	3.8	0.3
Prototype Testing	● Debug	4.0	0.5
	● System adaptation	3.7	0.2
Implementation	● System deployment	4.5	0.3
	● Training	4.8	0.4
Continuous Improvement	● Monitoring	3.8	0.5
	● Collect feedback from users	4.0	0.2

Table 4. Mean Values to the Significant RFID Implementation Steps by the Respondents (n = 201)

Classification	Critical success factors	Mean Rating	Standard Deviation
Technological Dimension	● Selection of appropriate hardware and software	3.9	0.3
	● Effective testing	4.1	0.4
	● Sufficient technical support	3.7	0.3
	● Clear process, data routing	3.9	0.2
	● Clear performance measures	3.8	0.4
Managerial Dimension	● Clear vision	3.9	0.5
	● Good project management skills	3.9	0.3
	● Good risk management skills	4.1	0.2
Social Dimension	● Teamwork	3.9	0.5
	● Effective communication	4.1	0.2

Table 5. Mean Values to the Critical Success Factors by the Respondents (n = 201)

7. Conclusions

A comprehensive implementation framework for the management level is presented in this paper. It provides decision-makers with a clear roadmap for the deployment of RFID technology in an organization. This simple, step-by-step approach to system implementation is generally applicable to all industries. It has been noted that many organizations have not considered implementing RFID technology yet. The authors hope that the findings of the study reported in this paper will arouse organizations' interest in considering the introduction of RFID technology. By synthesizing the implementation issues across various industries, the proposed framework gives managers a holistic perspective of the implementation RFID solutions in an organization. This can allow organizations to develop better implementation strategies by considering different methods of deployment. With the proper adaptations to different types of industry, the framework can achieve a better appreciation and execution of any project activities. Apart from presenting the general implementation framework, the discussion on the considerations of implementation also identified potential pitfalls that the project team should be aware of before the implementation of the system. It is important for the organization to consider both the pros and cons of implementation; most implementation approaches only focus on the benefits of deploying the technology while the potential problems are seldom highlighted. The part of this study that discusses project considerations provides decision-makers with a balanced view of the change initiative.

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