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RFID Assimilation Hierarchy

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Abstract

While much research has been conducted on adoption of complex technologies, relatively little has addressed the post-adoption deployment of that technology. This research proposes a hierarchy of RFID assimilation which proposes that the creation of supplier business value is dependent upon the depth of assimilation (extent of use). The proposed hierarchy is grounded in industry observations of the difficulty of early adopters to fully realize benefits of RFID assimilation. At the base level of the hierarchy is Technology Deployment, with the next level of Data Understanding, and, lastly, at the top of the hierarchy is Business Value Creation. Each level of the hierarchy is explored and organizational examples are provided to illustrate the three developmental levels.

1. Introduction

A plethora of research has been conducted on technology adoption, but much less has looked at technology assimilation[1]. Adoption generally refers to the point at which the decision is reached to implement a technology [1] or the physical purchase of a technology [18] whereas assimilation refers to the actual use of the technology throughout the organization. According to Gallivan [5, p. 59] assimilation can be further categorized into the *breadth* (i.e., how broadly the technology is used in the organization, e.g., the number of users), and *depth* (i.e., how extensively the technology is used and its impact on the organization). This research uses a depth of technology assimilation perspective to understand the phenomenon of radio frequency identification. Specifically, we relate the depth of radio frequency identification technology assimilation to an organization's developmental level in an assimilation hierarchy.

Radio frequency identification (RFID) is a method of tracking that uses radio waves to trigger a response from a device attached to a product (e.g., case or pallet) [13, p. XVII]. RFID is one example of a family of auto identification technologies. Several retailers (Wal-Mart, Target, Albertsons, Best Buy, etc.) as well as government agencies (FDA, DOD) are moving from barcode identification to RFID in an effort to reduce costs and improve operating efficiencies in the supply chain through improved product forecasting, reduced inventories, and decreased labor costs; identify new business opportunities; fix deficient processes; and create a competitive advantage.

While this is all fine and good for the retailer, what about the supplier? Does RFID create business drain or business value for the supplier? The proponents of RFID assert that the benefits for suppliers include more efficient production planning, improved inventory control, and smart recalls, among others (e.g., [8], [11], [14]). The naysayers assert that there are many challenges associated with RFID [10], and that often the only benefit for the supplier is the revenue generated by selling to the retailer [24].

We assert that both camps are right, and that there is no "one size fits all" RFID solution. Many factors can influence supplier success (business value) or failure (business drain) with RFID. From our work with suppliers assimilating the RFID technology, we are beginning to observe patterns within the process. Consequently, this research proposes a hierarchy of RFID assimilation. The proposed hierarchy is grounded in industry observations and the difficulty of early adopters to fully realize benefits from RFID assimilation. At the base level of the hierarchy is Technology Deployment, then Data Understanding, and, lastly, at the top of the hierarchy is Business Value Creation. The remainder of this paper explores each of the levels in the hierarchy and provides examples of organizations at the levels of RFID assimilation. Figure 1 graphically represents the

[1] The terms deployment, implementation and diffusion have also been used (e.g., [1], [4], [15], [18]).

hierarchy and demonstrates that as an organization proceeds up the hierarchy the depth of RFID assimilation is increased. Shallow assimilation is characterized as a technology in which limited functionality is utilized and there is little or no impact on the firm. In contrast, deep assimilation is characterized as a technology in which the organization is using the technology functionality extensively which leads to a significant impact on the firm.

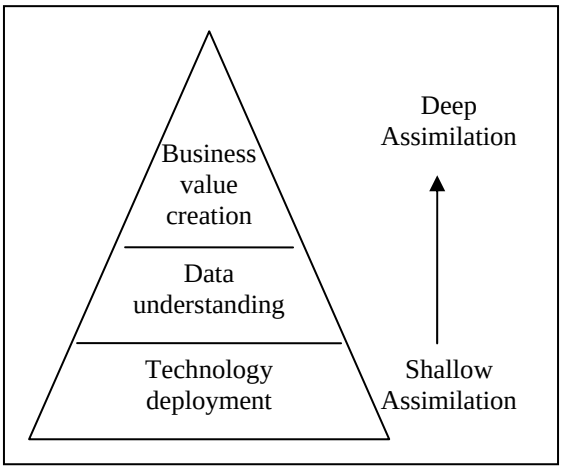

Figure 1. RFID assimilation hierarchy

2. Technology deployment

The foundation of the hierarchy of RFID assimilation is to deploy the technology (see Figure 1). Essentially, RFID is one example of a family of auto identification technologies which also includes the ubiquitous barcode. Since the mid-1970s, the retail supply chain (and many other areas) has used barcodes as the primary form of auto identification. Given the success of barcodes, the question arises 'Why move to RFID?' The answer lies in the numerous advantages of RFID relative to barcodes. Examples of these advantages include: (1) RFID does not require line of sight; (2) RFID allows hundreds of tags to be identified at one time; (3) RFID allows hundreds of tags to be read per second; (4) RFID tags can store more data; and (5) the data on RFID tags can be manipulated. These advantages have prompted many companies (e.g., Wal-Mart) to aggressively pursue RFID as a way to improve the supply chain (and, thus, reduce costs and increase sales).

In its simplest form, an RFID system consists of a tag (attached to the product to be identified), an interrogator (i.e., reader), one or more antennae attached to the reader, and a computer (to control the reader and capture the data). At present, the retail supply chain (the context within which this research is situated) has primarily been interested in using passive RFID tags. Passive tags are powered by radio waves created by a reader and transmitted via its antennae. The passive tag will remain powered only while it is within the read field. While in the read field, the powered tag will respond to the reader by reporting the data contained within.

When deploying the technology, companies have several options. Many companies, for example, are simply placing tags on their products in order to be in compliance with some mandate from a customer, such as Wal-Mart, or possibly the federal government. This 'slap-and-ship' strategy, where the companies simply place RFID tags on products (cases and/or pallets) going to designated distribution centers or stores, represents a short-term, immediate, and very shallow RFID technology assimilation. To implement a slap-and-ship strategy, most companies install the necessary technology in their facilities to write and affix RFID tags to outgoing products (e.g., cases and pallets). Often, the RFID solution entails an extra process whereby the merchandise to be tagged is de-palletized, RFID tagged, and then re-palletized for shipping to an RFID-enabled distribution center or store. Other companies have turned to readily-available solutions, such as IBM's Express RFID Services or Savi Technology's new Savi RFID-ACT (Assured Compliance Today). According to IBM [9], "The solution is highly standardized and modular, so you can implement just the tagging capabilities you need and avoid the additional hardware and consulting services that drive up costs." These solutions represent the lowest level of RFID assimilation since a company only needs to buy one piece of hardware (a printer/encoder) and have access to the hosted software. Although these slap-and-ship solutions provide a foundation of RFID technology assimilation, they limit the opportunity for eventual payback from the investment.

A slightly deeper assimilation strategy to slap-and-ship is 'tag-at-source.' That is, RFID tags are applied when the products are manufactured or packaged. By tagging at the point of packaging, organizations have increased their potential to exploit RFID technologies. For example, "Gillette tags most of the cases of razors, shaving cream and toothpaste it ships to Wal-Mart at its distribution centre in Romeoville, Illinois. But because Gillette thinks the benefits will be greater the earlier in the process it can tag goods, the company has also launched a pilot to 'tag-at-source' at its packaging facility in Fort Devens, Massachusetts, where it puts EPC tags on cases of Venus razors" [22]. This RFID

assimilation strategy provides a solid foundation for producing data both within the organization and inter-organizationally (and eventually obtaining a return on the investment).

Whether an organization uses the slap-and-ship or tag-at-source strategy, the 'benefits' of simply installing RFID technology and applying tags to cases and pallets are minimal. While the organization may be in compliance with a customer mandate, they are not realizing any significant benefits from the assimilation of the technology. Thus, at this first level in the hierarchy, the technology assimilation is quite shallow. The RFID technology is used only slightly and the impact of the technology assimilation on the firm is negligible. What is interesting is that many organizations are content to be at this level of the hierarchy. For example, one supplier of electronics has an existing and very effective product tracking process (necessary due to the high shrinkage for this particular product family). The increased visibility provided by RFID provides few additional benefits beyond the organization's current practice. Organizations like this see little incentive to move up the hierarchy, and are content to minimally deploy the technology (at least in the near term). Thus, they have little opportunity to create business value from their deployment (i.e., very shallow assimilation). On the other hand, companies (such as Gillette) which have adopted a tag-at-source strategy for some of their products (i.e., deeper assimilation than slap-and-ship), are poised to achieve payback from their RFID effort (as illustrated later).

3. Data understanding

Successful deployment of the technology is crucial to ultimately producing business value, but simply having the technology provides limited value[2]. The value of an RFID system ultimately resides in the data it produces. Thus, once organizations deploy the basic technology, the second step is to understand the data captured by the technology.

To understand the data, one must first understand the tag itself. Most RFID tags currently contain an electronic product code (EPC) [3]. Like the universal product code (UPC), the EPC is a globally unique serial number that identifies a product (e.g., case or pallet) in the supply chain. The serialized global trade identification number (SGTIN) is a method of identifying unique items at the product level. An SGTIN is essentially a 14-digit UPC (shipping container identification) with a serial number. The 96-bit EPC generally consists of a series of numbers that identify the manufacturer and the product, and contain a unique serial number for the tagged product. Figure 2 illustrates a sample EPC (specifically, an SGTIN) and compares it to its equivalent UCC-14. As shown, the vital difference between the 14-digit UPC used today and the SGTIN contained on an RFID tag is the serial number. For example, with UPCs, companies can identify the general product family to which a case belongs, but they cannot distinguish one case from another. With an SGTIN, each case is uniquely identified. This provides visibility at the case level, rather than the product family level.

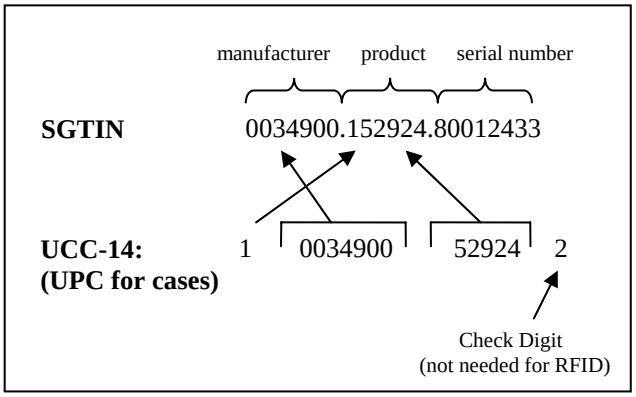

Figure 2. Tag data

As products (cases and pallets) move from the supplier, to the retail distribution center (DC), and then on to the retail outlet[3], they pass through a number of RFID-enabled discrete read points. Readers capture and record the RFID data as the product passes through these read points. Figure 3 provides an overview of the key read points in a generic distribution center. As product is delivered to the distribution center, read portals (created by stationary readers and antennae on each side of the receiving door) capture the case and pallet data. The product is stored in the distribution center for an indeterminate amount of time, then individual cases are put on the conveyor system to begin the sorting process; the conveyor system may contain multiple read points. Finally, the individual cases are sorted and shipped out the shipping doors which contain read portals similar to the receiving doors. The actual reads for a single case or pallet may vary depending on the type of

[2] As stated previously, one could argue that meeting a mandate by tagging products provides business value by keeping a large customer (e.g., Wal-Mart) happy.

[3] As most suppliers currently take a 'slap and ship' approach to RFID, the supply chain is abbreviated starting with the point of departure from the supplier's facility.

product (e.g., bagged pet foods are not placed on conveyors) and the type of DC it enters. Refrigerated / grocery DCs are different from general merchandise because, for example, grocery DCs have stretch wrap machines where readers can be placed, but may not have conveyors.

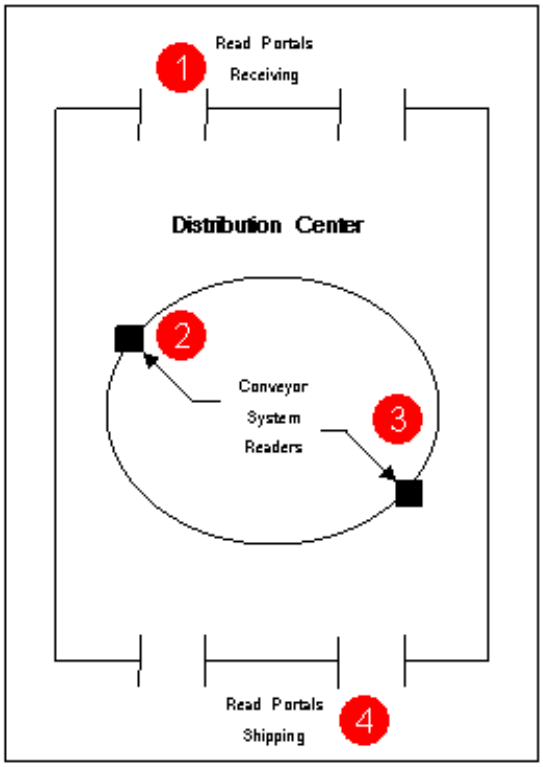

Figure 3. Generic distribution center read points
Adapted from [6]

At the store level, the readers are confined to the backroom area – no readers are on the sales floor (see Figure 4). Receiving doors have read portals similar to those found at the DC and capture reads from the individual cases as they are unloaded from the truck. The product then moves to the sales floor (where readers are placed next to the doors going to the sales floor) or onto backroom shelving. Eventually, all products should be moved to the sales floor and the empty cartons returned through the sales floor doors (a second read is captured at this point) and placed into the box crusher for disposal (the last read point).

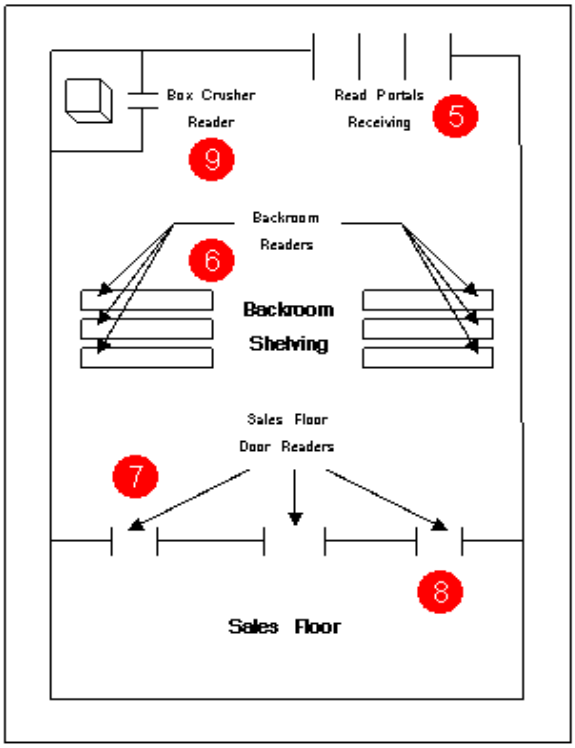

Figure 4. Generic retail store read points
Adapted from [6]

As product moves through the supply chain (as illustrated in Figures 3 and 4), there are four key pieces of information captured at each read point (see Table 1): (1) the facility (such as distribution center, store, etc.); (2) the EPC; (3) the date / time; and (4) the reader location. Table 1 traces the movement of a single case of product (SGTIN: 0023800.341813.500000024) from its arrival at the distribution center to its end of life at the box crusher. This particular case of product arrived at distribution center (DC 123) on August 4, was put on the conveyor system on August 9, and departed shortly thereafter. It arrived at the store (ST 987) about 12 hours after leaving the DC and went almost immediately to the backroom. The case stayed in the backroom until the following day when it moved to the sales floor, returned about 45 minutes later, and finally moved to the box crusher for ultimate disposal.

Table 1. Sample RFID data
source: [6]

Facility	EPC	Date/time	Reader Location
DC 123	0023800.341813.500000024	08-04-05 23:15	inbound
DC 123	0023800.341813.500000024	08-09-05 7:54	conveyor
DC 123	0023800.341813.500000024	08-09-05 8:23	outbound
ST 987	0023800.341813.500000024	08-09-05 20:31	inbound
ST 987	0023800.341813.500000024	08-09-05 20:48	backroom
ST 987	0023800.341813.500000024	08-11-05 15:01	sales floor
ST 987	0023800.341813.500000024	08-11-05 15:47	sales floor
ST 987	0023800.341813.500000024	08-11-05 15:49	box crusher

An understanding of tag contents and the possible data generated as tagged merchandise makes its way through the supply chain are fundamental and essential. Additionally, there are other data-related issues that must be addressed: (1) amount of data; (2) the need for 100% read rates; and (3) the overall quality of the data.

Given the amount of merchandise flowing through major retail supply chains (such as Wal-Mart), some have estimated that the amount of data generated from RFID may be overwhelming (e.g., [20]). A quick analysis of the contents of Table 1 provides some insight into how much data may actually be produced [6]. Each of the records in Table 1 is about 65 bytes and there are approximately nine read points in the supply chain (as currently utilized; see Figures 3 and 4). If a retailer moves about one million tagged products through the supply chain daily[4], then the amount of data generated daily is about 585 megabytes (65 x 1million x 9). From a storage perspective, 585 megabytes is not much. However, there are several million records generated – herein lies the challenge for companies: data mining large quantities of records produced from the new RFID-enabled supply chain.

The calculation of data size assumes that each tagged product will be read at each of the key read points. In reality, reading 100% of the tagged products at 100% of the possible read points is unlikely. There are limitations to RFID (such as the problems caused by water and metal) and some products simply do not pass through all the read points (as noted earlier). Thus, instead of trying to determine the reads for every product at every read point, it is better to look at the issues from a different perspective: (1) was the tagged product seen somewhere in each facility? and (2) can the path of that product through the supply chain be reconstructed from less than 100% reads? The answers to both questions are relatively easy to determine. Let us take an example of a case moving through a store. If we assume that the probability of seeing it at the various read points is 90% at any one read point[5], then the probability of seeing it at the store (assuming receiving door, out to sales floor, return from sales floor, and box crusher) is 99.99% (1- [(1-.9) x (1-.9) x (1-.9) x (1-.9)]). Should a product be missed at any one read point, its path can still be reconstructed from other reads with a high probability.

The aforementioned determination of data size and the ability to reconstruct a product's path (and essentially have 100% visibility) is dependent upon the quality of the data. Admittedly, the data presented in Table 1 is a bit misleading since it has been scrubbed considerably. Unfortunately, the RFID data currently generated is not nearly as clean as Table 1 would suggest. Rather, there are numerous reads per product per read point that could occur (e.g., case 123 could be sitting on a pallet at a dock door for several minutes and generate thousands of reads). Who is responsible for filtering this data: the retailer or the supplier? Most systems have rudimentary filters built in at the source

[4] This assumes a product makes it through all 9 read points in one day which is highly unlikely, so the estimate is very liberal. See [6] for more information about calculating the amount of data.

[5] This assumption is reasonable. Wal-Mart reported read rates at the store of about 95% [21]. Thus, 90% used in our example is appropriate.

(e.g., retailer), but it is still possible for massive amounts of duplicate reads to get through. For example, one anonymous supplier reported receiving more than 19,000 reads from one case at one read point from Wal-Mart [17]. As anecdotal evidence of the scope of this problem, we examined data from one supplier for a single product going through one distribution center to 33 stores. The data file contained duplicate reads from at least one read point for each of the facilities (DC and stores). Thus, suppliers must be diligent in removing unwanted, duplicate reads from their data before processing.

The data must also be cleaned of 'inadvertent reads'. These are reads that should not have occurred, but were captured because the product was taken near a read point inadvertently. For example, for the aforementioned 33 stores, 59% showed the product moving from the receiving door directly to the box crusher! The product was then moved to the sales floor. The path looked something like: receiving door -> box crusher -> sales floor door out -> sales floor door in -> box crusher. In this case, the inadvertent reads are caused by the location of the box crusher (near the receiving door). As the product is removed from the truck and rolled past the box crusher, the box crusher reader reads the RFID tags on the product. Suppliers must be aware of such anomalies in the data so that the data can be cleaned accordingly.

A baseline knowledge of tag data, read data, and the various data issues clears the way for companies to move beyond a simple (very shallow) deployment of the technology and allows them to move up the hierarchy where data analysis and subsequent insights are possible. For example, the company providing the data for the 33 stores mentioned above, discovered that several stores let the product sit too long in the backroom or never took the product to the sales floor. In a study of the movement of its promotional products, Gillette found that 38 percent of the stores did not get the product to the shelf within the promotional timeframe [16]. By studying the data provided by RFID technology, these organizations have been able to look into the black boxes of the supply chain.

RFID-enabled facilities will generate data for the involved parties (retailers, suppliers), but companies must develop a fundamental understanding of the data and its issues before it can be used properly. As illustrated, several companies have begun to grapple with analyzing RFID data. Recognizing poor rotation habits or inopportune movement of promotional products, for example, provides valuable insight for companies. Once companies understand the data and gain insights, they are poised to act upon this information to create business value.

4. Business value creation

Ultimately, companies will be evaluating the payback from their RFID investment. That is, what is the business value created from deploying this new technology? As suggested in the previous two sections and illustrated in Figure 1, RFID technology must be deployed and the resulting data understood before a company can realize any significant business value. Simply putting a tag on a product will yield little, if any, value to the supplier. An understanding of the data and the insights from it prepare the path to business value. Subsequently, we have identified three main avenues for creating business value from RFID: (1) immediate reaction to data insight with no process changes required; (2) incremental process changes; and (3) new process enablement.

Early adopters have used RFID to recognize problems in the supply chain, thanks to the unprecedented visibility provided by RFID. These companies can then react to these problems in an effort to save costs, increase revenues or both. For example, one company that we worked with tagged a shipment of products going to a major retailer. Most of the products were received at the distribution center and sent on to the store (the supplier could track this in near real-time since the retailer shares the data via an extranet portal with the suppliers). Some products, however, were never seen at the DC (i.e., no RFID reads). A follow-up call to the retailer determined that the products had not been unloaded and were indeed sitting in the DC parking lot. The products were then promptly moved through the supply chain to the store. Since these products were seasonal and had only a small window of opportunity to be sold, the visibility provided by RFID provided tremendous and immediate value (with no process change). First, the products were taken to the store where they could be sold rather than sitting in a trailer at the DC where they had no chance of being sold. Second, the retailer's forecast next year will be much more accurate as it will be based on product that was actually given an opportunity to be sold rather than what they thought was available for sale.

RFID can also be used by companies to improve either the efficiency or effectiveness of various existing processes by incremental process change. For example, early evidence suggests that RFID can reduce the amount of time to receive product at a warehouse [12]. Instead of scanning each case of product

individually with a barcode scanner, RFID tagged product can be read automatically at a receiving door portal. Gillette reported a reduction in pallet receiving time at their distribution center from 20 seconds to 5 seconds due to RFID and their tag-at-source strategy [12]. The process of receiving was not drastically changed (i.e., forklifts unloaded the product as before). The only change was eliminating the need to manually scan the product. Thus, the process became more efficient. Processes can also be made more effective (i.e., better). For example, in a widely publicized study of out of stocks, Wal-Mart found a 26% reduction in out of stocks by using RFID data to generate better lists of products to be replenished [7]. The shelf replenishment process was not changed, but improved (made more effective) by the use of RFID. Wal-Mart has also reduced the number of unnecessary manual orders by 10%; thus, making the ordering and forecasting system more effective [23]. RFID is also being used in receiving to reduce the number of errors [2] which improves the accuracy of inventory and ultimately leads to better forecasting and replenishment.

Lastly, companies can use RFID to radically change the way they are either manufacturing or distributing their products. As a radical technology, existing processes are drastically changed or the technology is used as a process enabler (i.e., to create new processes). For example, should RFID get to item level tagging, then the concept of 'contactless checkout' may become a reality. With contactless checkout the shopper would place RFID tagged items into a shopping cart and walk the cart through the RFID reader at the door. The reader would read the products in the cart and automatically debit the customer's RFID-enabled credit card, for example. If contactless checkout does come to pass, then the process of checkout will be radically changed. There has also been some discussion about RFID's facilitation of pay-per-scan as a new method of inventory (whereby the retailer does not pay the supplier until the product is sold) [19]. Pay-per-scan would radically change existing inventory methods and relationships within the supply chain. While most RFID efforts to date have been focused on its use as an incremental technology, RFID does have the potential to be used as a radical or disruptive technology.

5. Conclusion

As with any new technology, RFID is an investment. While some early adopters (driven by compliance demands) are finding multiple areas of business value throughout their supply chains (e.g., shipping and receiving, inventory accuracy, proof of delivery, on-shelf availability), others are content to merely deploy the technology. For these organizations, mandates may drive the assimilation of RFID in the short term and they may simply comply by employing a slap-and-ship solution. Understanding the data and getting a return on their RFID investment, at least initially, are unimportant.

As shown in Figure 5, organizations that have only shallow assimilation will limit their ability to create business value. As one moves up the hierarchy, from slap-and-ship to tag-at-source (for technology deployment), the foundation is established to generate and understand the data. Insights from the data – reliant upon an understanding of the tag data, read points, and various data issues – can be used by companies to take corrective action, improve existing process (efficiency and effectiveness), or create new processes. Business value can be achieved from any of these, though the biggest payoffs may come from the creation of new business processes enabled by RFID. It is important to note that although RFID can be used as the enabler for business process change – it is not the total solution. To maximize returns from investments in RFID, these investments must be matched by investments in business process change. Ultimately, all companies involved in assimilating RFID will be looking for ways in which RFID may provide a return on their investment.

RFID offers many advantages and potential opportunities to improve the supply chain. RFID can reduce product out-of-stocks, make product movement more efficient, and provide unbelievable visibility into the supply chain. Organizations must be cognizant of the fact that RFID is not a silver bullet for all supply chain problems. The key is to realistically assimilate RFID and identify those areas where benefits may occur.

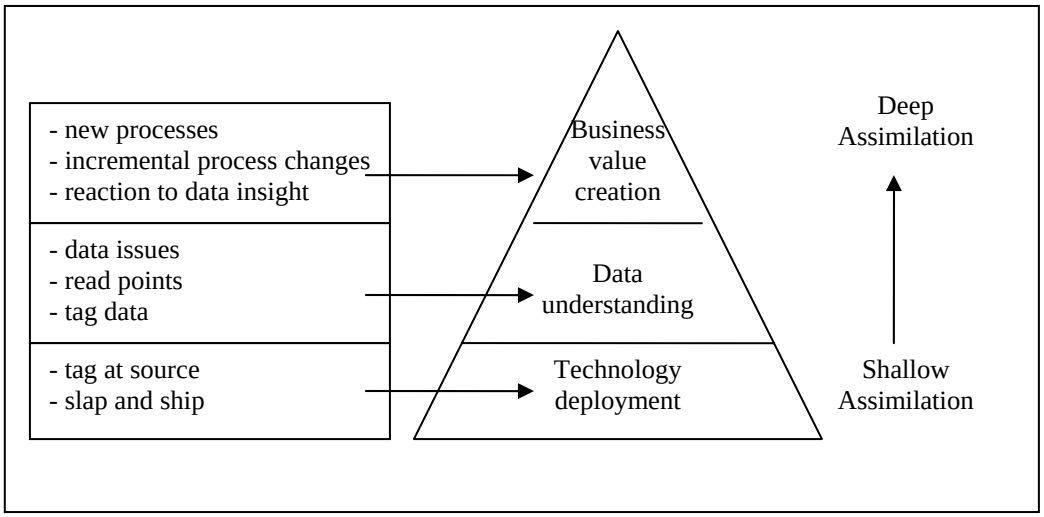

Figure 5. RFID assimilation hierarchy - revisited

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