

# Effects of the RFID Mandate on Supply Chain Management

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## Abstract

Recently, radio frequency identification (RFID) is being explored as a technology to be used in supply chain management. The use of RFID in the supply chain is an emerging technology that has attracted a lot of attention in the U.S., Europe, and Asia. Major retailers in various continents have given mandates to their suppliers to adopt the technology in order to continue business with them. As a result, there appears to be a shift in power dependency in the supply chain. This has had an impact on how the suppliers adopt RFID to embrace the mandates. The impact is likely to have a long term effect on current business models. Our study into the existing literature reveals three tiers of the effects of mandates. The effects are best examined by separating out the suppliers into two groups: suppliers adopting the technology under the mandates and suppliers not affected by the mandates and adopted a wait-and-see tactic. Moore's Technology Adoption Life Cycle is used to highlight the chasm between these groups and the early adopters.

The objectives of this paper are: (1) to show managers the effects RFID/SC may have on their business models, and (2) to identify possible research areas within the RFID field.

**Key words:** RFID, Supply Chain, Technology Adoption Life Cycle

## 1 Introduction

The recent publicity of radio frequency identification (RFID) and its use in supply chain management has created awareness among businesses. RFID for the supply chain (RFID/SC) is an emerging technological trend that has attracted a lot of attention in the U.S., Europe, and Asia. The potential benefits that RFID is perceived to bring to businesses are what make retailers so fascinated with the technology and are a manifest of power among the supply chain members. Retailers claim to have reduced stock-out and labor costs, improved inventory management, and achieved supply chain efficiency through greater visibility in their supply chains [15], [22], [32].

To achieve supply chain visibility, information sharing is important. RFID is a type of automatic identification and data capture technology that uses radio waves as a mean of communication between a tag and a reader. The tag is embedded with a micro chip that can be encoded with a numbering system known as the Electronic Product Code (EPC) [32]. The reader reads the EPC of the tag which can be used to uniquely identify an object. By applying a community of tags and readers, the information collected by the readers about the tags can provide visibility of the tags in the community. RFID/SC, with its data capturing capability, is thus explored as early as in the production phase, in order to gain optimum benefits. As a result, major retailers have given mandates to their suppliers to start tagging products for delivery to their retail outlets. The use of mandates seems to imply a dominance position of the retailers over their suppliers. Nevertheless, the mandates have some effects on supply chain management. On the one hand, the mandates have publicized RFID. On the other hand they created a string of changes that could transform existing supply chain models.

This paper explores the effects of the RFID mandate on supply chain management. The research begins with a literature review on RFID mandates with particular attention to content analysis [19]. Trends and patterns that managers can relate to in the context of RFID/SC are inferred from the content in the literature. The objectives of the research are to show managers the effects RFID/SC may have on their business models and to identify possible research areas within the RFID field.

This paper is arranged in 6 sections. First, a brief introduction of the research is explained. Second, supply chain management is discussed using a simplified supply chain model. The power shift within the supply chain is explained in the context of information systems. We highlight the need for more innovation research on the upstream of the supply chain in this section. Third, the effects of the RFID mandate are revealed. We analyze the effects of the mandate using existing research to establish what we called the three-tier effects of the RFID mandate. The effects are discussed as a chronological event. We highlight what managers should be aware of when embracing RFID/SC in this section. Fourth, we use Moore's theory on Technology Adoption Life Cycle to demonstrate the differences between early adopters and early majority in the context of RFID/SC. This theoretical analysis draws our attention to the need to resolve some of the important aspects of RFID/SC which inhibit the adoption of RFID in the supply chain. Fifth, we highlight the barriers to RFID/SC adoption. Last, we conclude this paper with a summary of our findings and propose future work around RFID/SC.

## 2 Supply Chain Management

It is a given fact that there is a power disparity among members in the supply chain with the power base now shifted to the retailers [9]. Retailers, like Wal-Mart, have the power to drive initiatives that are beneficial to them. This section looks at the power dependency in the supply chain and highlights the benefits to each partner.

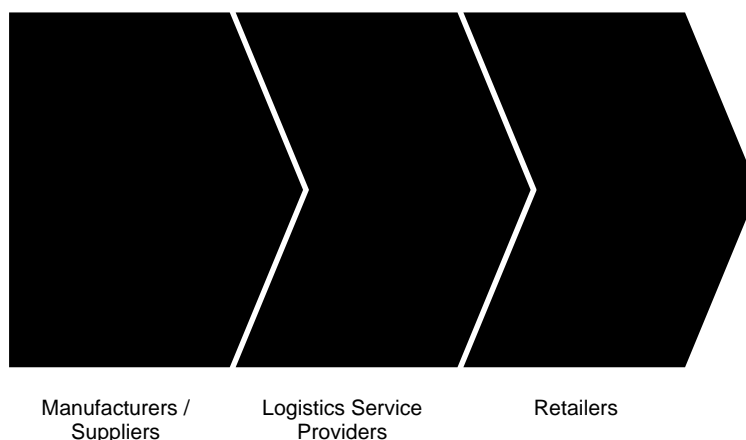


Figure 1: Simplified Supply Chain

For the purpose of this discussion, a simplified supply chain model is used as a platform to examine the key roles that are integral parts of the supply chain. Figure 1 shows the simplified supply chain. The figure depicts the distribution management of a supply chain showing at least three sets of organizations linked for the purpose of delivering products and services to consumers. The organizations are manufacturers or suppliers, logistics service providers, and retailers. In this context, the manufacturers or suppliers supply the products and services to the retailers via the logistics service providers who provide distribution and warehousing services. It should however be noted that the complexity of a supply chain multiplies as the supply chain expands and extends to the raw material management, which is omitted here.

## 2.1 Benefits Downstream

Traditional supply chains typically adopted the push method where products are manufactured and pushed to the sales front. In the 1950s, products or materials were pushed through supply chains by manufacturers. Typically the manufacturers operated a nationwide distribution to retail outlets [11]. As goods are pushed downstream, inventory piles up when demand is uncertain. This resulted in high held stock or inventory. The inventory is stored in warehouses or distribution centers. Prater, Frazier, and Reyes [25] suggest that high inventory is due to fragmentation in the supply chain. Retailers replenish goods according to their sales while manufacturers push their goods through the supply chain with forward buying and other promotions. Forward buying is bulk purchasing of product at a discount [25]. Davenport and Brooks [7] suggest that a break-up in a supply chain comes about because of the lack of information among the functions in the supply chain. Managers stock up costly inventory to create buffer and slack in the system to prevent stock-outs that cause disruption in their operations.

"The lack of information integration among supply chain functions ... means that hand-offs from one part of the business to the next are far from smooth" [7], p. 9.

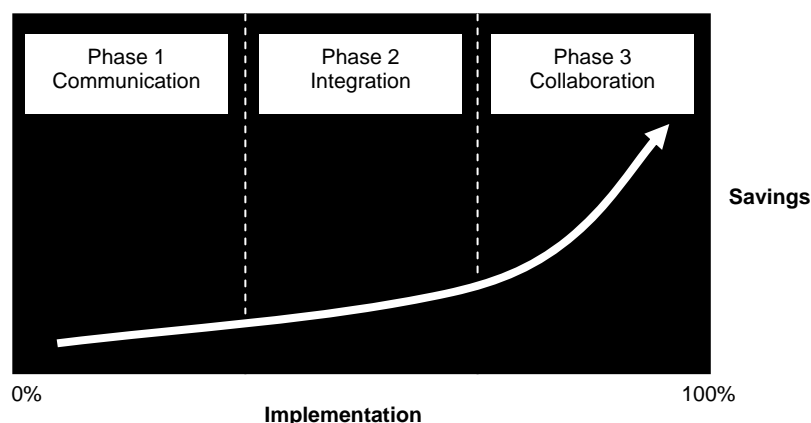


Figure from EDI, UCCnet & RFID – Synchronizing the Supply Chain by Nahid Jilovec [13].  
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Figure 2: Phases of Implementation in Supply Chain

The traditional supply side push method has changed over decades as enterprise systems, such as enterprise resource planning (ERP) systems and electronic data interchange (EDI) permit the sharing of information across organizations and throughout the supply chain. The sharing of information has made managers realize that their processes are inter-related and timely acquisition of sales information will help drive out inefficiency in the supply chain. Jilovec [13] recognizes that organizations began communicating with suppliers using EDI at departmental levels in the attempt to eliminate inefficient paper documentations such as purchase orders and request for quotations. Integration among departments within an organization follows when the organization realizes the benefits of sharing information among related functions such as procurement, accounts payable, and inventory planning departments. A more streamlined process is achieved when such integration occurs at the inter-organizational level. Collaboration among partner organizations presents opportunities for advance planning and almost real-time forecasting. This requires trust and an open relationship in the supply chain. Figure 2 illustrates the communication phases adapted from [13].

Inter-organizational sharing of information shifts the supply chain away from the traditional push method towards a demand-driven process. The demand-side concept embraces strategies like quick response (QR), collaborative planning, forecasting and replenishment (CPFR), and efficient consumer response (ECR). From push method to demand-side forward planning, the latter appears to afford the retailers, in place of the suppliers, with more power. Retailers have learnt and become more conversant in the management of demand and supply over the years [9], [11]. They are less dependent on their suppliers than they were in the past. For example, the adoption of ECR addresses the management of category, product replenishment, and enabling technologies [9]. Retailers typically

have to depend on suppliers, who are more product category focused and are better able to advise on product placement on shelves [26]. However, with data collected via RFID/SC on actual placement sales, retailers can now study product placement in their stores more readily and need not depend on suppliers for the information. With the information, retailers can improve their new product cycle, product ranges, and as well as store layout [15]. Being an early adopter of ECR, Wal-Mart is now driving the adoption of RFID/SC as the enabling technology. RFID/SC may further increase retailers' power in the supply chain by enabling the collection of actual sales and products visibility data in the supply chain [15]. Retailers may use this information to insist on certain sizes of retail-ready display cases which suppliers find labor intensive to re-pack products according to the requested display configuration. Besides having more control over replenishment and category management, retailers stand to gain from reduced shrinkage, stock-outs, phantom inventory, and increased inventory turns [32]. A. T. Kearney highlights that retailers experience more significant benefits than manufacturers through reduced inventory, labor and out of stock reduction [17]. This is supported by Vijayaraman and Osyk's [34] survey, which reveals that retailers are expecting a positive return on investment (ROI) while manufacturers are pessimistic about their initial investment on RFID/SC. Therefore, with the economic advantage over their suppliers, retailers have the power of influence to enforce the use of RFID/SC. The survey also finds that the majority of RFID/SC implementations are focused on the warehouse level. Shipping and receiving are two popular areas where benefits are perceived. The survey concludes the distribution of benefits in this order and is depicted in Figure 3; retailers stand to gain more benefits followed by logistics providers, distributors, and manufacturers. With the general perception that retailers stand to gain more, what benefits do logistics service providers and manufacturers/suppliers get from RFID/SC?

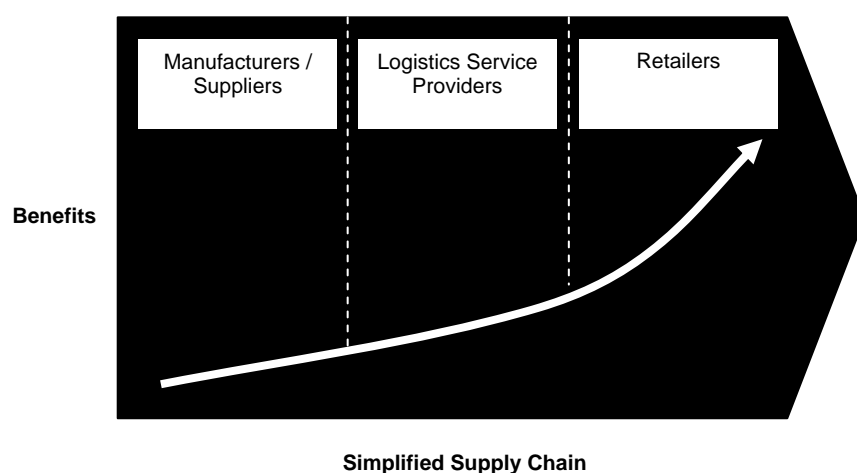


Figure 3: Perceived RFID/SC Benefits in Supply Chain

## 2.2 Benefits Upstream

Labor cost savings have been perceived to be the most significant in warehouses and distribution centers. This is because RFID/SC permits the authentication of products received and issued without much human intervention and in a much convenient manner. A conventional receiving procedure involves verifying products at the receiving dock against shipping documents. To do this, a warehouse operator has to visually match the product part number and quantity against the document. Upon verification, the operator has to perform a system transaction to complete the receiving task. This procedure can be simplified with radio frequency (RF) readers installed at the receiving dock to scan the inbound goods. The RFID/SC system automatically verifies the data with the electronic shipping documents (or advanced shipping notification) received prior. The warehouse operator only needs to visually check for any in-transit damage to products and moves products to their assigned storage locations.

Although there are speculations of improved inventory accuracy in storing and picking functions [15], [26], it should be mentioned that this requires a lot more investment to set up RFID-enabled pallet and shelving positions, and other infrastructure investment that goes with it, such as RFID-enabled material handling equipment. This will only be economically viable when item-level tagging is practical or when the product is of high commercial value. Its benefits will be a more accurate inventory, reduced shrinkage and theft, and more efficient use of storage space [15]. At the outbound operation, products can be picked and loaded onto assigned trucks similarly reducing labor intensive tasks such as the scanning of each case with a barcode scanner and manually charging out products from the warehouse management system (WMS). The RFID/SC system can automatically identify the cases with RF readers strategically positioned at the outbound area.

Manufacturers and suppliers have been looking for a positive ROI as Vijayaraman and Osyk [34] report. Most respondents to their survey implemented the technology to comply with RFID mandates. The bulk of the investment falls on the manufacturers. Besides investing on the infrastructure, the manufacturers have to incur cost to tag products. It is financially not feasible to tag at item level when each tag costs more than five cents. A. T. Kearney

identifies two groups of manufacturers, the high-impact manufacturers where their transaction volumes are low and of high value, and the low-impact manufacturers with high volume but low value products. The latter group has a harder time justifying the investment given their dependence on sales transaction information from supply chain partners. High volume for this group means higher tagging costs [17]. The low-impact manufacturers, also known as contract logistics in the supply chain, generally fulfill the orders in pallets and have higher inventory turns than the high-impact manufacturers. Because of the high volume, it is difficult for the manufacturers or suppliers to track sales stocks and keep inventory. They have to depend on the retailers for the information, often which can be difficult to obtain as retailers may not share them readily. Also, most contract logistics goods are low in value, and so it is invariable that low-impact manufacturers use RFID/SC at the case or pallet level to achieve a positive ROI.

Still, there certainly are benefits that the manufacturers and supplier can reap from the technology. Examples of the benefits are increased inventory visibility, labor efficiency, and improved order fulfillment [13]. Spekman and Sweeney-II [31] add that manufacturers could benefit from the elimination of chargeback for products that were not recorded as received by retailers. Deliveries are authenticated at a higher level of accuracy and thus human error in counting can be prevented. The dilemma that most manufacturers face is the different standards that their various partners would use. The concern is valid when manufacturers supply their products to multiple customers. It is thus difficult for the manufacturers to “commit substantial resources required if they do not know whether their suppliers and customers will be using a compatible technology” [32], p.229.

Without a doubt, manufacturers and suppliers would want to see more benefits from RFID/SC before taking the plunge; more research is needed on this subject, in particular, at the upstream of the supply chain as shown in Figure 4.

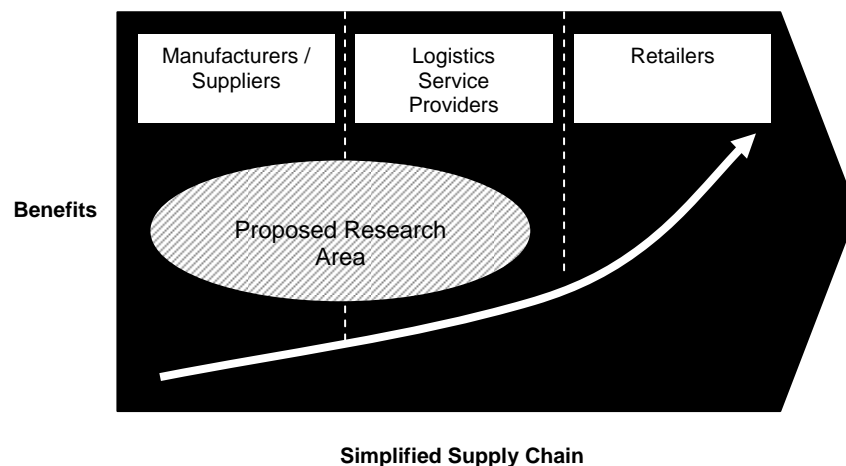


Figure 4: Proposed Research Area in RFID/SC

For now, the benefit of RFID/SC is perceived to be more apparent at the downstream of the supply chain. This is one of the reasons why powerful retail giants are keen to drive the implementation upstream [15]. Wal-Mart's mandate to suppliers to implement RFID/SC is one such example. It can be seen as a catalyst to the adoption of RFID in the supply chain. The next section analyzes the effects of the mandate and discusses the strategy of wait-and-see.

### 3 RFID Mandate

At the current stage of RFID/SC adoption, two groups are identified; organizations with the mandates to implement RFID/SC in order to continue business with retail giants, and organizations not affected by the mandates and that are either adopting the wait-and-see tactic or planning to adopt the technology. The reason for classifying them as such is that there is a clear division between the groups in terms of their positions in adopting the technology. Therefore, the main distinction between the two groups is whether or not there is a mandate that pushes for RFID adoption. The mandate could take a toll on smaller suppliers while those wait-and-see organizations would risk losing market share should RFID/SC take off. Both groups face a challenge of implementing a relatively new technology that has very few preceding examples to learn from.

The more recent use of mandates to drive adoption was enforced by governments on the use of electronic data interchange (EDI) [5], [33]. Mandates were then used as a binding obligation issued by a large authority. In the EDI mandates, the governments issued the mandates to use EDI as a platform for electronic transfer of data. While larger organizations were willing to accept EDI, smaller organizations were unable to justify the investment costs of implementing EDI [33]. Similarly, the mandates to suppliers to implement RFID/SC come from large organizations such as the United States Department of Defense, Wal-Mart, Tesco, and Target [21], [15], as an ultimatum to adopt RFID in order to continue their business relationships. Thus the resurface of mandates is used as a strategy by large



organizations to drive their organizations' initiatives on technology adoption such as in [12]. The rest of this section looks at the possible effects of RFID mandates on businesses and discusses issues that managers should be aware of when embracing RFID/SC.

### 3.1 Effects of RFID Mandates

For a comprehensive analysis, we propose to consider the effects of the mandate in three tiers. The first tier is the immediate impact as companies hurried the adoption of RFID/SC to comply with the mandates. The action creates challenges as it develops. The second tier ensues when the first tier suppliers have implemented the technology and begun to contemplate on the operational and tactical issues of sustaining the technology. At this level, managers are faced with integration issues. The third tier is the post RFID/SC challenge. The after-math in the long run, may change the way the supply chain operates and introduce new shifts that could potentially disrupt existing business models. The rest of the section discusses these effects.

Since the announcement of the RFID/SC mandates, the supply chain industry has been exploring the largely unfamiliar RFID technology. This is the start of the first tier of the effects of the mandate. The mandate means that RFID/SC is an obligatory reality. The foremost impacted suppliers are those key trading partners to the retailers, reasonably large in organizational size. The initial satisfaction level of those who adopted the technology in compliance with the RFID mandates was not very optimistic [34]. They are not as yet confident of the technology of which they have little knowledge and for which they have limited funding. They report a lack of foreseeable benefits and high cost with unsatisfactory results in their pilot tests. The poor results are due to the unavailability of hardware coupled with technical issues such as poor read rates and reliability issues [34].

While the technology is maturing, the sudden rush to comply with the mandates has increased the demand for its components, both the tags and the middleware. The industry is simply not prepared for the mandates nor to meet the demand for hardware and software. While undergoing the first tier effects, the suppliers are subjected to technical challenges and continuous struggles in finding a business case in the effort to stay in business with the retailers. This issue is more obvious within contract logistics, the low-impact manufacturers. Nonetheless, if that one retailer is a key source of revenue for the supplier, it may be justifiable to comply with the mandates to retain the customer or even for the organic growth of the whole. To find a stronger business case, companies have to expand the implementation beyond simply compliance with the mandate requirement [26], and "extend the use of RFID into other areas of their operations" [31] p. 738.

Moving on to the second tier, suppliers who have now implemented RFID/SC will start working at integrating the technology into their existing enterprise systems. In complying with the mandate's deadline, suppliers might not have the resources and the knowledge well in advance to design a full integration of the technology and might only be ready to integrate at the WMS level. Vijayaraman and Osyk [34] comment that most suppliers did not envisage a higher level of integration with their overall IT strategy and Kommareddi [18] estimates that 90 per cent of retailers implementing RFID are not incorporating business intelligence infrastructure or analytical systems to synthesize the data captured by RFID. This means that the initial implementation will need to be reworked within the organization to fully integrate all relevant information systems. Organizations without a scalable network infrastructure will likely have to incur additional costs in redesigning the network to cater for additional hardware and data traffic capacity.

On top of the impact on existing systems and infrastructure, business processes and organizational values are also affected. RFID/SC introduces efficiencies to logistic processes and in order to benefit from them, organizations have to educate and train their employees to use the new technology and to execute changes to their business processes. For example, a RFID tagged pallet has to pass through a reader. This is especially crucial in a multi-client warehouse, where an employee usually handles multiple systems and processes.

At the management level, managers may be busy figuring out what to do with the data collected. The use of analytical tools will help as Kommareddi [18] urges. It is also noted by Craig and Tinaikar [6] that most organizations, when designing their IT infrastructure, do so based on their existing capabilities with the objectives of improving the current service levels and costs. As such, it is often perceived that IT is incurring costs. Craig and Tinaikar [6] argue that IT investment should also be driven by generating revenue with creating strategic advantage as the long term goal. This foresight allows managers to invest on a scalable infrastructure that should be aligned with their corporate strategies, thereby putting forth a highly justifiable business case.

New ways of supply chain operation start to kick in when RFID/SC is integrated into the enterprise systems. This is the beginning of the third tier of the mandate effect. Overtime, warehouse operations will define new approaches and configurations. As inventory turn-over moves faster and products spend shorter times in storage, cross dock activity becomes more important [32]. This indeed has insightful implications for the design of a warehouse. The proportion of storage and working areas may change. The design of storage racks may need new configuration to suit cross dock activities. This in turn may affect the way material handling equipment is used. New won businesses are likely to take a longer implementation time given the added complexity of systems integration. Retailer and supplier relationship at this stage moves to a higher level of collaboration and there are likely to be more interactions between them. The interactions form a closer, long term relationship that ties both parties to strive to make the relationship work. New players thus may find it difficult to enter the market.

The three tiers effects of mandated RFID adoption provide some insights for organizations evaluating the technology. There are at least six important lessons we can learn from the early adopters' experience, who have faced some difficult challenges because of the lack of knowledge and funding. First, RFID in the supply chain is a reality. Learning from these lessons, organizations intending to adopt the technology should start by finding out about the technology and knowing how it fits with their supply chains. Then, they should put forth a business case to secure funding. Second, more benefits can be reaped down the road when RFID/SC is extended beyond complying with mandates. A T Kearney advises organizations to focus on implementing the technology within their domains to yield satisfactory benefits before trying to implement across the supply chain [13]. This helps organizations to focus on their core business instead of merely fulfilling immediate needs. Third, the integration of RFID/SC into the existing enterprise systems should be planned at the outset in the evaluation phase. This will avoid costly rework of infrastructure and minimize disruption to current operations. Mary, Hau, and James [20] suggest adopting the scope approach to identify areas where RFID provides more benefits or positive impacts, and using the scale approach to test and implement the technology. Fourth, management has to decide what type of information they require and how to report it. This is to avoid being clouded with massive amount of data and caught off guard without analytical tools for meaningful reporting. Fifth, managers are to be aware of any likely shifts in their operations that might affect future development. It will be costly to redesign infrastructure such as warehouse layout, to suit new processes or to try fitting new processes into an existing infrastructure that is overly rigid. Last but not least, managers are to be aware of future relationships with retailers and suppliers so as to position their strategies well.

### 3.2 The Wait-and-See

Many organizations are waiting for signs in the industry before committing resources to adopt RFID/SC [34]. "Those who wait run the risk of being pre-empted and losing market share" warn Spekman and Sweeney-II [31], p. 747.

Organizations not affected by the mandates might therefore want to get out of their comfort zones and start to establish themselves a foothold on their suppliers and retailers before losing ground to the early adopters. The 'mandate effects' provide a platform for organizations to catch sight of the mechanism of RFID/SC from a holistic view that the early adopters did not have the opportunity to do so.

The next section looks at the difference between early adopters and the majority using the Technology Adoption Life Cycle with attention given to the chasm. This provides our readers a reference point when deciding on RFID/SC implementation.

## 4 Technology Adoption Life Cycle

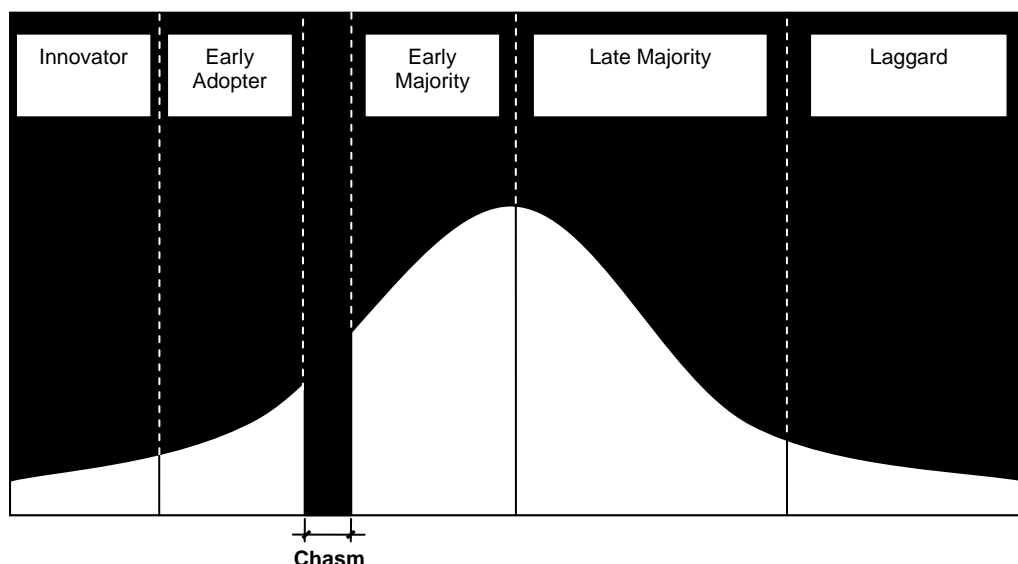


Figure from Crossing the Chasm by Geoffrey A. Moore (HarperCollins Publishers) [23].  
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Figure 5: The Chasm in the Technology Adoption Life Cycle

The Technology Adoption Life Cycle model is "a model for understanding the acceptance of new products ... the model describes the market penetration of any new technology product in terms of a progression in the types of

consumers it attracts throughout its useful life" [23], p. 11. The theory of this model is that technology is adopted by users corresponding to their social profiles and preferences. There are five categories of psychographic profiles [23] in the model spectrum, namely, innovator, early adopter, early majority, late majority, and laggard. Of significant difference between the profiles is the incompatibility or dissociation between the early adopters and the early majority, or known as the chasm, in adopting a new technology. Figure 5 shows the chasm within the Technology Adoption Life Cycle model adopted from [23]. Early adopters, like innovators, have insights into emerging technologies and are eager to try out these technologies even if they are not as yet fully functional. In contrast, early majority is the group of people in the mainstream markets who assess new technologies based on pragmatic evidence that the technologies are effective and reliable. As such, "because of these incompatibilities, early adopters do not make good references for the early majority. And because of the early majority's concern not to disrupt their organizations, good references are critical to their buying decisions" [23] p. 21.

The Technology Adoption Life Cycle model is applicable to RFID/SC because RFID is relatively new in the supply chain. There is also a clear division among the supply chain members in terms of their adoption of RFID which we can relate to as the early adopters and early majority. The main difference between the two groups, in the context of RFID/SC, is the fact that one group was faced with the predicament of having a mandate compelling their adoption of RFID/SC. It is therefore critical to address this chasm. The rest of the adopters shown in the figure are late majority who are conservatives and unreceptive of discontinued technologies, and the laggards who are usually not supporters of technologies and show skepticism towards the adoption of new technologies [23].

## 4.1 The Chasm

In this section, we look at the attributes of early adopters and early majority to study what sets them apart, so that we know what needs to be done.

Early adopters are usually the first people in the industry to adopt potentially beneficial technologies. They have a greater interest in technology than most in the same industry. Moore claims that early adopters build systems from scratch since there are no standards formerly in place [23]. By being the first to try the technologies, early adopters are in a position to establish standards to their advantages. Retailers like Wal-Mart and Tesco fall into this category. They saw the early advantages of RFID/SC and developed a mandate strategy to expedite the development of the technology. Other organizations like Gillette, Procter & Gamble, and those joining the Auto-ID Centre, now GS1, are also examples of early adopters.

Early majority are, as the term implies, the majority in a given market. They are cautious when taking risks. As such, they take measured and incremental steps when adopting new technologies. In contrast to early adopters, early majority organizations pay more attention to standards, support, and reliability of the technologies. They want the whole product, not just a generic product that is not easily adopted or integrated. By doing so, the early majority are minimizing disruption to their existing operations. As such, they see early adopters as potentially disrupting partners in their industry. This view explains why early majority organizations are not keen to reference early adopters in their buying decisions.

"From [the early majority's] point of view, [early adopters] are the people who come in and soak up all the budget for their pet projects. If the project is a success, they take all the credit, while the [early majority] get stuck trying to maintain a system that is so state-of-the-art no one is quite sure how to keep it working. If the project fails, [early adopters] always seem to be a step ahead of the disaster, getting out of town while they can, and leaving the [early majority] to clean up the mess" [23] p. 59.

Another characteristic of the early majority is their sensitivity to price. Moore describes the early majority as reasonably sensitive to price [23]. However, they are willing to pay more for better quality compared to most of the late majority. Therefore, Moore suggests right pricing as the basis to motivate the mainstream [23]. In RFID/SC, the cost of implementation is a key consideration factor to the mainstream suppliers. As previously discussed, suppliers are building business cases to support their investments. If the rewards are not attractive, it would be difficult to motivate this channel. This brings us back to the fundamentals of the RFID/SC. There is a need to look at the technological barriers to the adoption of RFID/SC in order to address the chasm that sets these two groups apart. Resolving the barriers will attract the mainstream to consider RFID/SC. This means that the development of RFID and EPC is critical to mass appeal. Only when the technologies are reliable, proven, and of relatively low price will they attract mass attention. Therefore the developmental priority should be the reliability and efficiency of the manufacturing process [28]. At present, the development is driven mainly by institutions and partly by governmental policies, or non-market factors. Some of these factors motivate the market while others impose political and economical implications [36]. Next, we look at four barriers identified by most researchers as the primary impediments to RFID/SC adoption.

## 5 The Barriers

The most frequently cited barriers in RFID/SC articles are standards [3], [22], [32], cost [22], [24], [32], reliability [1]-[2], [32], and privacy [10], [14], [16]. The rest of this section explains the barriers.



## 5.1 Standards

The use of the Industrial, Scientific, and Medical (ISM) radio bands for RFID has posed a challenge to the global supply chain. Radio spectrum resource is limited and controlled by the governments in different countries [22]. There is a need to align the frequency usage for RFID so that the RFID system can interoperate in different countries. The worldwide use of the ISM bands for other wireless applications and the lack of restrictions to the type of applications used have made it challenging to find a slot in the band for the international alignment of RFID. For instance, today, it is not uncommon for any one piece of equipment to structurally integrate different technologies, each of which could be adopting different frequency band(s) and/or standard(s). And yet in its entirety, the equipment operates seamlessly. An example of such equipment that adopts multiple standards that work in unity is the Subscriber Identification Module (SIM) card on any Global System for Mobile communications (GSM) compliant mobile phone [4]. In order to collect information of an item transiting in a global supply chain, there is a need for a distinctive standard not already adopted by any equipment in transit. This is so that there is no interference between the different frequency bands and standards when operating in the same environment. Of utmost importance, is the need to ensure the integrity and accuracy of collected information.

As such, standards are required to read the RFID tag and decode the EPC of an item. Beneath this simple process are a number of standards: the reader and tag interface protocol, EPC numbering structure, data encryption method, etc. To ensure that RFID and EPC work seamlessly and effortlessly, EPCglobal, an international subscriber-driven organization aimed at enhancing RFID standards, sets forth to define the standards so that any EPC compliant devices can interoperate. These standards, collectively known as the EPC Network, are driven by industry. It comprises the EPC, reader/tag interface protocol, middleware, Object Name Server (ONS), Physical Mark-up Language (PML), and the EPC information services (EPCIS).

## 5.2 Cost

There are various cost factors when implementing RFID/SC. Besides the cost of the tag, infrastructure setup, systems integration, and training, there are other hidden costs incurred in the course of implementing RFID/SC solutions [30]. As with any emerging technology, where there is still a lot to be uncovered, it is not surprising that many organizations will find it a daunting task to calculate the true cost of implementing RFID/SC to justify a business case and return on investment. An example is the cost of compliance with a RFID mandate [22]. A dramatic drop in the cost of tags, as was speculated, and five-cent (USD) per unit looks to be an economically viable unit price [27], will be much welcomed. Sarma [27] illustrates the steps toward achieving the five-cent goal. He carefully highlights the plausible issues of capacity constraints and price-elasticity. The need to redesign and develop manufacturing processes and machines will certainly delay the fabrication of the tags in high volume [27]. While efforts are visible to bring the cost down, organizations with high inventory turn-over are already looking to pallet or carton tagging to reap the benefit and return on investment [29]. It also makes economical sense to tag on high-value items. However, deploying RFID simply to capture what barcodes are doing does not add significant value [20]. Mary et al. [20] suggest the key to a positive return on investment is a detailed process mapping of the operations and linking the processes and performance metrics used in an organization. Walt [35] suggests addressing the impact of RFID adoption on an organization's marketplace, business strategy, and operating model.

The empirical survey by Vijayaraman and Osyk [34] shows that organizations already pilot testing RFID/SC find that the cost of the tags, hardware, and the availability of these components are the main issues surrounding implementing the technology. Technical problem linked to the reader/tag is another directly related issue. An example of this being the lower accuracy of read-rate [32].

## 5.3 Reliability

Problems such as unreliable RFID read-rate hinder the adoption rate and falter the confidence of users. Smith [29] reveals that at pallet and case levels, the read rate reliability was less than 80 per cent as reported by the suppliers preparing to comply with the Wal-Mart mandate. Another issue is the massive amount of data collected. Angeles [2] reveals that there was a 30 per cent increase in the amount of data when RFID is tagged at pallet and case levels. Organizations will have to determine the level of data integrity, or the granularity required, and employ middleware to filter and manipulate the data. The computer network will have to be able to tolerate the increase in data traffic to avoid downtime that could affect other applications, and the databases used will have to be robust and scalable to handle the data volumes. Another reliability issue is the interference of RF. Alu et al. [1] in their experiment conclude that the reliability of the reader is dependent on the electromagnetic environmental conditions and structures. They note that "when the reader is in the presence of typical noise spikes the energy range is much shorter than the case in which the reader is in a typical outdoor environment" [1] p.106. Every environment has different amount of RF pollution and therefore it is recommended that site surveys be conducted on the physics of the environment [31]. In addition, it is recommended that different type of tags be tested on different products to ensure that the interference caused by the product properties is minimal [30].

## 5.4 Privacy

While standards, cost, and reliability issues are by far non-market related and technical, privacy is seen as an educational issue both internally and externally, with the need to involve relevant legislative authorities. Twist [32] suggests that consumers need to be educated and informed of the new technology. To refute the preconception of tracking personal information, he argues that retailers are already using information collected from credit cards for forecasting sales and buying behaviors. RFID/SC is simply another data collection tool for tracking only the flow of an item. Sarma [28] also draws the attention of privacy violation to other RFID applications such as the electronic toll collection which in fact has a much longer read range. He argues that EPC is designed to be simple with minimum functions, and thus, inexpensive, adding that "EPC has safeguards to protect the consumer" [28], p.49. Other advocates of privacy raise the importance of legislation to protect consumers and that the retailers are to abide by the public policy [14], [16]. EPCglobal has issued guidelines on EPC for consumer products. The guidelines in brief state that consumers are to be given clear notice of the presence of EPC on products they purchase and given the choice to discard or remove the EPC tags. The EPCglobal guidelines assure consumers that EPC "does not contain, collect or store any personally identifiable information" [8].

## 6 Conclusion

This paper has presented a chronological view of the effects of the RFID mandate which provides useful information to managers planning on a RFID/SC project. The first tier is the rush to comply with the mandates. This may result in hasty implementation of RFID. The second tier is the integration of RFID into existing systems after complying with the mandates and the third tier is the formation of new operating processes as a result of the integration. The findings are summarized in Table 1.

From a macro view, the RFID mandates have spawned various differing views of RFID/SC implementation. We identified the reasons for the different views using the Technology Adoption Life Cycle. The model explains that there is incompatibility between the early adopters and the early majority. We highlighted the incompatibility and called for more research in the standards, cost, reliability, and privacy issues so that RFID/SC picks up its pace within mainstream users and organizations. There is also opportunity for more research on the upstream of the supply chain to justify more business cases for manufacturers, suppliers, and distributors to adopt RFID/SC.

While this paper involves a qualitative literature and theoretical study, it surveys the work of many researchers in the field. The results are particularly useful to managers and researchers wanting to extend the body of knowledge. It is essential to note that this study offers a simplified view of a multifaceted technology adoption in the supply chain management. As such, there are factors that are not discussed here but might be critical within your context, such as government policy, market competitiveness, and corporate values, to name a few. We hope that researchers will extend the knowledge using these guidelines to support managers in the adoption of RFID/SC as well as to validate the findings put forth in this paper.

Table 1: Summary of the Effects of RFID Mandate

1.	Know the technology and learn about how it fits in your supply chain
2.	Focus on your competency and extend the implementation across the supply chain
3.	Plan for enterprise wide implementation in the beginning to minimize costly rework
4.	Decide on the type of information and how it should be reported
5.	Beware of a likely shift in your operations and have a process in place to mitigate the disruption
6.	Be knowledgeable about your retailer-supplier relationship to position your strategies

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