The RFID e-Valuation Framework
Determining the Business Value from Radio Frequency Identification

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Abstract

In this paper, we develop the RFID e-Valuation Framework to help managers identify the value proposition from using RFID. The framework is based on three concepts. First, firms can apply RFID along five dimension of commerce. Specifically, by using various modes of interaction, firms compete over both time and distance in order to provide some product or service through a chain of relationships eventually ending with the end customer. Second, new investments in RFID are typically justified by generating efficiency, effectiveness, and/or strategic benefits. Third, RFID can be applied to four different structural settings across the value chain including inbound logistics, internal operations, outbound logistics, and marketing and sales. By mapping the five dimensions of commerce and the three types of justification, we have developed the RFID e-Valuation Grid which can then be applied to the four structural settings to see where RFID can generate business value.

1. Introduction

Many types of organizations are asking whether Radio Frequency Identification (RFID) technology can add value to their operations. This list of organizations includes manufacturers, retailers, third party logistics providers, and various service providers to other companies and end customers. Some organizations are interested in learning more about the technology and how it might benefit them because of mandates from external trading partners. Others have heard or read about the technology and wonder if the track and trace capabilities of RFID can make their operations more efficient. Others simply want to learn more since they don't want to be left behind in case this emerging technology becomes a staple of tomorrow's business operations. While many of these organizations recognize there could be many benefits from better real-time tracking of important mobile items, they also are cautious due to the potential costs of developing the infrastructure required to perform these tracking activities.

In most of today's organizations information technology (IT) is a necessity for carrying out normal operations since it provides the infrastructure on which information is circulated throughout and beyond the organization to inform employees, customers, trading partners, and other entities about the activities of the organization. Occasionally, a new technology emerges that is touted as promising major improvements in the cost-performance capabilities of the firm's systems. RFID is one such technology that has the potential to dramatically alter the ability of the organization to acquire data about the location and condition of any item that can be physically tagged and wirelessly scanned within certain technical limitations [2].

While RFID is considered to have many uses along the supply chain adoption has been relatively slow, despite that fact that some important buyers have mandated adoption of the technology. Riggins and Mukhopadhyay [8] point out that these types of interorganizational information systems typically carry more risk than internal information systems projects and therefore may lag behind in adoption. In particular, in this climate, it is important to have insightful frameworks that managers can use to judge the potential business value of such technologies and help them build the business case for related investments. Curtin, et al. [2] suggest that researches need to development frameworks and methodologies to estimate the business value from RFID and its impact on market structure in the supply chain. Some of the questions they recommend addressing include:

- How can the firm best measure the impacts when RFID is integrated with other applications?
- How will the business value of RFID technology implementations be mediated by other

978-0-7695-3450-3/09 $25.00 © 2009 IEEE

organizational capabilities that drive value conversion?

- How will the decision making capabilities of the firm actually be transformed? How can those be quantified?
- How will B2B logistics, internal operations, B2C marketing and B2C service be impacted?
- Will new information processing intermediaries alter the balance of power in the marketplace?
- Will the need for improved operational control lead to RFID-based risk management intermediaries?

In this paper, we draw upon prior work to develop a framework that can be used to address several of these questions to analyze the business case for adopting RFID. The framework is based on concepts that have provided value to managers of e-business enterprises for over a decade. We believe that by applying these concepts to RFID technology, managers will be in a better position to develop a comprehensive RFID strategy for their organization.

2. Background to the Technology

In 2005, MIT listed RFID as the tenth most innovative technology of the past 25 years ahead of ATM bank machines, automobile air bags, hybrid cars, HDTV, the space shuttle, voice mail and nanotechnology. Among other reasons, RFID is innovative because it can be used to track tagged items wirelessly, can quickly read and record data from multiple tags as items move through the read zone, and can be linked with sensor technology that collects data about environmental conditions such as temperature, shock, or light. RFID has the potential to bring computer-based intelligence to any mobile item that can be tagged. For example, by tagging individual items held in a retailer's stock room, the system can act as if there were a unique manager assigned to watch over each item in inventory. If the sales associate begins to take an item to the showroom, a tag can be used to notify the associate that a different item should be taken due to its soon-to-expire expiration date. For other types of perishable items, sensor-based tags can monitor the ambient temperature of the truck or warehouse and cause the environmental systems to automatically adjust the temperature settings if conditions dictate. Tags on checked baggage can communicate with the airport baggage handling system to notify airport employees of the location of each bag. This type of micro-management of individually tagged items can deliver efficiency benefits, make the organization more effective in its decision-making, and bring strategic benefits over rivals when integrated with other internal and external systems.

While RFID has been in existence for several decades, the technology has gained considerable attention recently as large retail buyers have promoted the technology as a way to track inventory through the supply chain from supplier through the warehouse and on to the store. Today, RFID technology is made up of three main components [5]. The RFID tag itself consists of two items: a tiny *silicon chip*, perhaps only a few millimeters in size or smaller, contains a limited amount of data and can receive and emit a radio signal through an attached *antenna*, which may be shaped in a maze-like pattern to increase the length of the antenna while keeping the size of the tag to one square inch in size or smaller. The emitted signal is read by a *reader* which can be placed in a variety of locations such as the warehouse receiving door or at the box crusher area. The reader is linked to other systems which process, store, or transfer the data to various applications.

RFID tags come in a variety of shapes and sizes which impact their cost, read-range distance, amount of data that can be stored, and their ability to monitor more than simply location [1] [3]. These all impact the usefulness of RFID for a given application. The cheapest tags are *passive tags*, which have no internal power source, but rather draw power from the signal sent by the reader. The reader scans the surrounding area by continuously sending out a signal within a certain frequency range. When a passive tag comes within the read range of the signal, the passive tag is "awakened" and responds to the reader by transmitting an identifier code. *Active tags* are larger, perhaps the size of a credit card or a cell phone, and include a battery source to power the tag, which can increase the read distance or power additional features of the tag such as an internal temperature or vibration monitor. The larger tag size also allows for more data storage capacity. While more expensive and bulkier, active tags have more potential uses than passive tags. The type of tag that is right for a specific application depends on the functionality needs of the problem, size limitations, read distance requirements, and financial constraints.

In addition to the size and battery source, another important characteristic of RFID tags is the frequency at which they transmit their signal. Standards play an important role as tags and readers must be tuned to transmit and receive at the same signal frequencies. The frequency used not only determines the feasible distance of reading the signal, it is also a fact of physics that certain frequencies are better at penetrating certain items such as metal, water, or skin. Low frequency (LF) (125 – 134 kHz) is used for

tagging pets because it is good at passing through water and skin, but requires a very close read range such as passing a handheld device over the pet. High frequency (HF) (internationally accepted 13.56 MHz) ranges have a higher read distance and have a faster data transfer. They are commonly used in retail theft prevention applications for high value goods, smart cards, and for tagging books in libraries. The tags used in supply chain applications are typically in the ultra high frequency (UHF) range (860 – 930 MHz) and are useful because of a longer read distance and the low cost of producing many tags. Finally, some applications that require longer read distances and large data files may use microwave frequencies (2.45 GHz).

3. The RFID e-Valuation Grid

Riggins [6] introduced the Electronic Commerce Value Grid as a way of identifying opportunities to add value to online users of an organization's web presence. The grid concept was further developed into the "e-Valuation Framework" that can be applied to broader e-business applications in Riggins and Mitra [7]. The original framework combines five dimensions of commerce with three methods of justifying IT investments to map a 5 x 3 grid space that shows where value can be derived from a portfolio of IT investments. In this paper, we adapt these concepts to the RFID context to develop a framework for evaluating the value of RFID applications along various places within the value chain. Specifically, our framework is based on three components:

- **Five Dimensions of Commerce**. Firms compete along five dimensions of commerce. Specifically, by using various modes of *interaction*, firms compete over *time* and *distance* to provide some *product* or service through a chain of *relationships*;

- **Three Ways to Justify IT Investments**. New investments in information technology are typically justified using three criteria: generating *efficiency*, *effectiveness*, and/or *strategic* benefits; and

- **Four Structural Settings along the Value Chain**. RFID can be applied to four different structural settings across the value chain: *inbound logistics*, *internal operations*, *outbound logistics*, and *marketing and sales*.

3.1. Five Dimensions of Commerce

3.1.1. Time. In today's competitive business climate companies now compete within an accelerated time frame. The time it takes to develop and deliver products is now being measured in days or weeks, rather than months or years. Because of this, companies are seeking ways to use information technology to dramatically reduce or even eliminate the time it takes to deliver information, products, and services on demand. By attaching RFID tags to various items, RFID automates many of the processes that formerly required time consuming human intervention, scanning, and inspection. By automatically identifying the location and condition of items, RFID systems allow many processes to be accelerated, allows the system to be constantly updated in real-time as conditions change, and allows users and other systems to know the precise location and condition of the item on demand.

3.1.2. Distance. By placing RFID tags on moveable items, the RFID system can monitor and control items and processes from remote locations and thereby overcome barriers created by geographical distance. While RFID tags may be read from relatively short distances, users and other systems can monitor and control the location and condition of items remotely by linking the readers to global networks. This essentially allows each tagged item to function as if it had a unique personal manager attached to it at all times. Imagine the possibilities for a retailer if each individual item were assigned a manager to be present with it at all times whether during delivery, in the stock room, or on the sales floor. Or consider the implications of having a unique manager be assigned to accompany any expensive piece of equipment in a hospital as it moves from one procedure to another. This ability to monitor and control items from a distance allows the organization to extend its reach to more distant locations than was previously feasible.

3.1.3. Relationships. RFID systems present opportunities to alter the structure of relationships in internal, business-to-consumer (B2C), and business-to-business (B2B) relationships. By using this technology, organizations that are able to capture RFID generated data, analyze the data using sophisticated data analytic tools, and thereby better understand processes and conditions across the value chain can find their position within the chain enhanced. Combining this technology with personalization technology and customer relationship management (CRM) tools can allow for more personalized and closer relationships with internal and external users.

Finally, to the extent that users alter their behavior due to the availability of RFID-generated data and the resulting information, users will become dependent upon the system and thus more tightly bound to the owner of the RFID system and resulting data.

3.1.4. Interaction. RFID is a sensing technology that essentially adds eyes and ears to the intelligence of an existing system. As such, RFID allows the system to employ much more powerful interaction capabilities with other entities with which it interacts. These entities could include users of the system, as well as other interfaced systems, both within and outside the organization. By using these interacting capabilities, RFID allows more accurate and timely feedback into the system about the location and condition of tagged items. In addition, these eyes and ears allow the system to automatically respond more intelligently to its surroundings to control processes, alter environmental conditions, move items, or respond to system users. Further, when RFID is integrated across the value chain it helps create an intelligent network which allows the organizations within that network to integrate their activities more closely.

3.1.5. Product. By being able to monitor and control the location and condition of tagged items from a distance, RFID systems allow for the creation of entirely new products and services. When intelligent systems have RFID-enabled sensing capabilities, as well as the authority to act on its own based on predefined logic and parameters, new automated services can be offered to internal and external users of the system. In addition, new information-based products can be offered to help decision-makers understand and respond to changes in conditions. When used creatively, these proprietary products and services can be leveraged in the marketplace for competitive advantage.

3.2. Three Ways to Justify IT Investments

3.2.1. Efficiency Benefits. There are many processes that can be done more quickly using RFID, thereby creating efficiency benefits. When various items, such as equipment, people, or materials are being routed through a process their presence and/or condition can be automatically detected and logged into the system. Otherwise, they would need to be manually scanned, inspected, and logged one-by-one. This is a considerable labor and time savings.

Further, by knowing the location and/or condition of these items, the system can pre-determine optimal routing such that they can be directed to the appropriate place. Also, by using RFID systems to monitor the location and conditions of these items, the system or authorized personnel can reroute them to adjust to changing needs at various locations.

Further, by monitoring the condition and environmental status of items, the system can remotely request changes in the environmental conditions around them. This type of location and condition monitoring allows the organization to bypass employees and other intermediaries by automating the process. On the other hand, by owning the data associated with the location and/or condition of various items within the supply chain, the organization may emerge as a new intermediary that is able to collect RFID-generated data, analyze it, and offer it to interested parties. In some cases, owners of RFID-generated data may be able to understand a multi-party value chain process better than any one member of the value chain.

The real-time data gathering capabilities of RFID generates efficiency benefits by creating new forms of interaction that were previously not possible. When integrated into existing systems, a new form of automated two-way dialog can be created that can result in considerable efficiency benefits as interacting systems trigger process actions, generate real-time data updates, and monitor potential problem scenarios more efficiently than humans. In addition, this real-time data can be used to update marketing campaigns on the fly or change inventory plans on a moment's notice.

One of the most powerful ways to use IT is to use software agents to automate a series of time consuming or otherwise infeasible tasks. Software agents are intelligent applications that are able to learn from their environment and improve their performance based on data collected over time. RFID-enhanced agents that are able to remotely monitor the location and condition of mobile items, have unique eyes and ears into the tagged item's surroundings that improve their ability to learn and adjust. In this way, RFID can provide considerable efficiency benefits when integrated into intelligent agents.

3.2.2. Effectiveness Benefits. RFID can generate effectiveness benefits by making data and information available to decision makers in a more timely fashion. With RFID, the system is able to reflect exact current inventory levels and status conditions since systems are constantly updated to reflect the movement of items into, within, and out of the facility.

By knowing the exact location and condition of items, the system can better forecast future inventory levels and conditions. By receiving real-time remote telemetry about the location and condition of various items, RFID systems can aid the effectiveness of decision makers over long distances. These systems

allow managers to essentially be in multiple places at a given time by giving them eyes and ears into distant processes and locations. Further, by monitoring the location and condition of items, the system can automatically forecast future problem scenarios and be authorized to make decisions to take into account the anticipated future location and condition of items.

RFID allows organizations to be more effective at creating a personalized service to users of the system, other internal employees, or external constituents. When the system knows the exact location and condition of various items being tracked and monitored, it is possible to provide a more personalized interface to users, present current information to decision makers, alter the work environment of employees based on who is present at the time, and provide a unique experience to external entities.

In addition to personalizing to users, RFID systems that can monitor the location and condition of mobile items, as well as the conditions of the environment surrounding them, are able to respond with intelligence to the environment itself to alter it, respond to queries, notify managers of problem areas, or make routine decisions automatically. This capability is based on pre-defined decision criteria as specified by management.

Finally, another form of personalization occurs when decision makers use decision support systems that respond to inputs to create a unique decision output based on the decision maker's current situation. RFID can be used to make decision support tools reflect the current location and condition of any mobile tagged entity. These RFID-enhanced decision support tools can help users be more effective in decision making. In addition, RFID data can enable the creation of new decision support tools that were not feasible prior to RFID. In some cases, these new decision support tools can be made available to outside users, perhaps as a revenue-generating business opportunity.

3.2.3. Strategic Benefits. Firms often use information technology to integrate their systems across their value chain making their business ecosystem more competitive vis-à-vis other competing ecosystems. When RFID data is integrated into other systems within and outside the organization, the system can provide strategic benefits by creating a seamless flow and thus real-time availability of items across a virtual enterprise. This allows authorized users to know the location and condition of items at all times and to ensure their availability 24/7. When this capability is integrated across the enterprise and outside the enterprise to include other consortium partners, competitive advantage can be achieved relative to other organizations or consortia that don't have such seamless integration.

One way this is done is to use RFID to know the current exact location and conditions of equipment, people, and other items, which allows the system to reroute these items to balance the availability of the right number of items within a globally distributed value chain. By doing so, an organization can achieve strategic benefits by extending its physical reach and locate new facilities to further locations that otherwise may not have been feasible.

When RFID-generated information is valuable to users of the system, other employees, or external parties, these people typically will alter their patterns of behavior to make use of that information. When this happens, the system becomes indispensable in their job and they become locked-in to using the system. This may be a significant source of competitive advantage, particularly when the entity being locked-in is an external customer. The potential to generate benefits from RFID are enhanced when coupled with process redesign by both providers and users of the system. When this type of technology is coupled with process redesign, both parties are able to gain advantage and the implementer of RFID can achieve advantage over rivals who don't engage in such redesign.

Virtual integration occurs when multiple parties along the value chain integrate their systems to the extent that they are able to act as if they are one entity. This type of consortium is able to achieve many of the benefits of physical integration without the difficulties of getting too large or engaging in an actual merger. RFID monitoring capabilities enhance the ability of organizations to integrate virtually by providing real-time data transfer across organizational boundaries of information associated with mobile items at any facility. By increasing the monitoring capabilities across organizational boundaries considerable process benefits can be achieved by the consortium resulting in strategic advantage relative to competing consortia.

RFID systems allow organizations to gather large volumes of data that may be unique to the value chain or marketplace. When combined with sophisticated data analytic capabilities, these systems can generate unique information that may be used to create new products or services that were not previously possible. By offering this proprietary systemic competency into the marketplace, an organization may generate new revenues or enhance their competitive position within the industry.

By mapping the five dimensions of commerce with the three ways to justify RFID investments we can create the 5 x 3 RFID e-Valuation Grid as shown in Figure 1. This represents fifteen ways that RFID

can add value within a given context. We now turn to the different structural settings along the value chain.

	Efficiency	Effectiveness	Strategic
Time	Accelerate Process Tasks	Eliminate Information Float	Establish 24/7 Integrated Service
Distance	Control Processes Remotely	Receive Real-time Remote Telemetry	Achieve Global Presence
Relationships	Alter Role of Intermediaries	Enable Personalized Service	Create Dependency to Lock-in User
Interaction	Make Use of Extensive System Feedback	Respond Intelligently to Environment	Promote Virtual Integration
Product	Automate Tasks Using Software Agents	Provide Decision Support Tools	Offer Proprietary Systemic Competency

Figure 1. The RFID e-Valuation Grid

3.3. Four Structural Settings in the Value Chain

3.3.1. Inbound Logistics. RFID can monitor the location and condition of items that are being shipped to the organization's facilities. Having visibility into the current location and status of the shipment allows for accurate inventory management through inventory anticipation. In addition, using monitoring technology along with basic RFID technology allows the recipient to monitor the condition of items while in transit. Monitoring vibration can help predict breakage and other quality control problems. Tracking temperature, humidity, light, or air pressure during shipment can be important for certain perishable items such as food or pharmaceuticals. Just as delivery time status can impact the organization's inventory control systems, being able to predict the condition of items when they arrive can be useful for determining appropriate routing and re-order decisions. Finally, RFID coupled with sophisticated monitoring technologies can allow the recipient of the shipment to remotely control processes during shipment. For, example, when monitoring temperature in the truck, the recipient can request changes in the truck temperature or request the shipment be diverted to a closer facility rather than risk spoilage over a long truck haul over the desert.

3.3.2. Internal Operations. Just as monitoring the location and condition of items during inbound transit directly impacts the organization's inventory management system, monitoring the location and condition of items within the firm's internal operations facilities impact these systems. Another area of impact is through asset management of expensive pieces of equipment which may easily be misplaced, lost, or hoarded by employees. Hospitals, manufacturing facilities, and computer support teams can all benefit by knowing the exact location of expensive mobile equipment that needs to be at a specific location at a specific time for a specific task. This is particularly beneficial when the equipment is used by high-paid employees who otherwise may need to wait or search for the item. Finally, tracking the location of employees themselves may be beneficial to the organization for planning workflow, work assignments, and other types of employee monitoring needs. This type of monitoring must be balanced with a respect for personal privacy. RFID is just one type of monitoring technology that will make this a more delicate issue in human resource management in the coming decade.

3.3.3. Outbound Logistics. Just as monitoring the location and condition of items during inbound transit adds value to the firm, monitoring finished goods during outbound logistics provides an important service to customers. Being able to reroute outbound shipments as conditions change or respond to customer queries about the location and condition of items may allow the firm to gain a competitive advantage over rivals. Also, linking this tracking system with internal systems may allow the firm to carry less inventory and still be able to support a customer's just-in-time manufacturing environment.

3.3.4. Marketing and Sales. In a sales floor environment, RFID systems integrated with internal operational systems can be used to reduce out-of-stock situations thereby providing the customer a better shopping experience. Similarly, there are many situations where a customer service associate needs to locate a specific item related to the customer's visit such as a physical medical record, a book in the library, or an item stored in the backroom. By equipping the associate with handheld RFID scanners they can quickly locate the item leading to better customer service. Smart shelves can detect when an item is not on display or has been inadvertently moved to a different location by a customer. Smart shelves can also detect when a prospective customer browses through a brochure or some other physical promotional item which could cause a customized promotional video to be displayed. Finally, just as tagging employees can add benefits, encouraging customers to carry RFID-enabled promotion cards can make for a highly personalized store visit. Again, personal privacy must be ensured in such situations.

3.4. The RFID e-Valuation Framework

By mapping this 4 x 5 x 3 value space, we can construct the RFID e-Valuation Framework as shown in Figure 2. By thinking about the value proposition at this level of detail, a manager can ask the following questions when developing the business case for RFID:

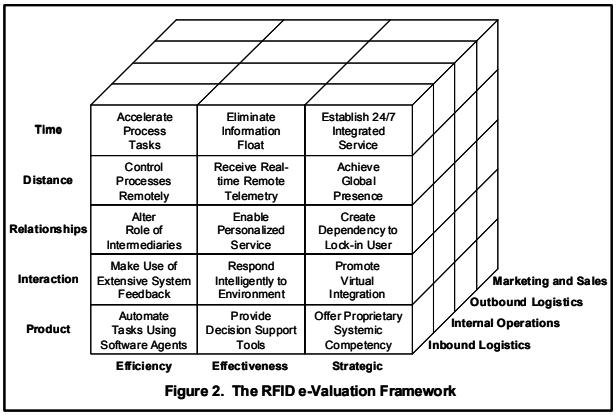

Figure 2. The RFID e-Valuation Framework

- How can RFID be used to track the location and monitor the condition of items during inbound logistics to achieve efficiency benefits within each dimension of commerce? To achieve effectiveness benefits? Strategic benefits?

- How can RFID be used to track the location and monitor the condition of items within internal operations to achieve efficiency benefits within each dimension of commerce? To achieve effectiveness benefits? Strategic benefits?

- How can RFID be used to track the location and monitor the condition of items during outbound logistics to achieve efficiency benefits within each dimension of commerce? To achieve effectiveness benefits? Strategic benefits?

- How can RFID be used to track the location and monitor the condition of items for marketing and sales to achieve efficiency benefits within each dimension of commerce? To achieve effectiveness benefits? Strategic benefits?

3.5. Mapping Functionality Interactions

Once opportunities have been identified within this 4 x 5 x 3 value space, the framework can be used to map out how certain functionalities enable or enhance other functionalities (see [7] for more specifics on applying this methodology). If functionality A is necessary for functionality B to exist, then we say that *A enables B*. If functionality A helps improve the benefits from functionality B, then we say that *A enhances B*.

For example, suppose the firm's contracted trucking company allows the firm to monitor and receive updates of the environmental conditions in the truck while in transit to the firm's facility. In this case, by receiving *real-time remote telemetry*, the firm could use this information to

- *provide decision support tools* with updated status of the shipment (enhancing functionality),

- *accelerate process tasks* as the inbound facility by taking needed advanced action before the shipment arrives, rather than simply responding to the shipment when it docks (enabling functionality),

- *control processes remotely* by signaling instructions to the driver to alter the environmental conditions in the truck if needed (enabling functionality), and

- *alter the role of the intermediary* (the trucker) by using this detailed information to increase operational and strategic leverage over the contracted trucking firm by exerting additional control or penalties based on the information (enhancing functionality).

These four benefits are mapped into the RFID e-Valuation Grid in Figure 3. In a similar way, other functionality interactions can be mapped within and across the four structural settings along the value chain.

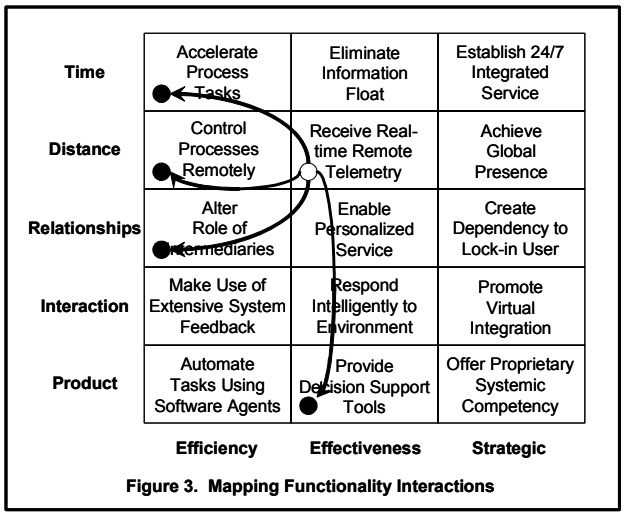

Figure 3. Mapping Functionality Interactions

By indicating which functionalities enhance or enable others, this methodology helps the organization plan and organize a portfolio of functionalities that may be developed over time.

4. Two Case Examples from the Food Industry

To illustrate the application of the RFID e-Valuation Framework we will discuss two examples from the food industry.

4.1. Case Example 1: RFID at Wells Dairy

Iowa-based Wells' Dairy produces various dairy products including Blue Bunny ice cream. In order to meet Wal-Mart's RFID mandate, Wells' Dairy began looking into how they could use RFID in their production line [4]. They instituted a new RFID labeling system on their one-gallon bucket Blue Bunny ice cream production line by automatically adhering RFID tags to cases which are defined as two one-gallon containers packaged together. The tag is attached to the case prior to having the case sent to the freezer for the freezing process. After freezing, cases are then wrapped into 75-case pallets which are also automatically labeled with an RFID tag. Pallets are then loaded onto trucks and then sent to Wal-Mart distribution centers.

There are numerous ways RFID adds value to the internal operation and outbound logistics according to the RFID e-Valuation Framework.

1. Wells' Dairy *promotes virtual integration* across the supply chain when it responds to the Wal-Mart mandate to its top 100 suppliers.

2. By using RFID tags on cases and pallets which can then be automatically read without line of site bar code readers, RFID *accelerates process tasks* since the tags are adhered automatically, tags are read automatically without human intervention to ensure line-of-site, and there is no rekeying of bar-code information. Further, by accelerating process tasks using this automation, RFID *alters the role of intermediaries* by taking the need for human intervention out of the process equation. In that sense, accelerating user tasks *enables* the altering of the role of intermediaries.

3. Another benefit in internal operations is that the RFID-populated database tracks inventory in real-time allowing Wells' Dairy to quickly find a product within the production line if a problem occurs. Here *accelerating process tasks* combined with *eliminating information float* allows Wells' Dairy to *respond intelligently to the environment* when there is a problem on the line.

4. By having intelligence built into the RFID system, it is able to quickly determine when a low quality product should be withheld from a shipment, thereby increasing overall shipment quality. Therefore, by *automating tasks using software agents*, the system is able to *accelerate process tasks*, which in turn allows Wells' Dairy to *offer proprietary systemic competencies* when product quality is improved.

5. Similar to the second point above, worker productivity in increased since personnel do not need to ensure the correct physical placement of pallet bar codes. Therefore, the RFID system *accelerates process tasks* which reduces the need for intervening labor thereby *altering the role of intermediaries*.

6. Outbound logistics are improved by using RFID readers to ensure that the correct pallets are in the proper outbound queue which results in zero shipping errors. This in turn improves the overall quality of customer service. Because the system does this automatically there is no need to have a person double-checking bar-codes on the outbound truck as was the case prior to RFID. Therefore, by *accelerating process tasks* and *eliminating information float* RFID Wells' Dairy is using the technology to *alter the role of the intermediary* (less manual intervention) and *offer proprietary systemic competencies* to its customer (improved customer service).

4.2. Case Example 2: RFID at Sachsenmilch

Sachsenmilch is a large German dairy producer of a variety of high-quality cheese products [9]. The cheese product process is quite sensitive to changes in temperature and humidity, and requires precise timing of the sweating and ripening process in order to produce fine-tasting cheeses. Sachsenmilch decided to institute RFID in its internal cheese production process to track the movement of cheeses into and out of its environmentally-controlled sweating and ripening rooms. This effort was done in part to ensure compliance with new regulations from the European Union (EU).

In the new RFID-enabled operation, trays loaded with fresh cheese blocks are routed via a conveyor to various ripening and sweating rooms. The trays have

RFID labels affixed to them and readers along the conveyor and at the entrance to the ripening and sweating rooms allows the RFID system to keep track of where each cheese-loaded tray is, how long it has been in a given room, and what are the current environmental conditions along the conveyor line and in the ripening and sweating rooms.

RFID adds value to Sachsenmilch according to the RFID e-Valuation Framework in several ways.

1. Because the RFID system collects data on location and time as the cheese products moves through the ripening process, Sachsenmilch *accelerates process tasks* of collecting such data in order to fulfill EU requirements. Also, similar to the case of Wells' Dairy, since the data is being collected automatically without human intervention the system *alters the role of intermediaries* by taking the need for human intervention out of the process.

2. If audited, Sachsenmilch is able to access its RFID-enabled database which is used to show the origin and process used for each piece of cheese thereby *eliminating information float*.

3. Sachsenmilch believes that improved process precision results in improved quality of the cheese product allowing them to *eliminate information float* in order to *offer proprietary systemic competencies*.

4. Engineers studying the sweating and ripening process are able to *make use of extensive system feedback* in order to make process changes to improve the quality of the product thereby allowing Sachsenmilch to *offer a proprietary systemic competency* of better tasting cheese products.

These two brief examples illustrate how the RFID e-Valuation Framework can be used to map the business value generated from RFID at various places along the value chain. It further allows the analyst to map out when certain RFID functionality enables or enhances other functionalities.

5. Benefits of the Framework

In this paper, we have provided an overview of the RFID Value Grid, which when applied at various points along the value chain creates an overall RFID e-Valuation Framework that can be used to map the business value generated from RFID. There are several benefits of such a framework.

First, the framework helps stimulate a structured discussion on the business value of RFID. For managers this allows stakeholders to address the value discussion from the same starting vantage point. For researchers, the framework can stimulate a discussion of the key research points that should be addressed with further research methodologies.

Second, the framework helps to identify where RFID has the potential to impact the organization. Some areas are more obvious than others. By examining the grid and considering different points along the value chain, additional value-added functionalities emerge further enhancing the total business value of RFID and enabling the creation of an overall RFID business strategy.

Third, the framework helps to identify functionality interactions where one functionality enhances or enables other functionalities. This helps the RFID manager not only map where value is created, but can also help the manager determine the appropriate timing of investments and rollout of different functionalities over time.

Fourth, each cell in the grid where RFID has an impact, as well as each interaction between functionalities within the cells, indicates where the RFID manager should consider implementing certain metrics to measure performance of the RFID system. Such metrics are important for evaluating the effectiveness of the system and further refining the RFID business case.

Finally, the grid and the framework can be used as a tool to communicate the business case for RFID to other stakeholders. Effective communication using such a tool generates more refined discussion and furthers understanding of the value of the technology.

6. References

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