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AN EMPIRICAL STUDY OF POTENTIAL USES OF RFID IN THE APPAREL RETAIL SUPPLY CHAIN

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An Empirical Study of Potential Uses of RFID in the Apparel Retail Supply Chain

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An Empirical Study of Potential Uses of RFID in the Apparel Retail Supply Chain

EXECUTIVE SUMMARY

Phase I of an empirical study of potential uses of radio frequency identification (RFID) in the apparel supply chain was conducted in the fall of 2010. This Phase of the research was designed to identify potential use cases for the use of RFID in an apparel supply chain and was funded by GS1 US and the American Apparel and Footwear Association (AAFA). The three-phase Supplier ROI study is commonly referred to as the Many-to-Many study. Phase II will involve the measurement of ROI for select use cases identified in Phase I. Phase III will study the effect of RFID on multiple suppliers simultaneously through an experiment.

The use cases were solicited from a wide range of companies, in several different countries, in many different types of facilities, and thus reveal where the industry collectively believes the greatest RFID benefits reside. Over a period of several months, we collected more than 60 use cases.

The findings of Phase I show that the potential benefits of item-level RFID in the apparel supply chain reach beyond the retailer and include apparel manufacturers. To begin, improved backroom-to-shelf replenishment and greater perpetual inventory (PI) accuracy, which result from RFID are shown to offer manufacturers the opportunity *to increase top-line sales*, due to higher product availability at the retail shelf.

Not surprisingly, we found that RFID offers manufacturers the opportunity to *improve inbound and outbound operations* at all echelons. By implementing RFID, the supply chain can undertake scanning as each carton crosses the dock door at any location, which should substantially *decrease the number of touches per carton*. Because labor accounts for the largest portion of variable costs in an apparel distribution network, RFID is quite promising in terms of *labor cost reduction*.

Item-level RFID tagging also offers apparel manufacturers the ability to *audit the contents of each carton* being shipped to its retail customers through an automated audit process, such that *the apparel manufacturer can find errors in the redistribution process prior to those errors being found by the retail customer*. This step ultimately *reduces the deductions or chargebacks* from the manufacturer's customers.

In addition, RFID can *reduce inventory-related costs* throughout the apparel supply chain by *reducing ordering costs* in the form of *reduced shipping and receiving costs* and *fewer errors associated with shipping and receiving*. As the ordering costs decline due to RFID business processes, the optimal time between orders shortens, and the optimal frequency of orders increases. Thus, *cycle stock is reduced*. Furthermore, RFID improves PI accuracy, which means that it *reduces stock safety* levels throughout the supply chain.

Our use cases also suggest that is it reasonable to speculate not only that RFID could reduce safety stock and cycle stock but also that it would *reduce the cost of carrying inventory* per se, through the reduction of inventory risk, due to lower levels of shrinkage and obsolescence.

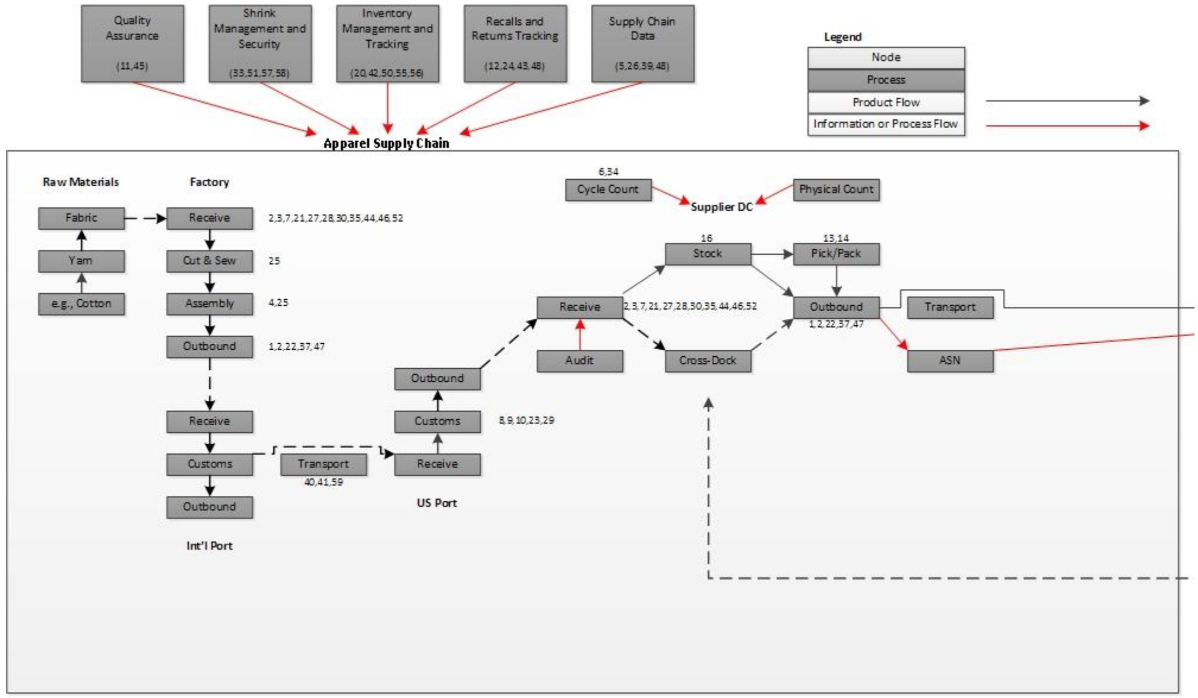
Furthermore, the use cases suggest it is conceivable that tracking and tracing due to RFID will enable *continuous quality improvement* and thus result in *fewer return-related costs and markdowns*. By enabling tracking and tracing, RFID has the potential to *reduce the cost of compliance with free trade agreements* and improve customs processes.

For the most efficient overview of our findings, you can look at the Apparel Supply Chain Map of Use Cases Figure on the following page along with the Table following it, as a summary of our findings of use cases in the apparel supply chain. The map of business use cases is identified according to the locations the participants indicated that RFID could potentially create benefits within their supply chain. The legend to the numbers on the map can be found in the Table following the map.

The map allows a particular use case to appear at multiple locations on the supply chain map, because certain business problems for which RFID may solve or create benefits can occur at multiple points in the supply chain. Further examination reveals that the business use cases should enhance multiple business processes at each node in the supply chain.

There are many claims about RFID and how it will improve some process or reduce some cost but without explanation as to how it might do so or why it might do so. In this white paper we explain the logic behind the how and why regarding selected causal relationship between RFID and various costs and processes. These explanations extend beyond the apparel supply chain and are needed in our dialogs.

Finally, in the last Section of the main body of the document, we discuss the need for visibility and how it improves performance. We also discuss the need for adoption of standards around identification, capturing, and sharing, information. This is critical for successful adoption and implementation. In fact, we argue it is necessary for successful management of logistics and supply chain management, in general. We recommend that industry consider not waiting until EPC-enabled RFID item-level tagging is fully implemented to begin implementing sharing standards around physical event data. There are two reasons for this: (1) data is already available and not fully utilized, and (2) when EPC-enabled RFID grows in adoption, the benefit of the additional data that is captured can be realized more quickly.



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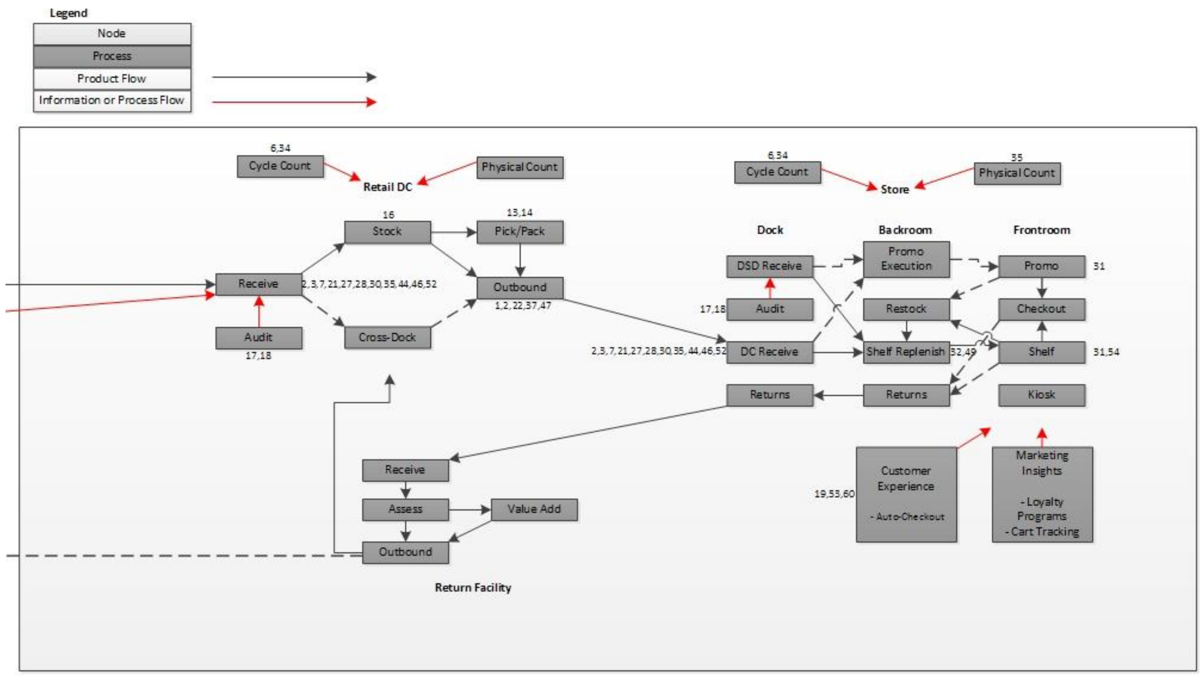

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No.	Apparel Use Cases	No.	Apparel Use Cases
1	Outbound automation	31	Plan-o-gram compliance
2	Inbound and outbound audit processes	32	Shelf replenishment
3	Electronic proof of delivery	33	EAS consolidation
4	Right tag on product	34	Reduce cycle count time
5	Supply chain data quality	35	Receiving accuracy
6	Could eliminate audits & manual inventory	36	Eliminate physical inventory counts
7	Smart inspect	37	Carton accuracy
8	Country of origin	38	3rd party consolidation efficiency
9	FTZ (Free Trade)	39	Increased store PI accuracy
10	Trade agreements	40	Country specific shipping documentation
11	Traceability through supply chain	41	Country specific care labels and placement
12	Track deffectives & recalls	42	Inventory tracking within DC
13	Pick/ pack speed	43	Prodcut recall
14	Pick/pack accuracy	44	Electronic proof of delivery
15	Detail of available data	45	Counterfiet tracking
16	Item level data	46	Inbound quality
17	Claims accuracy	47	Outbound quality
18	Potential to eliminate claims	48	PI accuracy
19	Brand visibility in store (integrated)	49	Shelf replenishment
20	Speed and accuracy	50	Dormant inventory reduction
21	Inbound quality	51	Reduce shrink
22	Outbound quality	52	Electronic proof of delivery
23	FTZ and first sale	53	Shopper item interest vs. purchase
24	Track returns	54	Density and space planning
25	Tracking through processing areas	55	Multi-channel inventory management
26	Drive accurate costing	56	Inventory tracking
27	Vendor pack accuracy	57	Security and shrink reduction
28	Case pack accuracy	58	Shrink due to employees
29	Source validation	59	Accurate export documentation
30	Shipping validation	60	Store to store transfers

An Empirical Study of Potential Uses of RFID in the Apparel Retail Supply Chain

1. INTRODUCTION[1]

Background

During the fall of 2010, researchers from the University of Arkansas conducted Phase I of a study designed to collect potential cases for the use of radio frequency identification (RFID) in an apparel supply chain. The study is funded by GS1 US and the American Apparel and Footwear Association (AAFA).

The use cases were solicited from a wide range of companies, in several different countries, in many different types of facilities, including sewing, assembly, distribution, knitting, finishing, distribution, and others. This collection of use cases is an indication of where the industry collectively believes the greatest RFID benefits reside. Over a period of several months, we collected more than 60 use cases.

Research Method

In the exploratory Phase 1, a multiple method approach serves to clarify the potential business value of RFID, specifically for apparel manufacturers. The multiple research methodologies employed include site visits, use case collection, in-depth interviews, extant literature reviews, case studies, logical deduction, and the application of existing theoretical frameworks.

Scope

Previous research published by the University of Arkansas's RFID Research Center has focused on measuring the quantitative determinants of retail inventory accuracy, such that the results often represent a certain increase in the percentage return on investment (ROI). In contrast, this study presents a qualitative collection of observed business processes, or use cases, in which RFID might provide key benefits to apparel suppliers. This is an important precursor to any field experiments or large scale empirical studies.

The term RFID, as applied throughout this document, refers to the use of readers and tags to capture and leverage a standard electronic product code (EPC). Therefore terms such as EPC-

[1] Throughout this document we will use footnotes to clarify terms and concepts as well as to provide additional technical detail. If the concepts are understood, or if the reader wishes to ignore some of the technical details, then the footnotes can be skipped, without loss of understanding. We decided to include as much as possible in the footnotes to help the reader understand the concepts and to prevent the reader from having to look up various concepts. We recognize that readers of this manuscript come from many different backgrounds, so we attempted to clarify industry jargon. The footnotes are also used to explore a few ideas that might appear to be tangential. We also recognize that there are a few technical issues addressed in the footnotes that will only be appreciated by a few readers. We decided to leave them in the footnotes because (1) they can easily be ignored by those who are not interested in the specific technical detail, and (2) they are substantive to the meaning of the concept for a technical reader. There are only a handful of instances of these highly technical notes in this manuscript.

RFID or EPC are encompassed within the umbrella of RFID in general, and the overarching reference will be used globally throughout this paper.

To further understand the scope of this research, consider the GS1 US Visibility Framework (June 2010).

Figure 1: The GS1 US Visibility Framework[2]

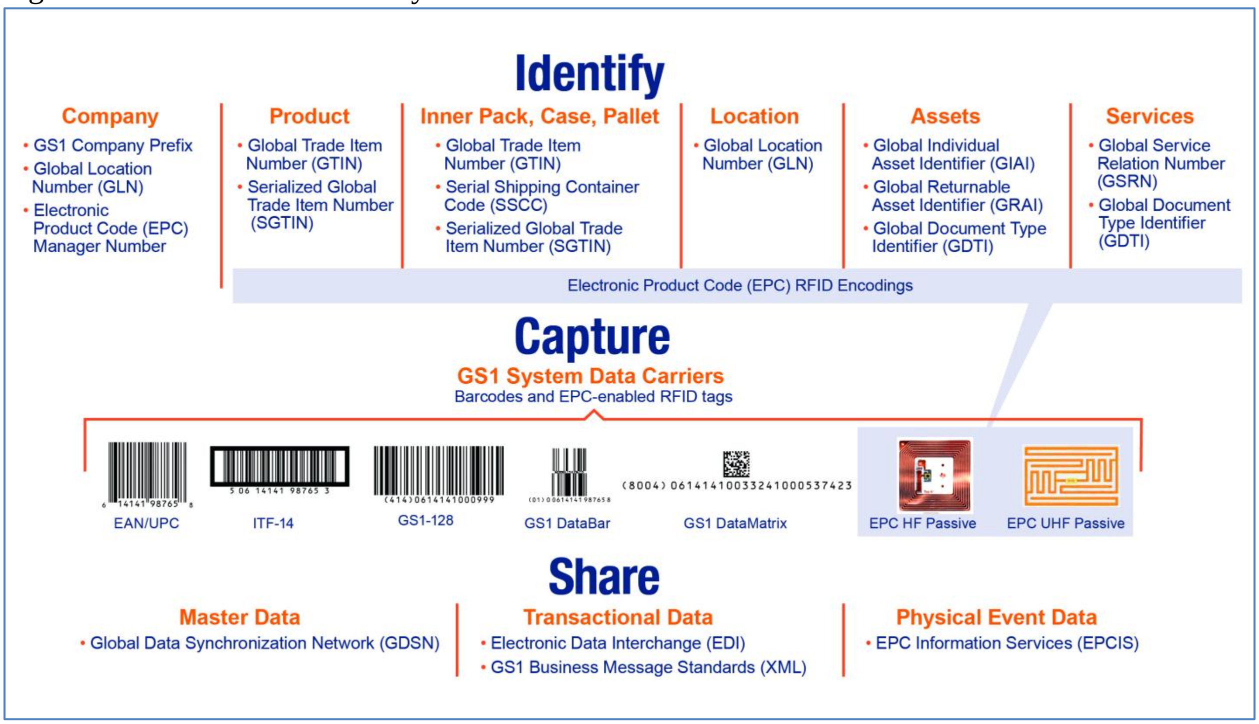

Figure 1 is the GS1 US Visibility Framework, which includes the three salient abilities associated with visibility: Identify, Capture, and Share. Throughout the visits, we were attempting to identify ways RFID could be used to identify, capture and share, information in unique ways that would provide visibility that could lead to improved performance. Towards the end of this document, we explicitly return to the concept of visibility.

Phases of the Research

The completion of Phase 1 produced a set of potential use cases of RFID for suppliers. The three-phase Supplier ROI study (commonly termed the Many-to-Many study) also contains Phase II, which will achieve a practical measurement of ROI for select use cases, and Phase III, which will look at the effect of RFID on the interplay among multiple suppliers providing RFID-tagged products to multiple retailers, as well as the effect of this many-to-many dynamic on RFID implementation.[3]

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[2] See GS1 US's White Paper, "The GS1 US Visibility Framework." http://www.gs1us.org/DesktopModules/Bring2mind/DMX/Download.aspx?EntryId=2969&Command=Core_Download&PortalId=0&TabId=73

[3] Most of the potential benefits of Phase I and Phase II would be categorized as continuous improvement since it would involve taking current business processes and applying RFID. However, even in Phase I, as can be seen in this white paper, there are a few ideas that came out of the study of potential use cases that can be categorized as

Visits to Identify Use Cases

Suppliers visited during Phase 1 to gather use cases were not chosen at random, but they nonetheless displayed significant diversity in their scope and the range of their operational excellence. High levels of dependence on sophisticated technology were observed during the visits, as were entirely manual processes—and sometimes both methods were used by a single supplier.

The use cases were collected from a variety of suppliers currently engaged in mass tagging operations for large retailers, as well as from suppliers not yet practicing RFID tagging. University faculty and staff visited at least one facility within each supplier's supply chain, many located outside the United States.

Further, replenished inventory items, not fashion items, were the focus of Phase I, for two primary reasons. First, most suppliers currently engaged in RFID only tag replenishment items. Second, a vertical investigation of item and process flows is more pragmatic in the replenished apparel supply chain.[4]

Integrated Conceptual Framework

Apparel manufacturers use supply chain processes to manage the flow of products and information throughout the supply chain. These supply chain management processes span the many internal functions of an apparel manufacturing organization, from logistics, purchasing, and production to suppliers, customers, and ultimately consumers. Supply chain management processes also include the functional area of the apparel manufacturer's business, as well as its inter-organizational links with suppliers and customers. Therefore, this study uses a supply chain–oriented framework to understand and communicate RFID's role in the apparel supply chain. See Figure 2 for an overall depiction of this framework.

In Figure 2 you will see that there are four columns: (1) Forecasting, Inventory, and Transportation, (2) Product Quality, (3) Supply Chain Documentation, and (4) Labor. These are the cost areas for which our findings can be grouped. You will also notice in Figure 2 that there are five rows: (1) Order Fulfillment, (2) Customer Relationship, (3) Supplier Relationship, (4) New Product Development, and (5) Sustainability. These five rows represent cross functional and/or inter-company business processes that affect or are affected by each of the functional cost domains in the columns. The purpose of presenting this up front is to emphasize the interrelationships of the use cases. As we present them in the paper, the reader could erroneously think of them in isolation when in fact they are a part of a complex system of causes and effects. We do not have room to elaborate on all of these interconnected relationships but we do point

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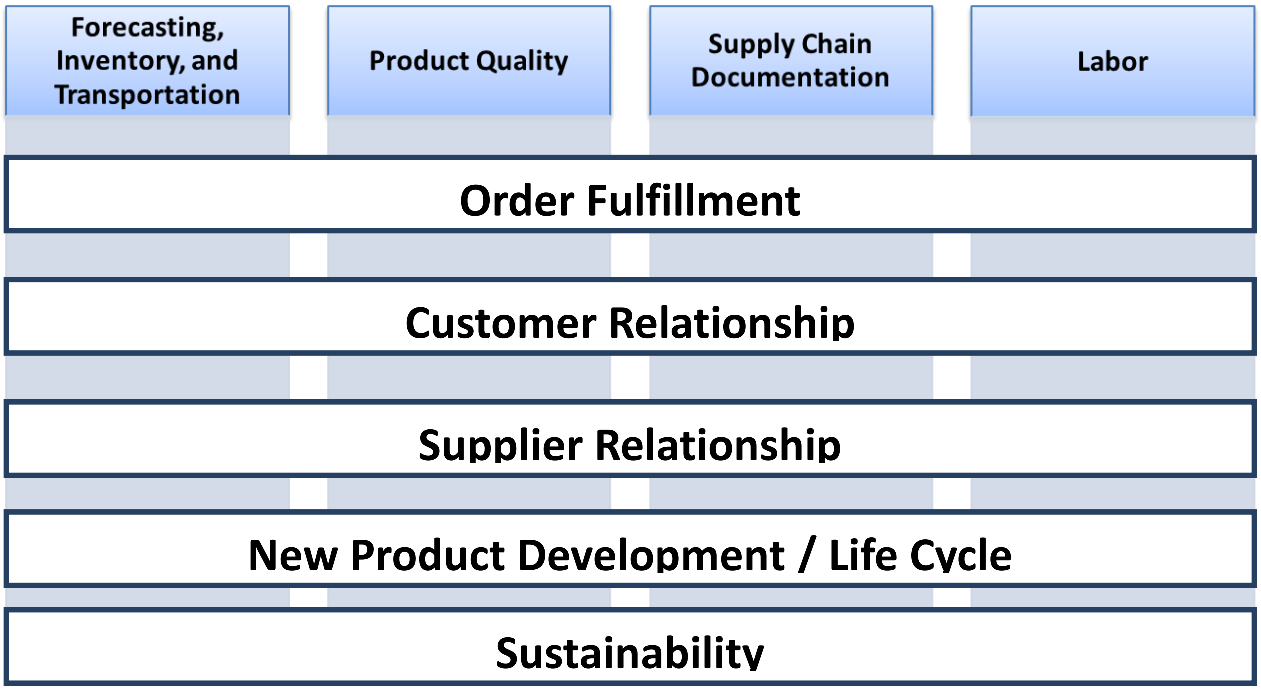
breakthrough improvements. Breakthrough supply chain reengineering opportunities would be the focus of a Phase III study. Finding potential "quick wins" in Phase I is an important part of an effective change management process.

[4] The most salient challenges facing the replenished apparel supply chain are quite different from the fashion apparel supply chain. Perhaps a set of parallel studies should be conducted on the fashion apparel supply chain. Later in the paper, we spend more time differentiating between the two types of supply chains. It is important that the reader not take findings of this study and assume that they directly apply to the fashion apparel supply chain.

out a few of them. Instead, this paper focuses on them in isolation, in most cases. A thorough and careful discussion of all of these relationships could be included in a future study.

Figure 2: Supply Chain Process Framework



Prior to this point, most item-level RFID apparel research has focused on the potential benefits for apparel retailers (Hardgrave 2009; Hardgrave, Miles, and Mitchell 2009; Miles, Mitchell, and Hardgrave 2010), with little attention to the likely benefits of item-level RFID tagging for apparel manufacturers. This study therefore evaluates potential business uses of RFID solutions in the apparel supply chain, focusing on applications that involve tagging at echelons[5] above the retail store.

A key functional area with regard to potential RFID benefits is the logistics function. Logistics refers to the management of the flow and storage of inventory, with the goal of minimizing total costs even while achieving customer service targets. Thus, we examine various ways that item-level tagging might affect total logistics costs, which consist of the combination of inventory holding, transportation, labor and handling, lost sales and backorders, ordering, warehousing, recycle and reuse, packaging, tracking and tracing, customs clearance, and compliance costs. Many of these costs involve trade-offs; that is, they cannot usually be eliminated, so the goal is

[5] "Echelon" is a term used throughout this paper. There is a difference in meaning between a level of a supply chain and an echelon of a supply chain. For example, at a DC-level of a given retailer's supply chain, there is a DC and all of the stores served by that DC. As another example, from a supplier's perspective, at the account level of the supply chain, it would include retailers' DCs and all of the stores served by those DCs. Just for clarification, a supplier's DC echelon would include those DC's, all of the retailers' DCs and stores served by those supplier's DCs.

to minimize total costs. In this context, customer service targets might be defined narrowly, such as item fill rate, or broadly, such as customer satisfaction.

Supply chain management in turn integrates business processes across functions and companies. Such integration often allows firms to overcome existing logistics cost trade-offs and provide higher service at lower costs. Using a supply chain management lens, we collected use cases that span multiple strategic issues and thus address the impact of item-level tagging on supply chain security, as well as the potential upstream benefits of improved store execution and visibility.

Clarity Regarding Experiments

Beyond describing potential business uses, benefits, and costs of upstream item-level tagging, we hypothesize about how costs and benefits accrue; in certain instances, we also broadly propose potential tests of these hypotheses. Large-scale field studies and experiments are necessary to develop generalized benefit estimates, which is not the purpose of Phase I. However, this study makes the potential experiments and field studies more apparent.

Processes and Information

The potential for successful implementation also must be considered. For example, could RFID enable a reduction in ordering-related costs, which would reduce the required cycle stock? This possibility raises a couple of questions: Will the reduction in ordering costs be taken into account when setting order quantities? If not, then the estimated reduction may simply come in the form of ordering costs, not inventory reduction. Moreover, to take full advantage of such a benefit requires the ability to implement more than RFID-related, cross-functional processes. Such an implementation in turn is often a function of change management. The ease of change management itself depends on the corporate culture and varies greatly. Because the capabilities observed ranged widely across the suppliers we visited, it seems likely that existing legacy software and systems architecture place some suppliers at an advantage in terms of having a supporting structure that is more open to accepting RFID data.

Furthermore, RFID may enable continuous quality improvements in the apparel sector, which then leads to a similar question: Does the information provided by supply chain tracking and tracing really get used to achieve continuous quality improvements? Realizing these and other types of benefits requires the design and implementation of new business processes or improvements to existing business processes. That is, processes must account for the new information, because the "real value of these data is in leveraging this information to make better business decisions" (Delen, Hardgrave, and Sharda 2007, p. 623).

Such challenges are typical and critical to the long-term success of RFID. Studies cannot simply estimate the magnitude of benefits through experiments and field studies; rather, they should address the new business processes that might be enabled through RFID within the apparel supply chain. To provide an initial response to this call, we address the issue as it appears in several use cases.

Although we raise some implementation issues and contemplate possible new processes, these outcomes are not the primary purpose of this white paper, nor do we focus on implementation issues per se. Use cases cannot be discussed fully without speculating about business processes. To that end, the details of the business processes presented herein serve simply as examples. The most appropriate business process needs to be tailored to the specific manufacturer.[6]

One thing evident from all of our visits to stores, distribution centers, assembly facilities, sewing shops, finishing areas, cutting plants, dying nodes, and knitting and weaving plants was that even when processes have similar characteristics throughout the apparel supply chain, the specifics of the internal business processes vary substantially from one manufacturer to the next. The amount of variance was truly surprising. Consequently, we recognize and highlight the need for a generalized identification of use cases, which we attempt to provide in this white paper.

Exploratory Research

We used exploratory research methods, such as in-depth interviews and individual case studies of each process observed through the supply chain. This approach represents an important precursor to any large-scale field study or set of experiments and ensures that more rigorous and detailed studies get conducted in the appropriate areas, as well as that no important opportunities get overlooked.

On each visit to each facility, we tried to interview as many individuals as possible. We found that questioning each step of a process often revealed an evolution that reflected practical restrictions, such as the layout of a preexisting building and the available floor space, or taxation agreements that enforced inefficient material routing. More than one supplier we visited was forced to split its sewing process into two geographically separate facilities in the same country to take advantage of both taxation and labor rates. Such geographic separation often highlighted infrastructural inequalities within the region, creating further and additional hurdles.

However, with this paper, we do not mean to presume or imply that RFID is a panacea for the entire complex network of supply chain processes and partners found in replenished apparel supply chains. We simply establish a central repository of observed use cases that can be influenced by RFID, including their relationships with the processes surrounding them.

2. APPAREL SUPPLY CHAIN

The apparel industry represents a rather complex supply chain. Most supply chains in this industry are unique, though some similarities mark them. Figure 3, which we present later in this

[6] Two companies can be in the same industry, serving the same set of customers, in the same retail category, and yet have significantly different manufacturing processes. There are many possible reasons for this and this paper will not delve into these reasons. However, an example of one of the reasons has to do with the culture of the company. For example, it might be that in a hierarchical organization that more of an assembly line design with a focus on specialization of labor, might work best; whereas, in a decentralized, less formal organization, cellular manufacturing might work best. The point of this brief discussion is simply to explain why some of the business processes discussed are simply examples and would need to be customized to the specific company attempting to implement the new RFID-enabled business process.

paper, represents a generalized view of an apparel supply chain. These chains are both global and domestic, depending on the specific items, manufacturers or retailers involved. Inventory flows through domestic and global supply chains differently. For example, some manufacturer–retailer combinations send inventory from production facilities to supplier ***distribution centers*** (DCs) to retailer DCs and finally on to the retail store. Others move inventory to the retail store directly from the factory. Finally, retailers usually have multiple channels of distribution. For example, a retailer may have "dot.com" site and mobile channels, in addition to traditional brick-and-mortar retail stores, and some retailers maintain multiple brick-and-mortar store formats. Therefore, the various retail channels and formats, together with the multiple methods of moving inventory through the supply chain, result in a vast number of possible combinations. We use the generalized supply chain map to understand the aggregate business use cases, with the caveat that their individual supply chains will differ to some degree from Figure 3.

The apparel supply chain contains two structures that demand consideration: the replenished apparel supply chain (RASC) and the fashion apparel supply chain (FASC). Examples of items in the RASC include underwear and intimates, that is, items that are produced year round and whose styles do not change much from year to year. Orders for items in the RASC usually are based on inventory positions[7] at the retail echelon of the supply chain, and stores often receive their replenishments from inventory held in the ***retailer's distribution center*** (RDC).

Examples of items in the FASC instead include dresses, winter coats, and sweaters. These items have styles and colors that change from season to season or year to year. Demand often is estimated 12 to 18 months or more in advance of actual demand, ordered from overseas suppliers, shipped into country, and then pushed to RDCs and stores. The most significant costs include markdowns, shrinkage, transshipments[8], and the cost of lost sales. Furthermore, one of the most significant challenges in the FASC is the ability to forecast size/color/style combinations well in advance of any sales. Overall then, the complexity of the logistics decisions in the FASC is greater than that of the RASC.

However, even the RASC tends to be more complex than other consumer goods, because few apparel manufacturers own their own manufacturing facilities, and most contracted manufacturing facilities are offshore. Manufacturers ship inventory into their U.S. distribution network, which likely includes a national or set of regional distribution centers, and then sends it on to RDCs, which replenish the retail stores. Because apparel manufacturers typically do not own their production facilities, they often outsource assembly to producers with very low barriers to entry.

Furthermore, apparel manufacturers generate the preponderance of their profits from design and marketing features, including their brand equity. Some apparel manufacturers, especially those in the RASC, appear especially interested in reducing costs because the value of their brand equity

[7] Inventory position is equal to the amount of inventory on hand plus the amount of inventory on order minus the amount of inventory on backorder. Inventory position might be used in a system with a reorder point, a reorder time, or some combination of the two.
[8] For example, if inventory is sent from one store to another to balance inventory, that is referred to as an inter-store transshipment.

is not as high as it is for their compatriots in the FASC, nor as high as it has been in the past.[9] Thus, the appeal of RFID strategies to apparel manufacturers in the RASC involves both the potential for cost reduction and top-line revenue growth.

The contract manufacturers that assemble RASC inventory will use RFID—if they are required to do so and receive sufficient compensation.[10] Otherwise, they are generally indifferent, because the globally competitive nature of the contract apparel industry offers them very low profits, and business comes and goes over time with few guarantees. Yet there is a twofold value proposition for contract manufacturers. First, RFID could offer significant value through improved inventory control practices. Second, it is possible that a contract apparel manufacturer could differentiate itself by demonstrating its RFID capabilities and thus secure more profitable contracts.

Textile or fabric manufacturers represent the next echelon in the apparel supply chain. They are more capital intensive and confront higher barriers to entry, which allows them to earn higher profits. Textile manufacturers include companies that take cotton, silk, and wool and spin it into yarn. These same companies might take the yarn and weave and knit it into fabric, or they may send their yarn to other specialized fabric producers. Still others take petroleum or chemical products and produce petrochemicals for manufacturing synthetic fibers, woven into fabric or mixed with natural fibers for weaving and knitting. If there is business value in tagging the lots of natural or synthetic fibers, when the yarn gets spun, each lot could be tagged. The identity of the fiber lot then could be associated with[11] the tagged yarn lot, allowing for tracing and tracking. Similarly, the lots[12] of fabric could be tagged, such that the lots of yarn and synthetic fiber used in their manufacture might be clearly associated with the lot tag in a database. The result would be potential logistics cost reductions, though perhaps the more significant opportunity entails marketing benefits. A textile company offering RFID capabilities that can trace the lots of natural and synthetic fibers allows the apparel supplier to exploit this information in its marketing strategy. In the long run, this information might even represent a necessary condition for competing. For example, if consumers come to expect this level of visibility, additional entry costs would be created throughout the apparel supply chain, which in turn might increase profits throughout the supply chain. Thus, some of the cost savings secured at the lowest levels of the apparel supply chain might be counterbalanced by additional profit reaped at higher levels. Finally, beyond a marketing strategy, there could be regulatory measures that necessitate RFID throughout the supply chain.

Previous apparel studies already have documented the benefits of RFID to retailers. Published studies of large companies such as Dillard's, Bloomingdale's, and JCPenney have calculated the significant benefits. In particular, these studies indicate store inventory accuracy improvements ranging from approximately 5% to 27%. The use of RFID also substantially reduced cycle time (96% less time in the Dillard's study) and positively affected out-of-stock situations, due to the improved inventory accuracy.

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[9] The top 100 brands for 2010 based on Interbrand's ratings, does not include any firms in the RASC. There are three apparel companies on their list of the top 100 brands, but all three are in the FASC. See http://www.interbrand.com/en/knowledge/best-global-brands/best-global-brands-2008/best-global-brands-2010.aspx

[10] To some degree, this is true of nearly everything a contract manufacturer does, by definition. That is, they produced based on a contractual agreement.

[11] This association would be within the database.

[12] We use the term "lot" to refer to batches.

Because it is already clear that many retailers can make significant gains at the store level by using apparel RFID, they have a greater incentive to contract for RFID capabilities throughout the apparel supply chain. Perhaps there is thus an opportunity for modern apparel retailers to be the first to create an RFID branding strategy. Such a strategy might include a claim such as, "we know where every fiber in this shirt came from." Whether such a strategy would work is an empirical and strategic fit question. Yet a retailer would enjoy less risk with such a strategy, because if it failed, the retailer at least gets to enjoy the reduction in store logistics costs. If the strategy fails for the supplier, no cost-level savings offset it, though perhaps there are costs at other points in the supply chain that provide savings.

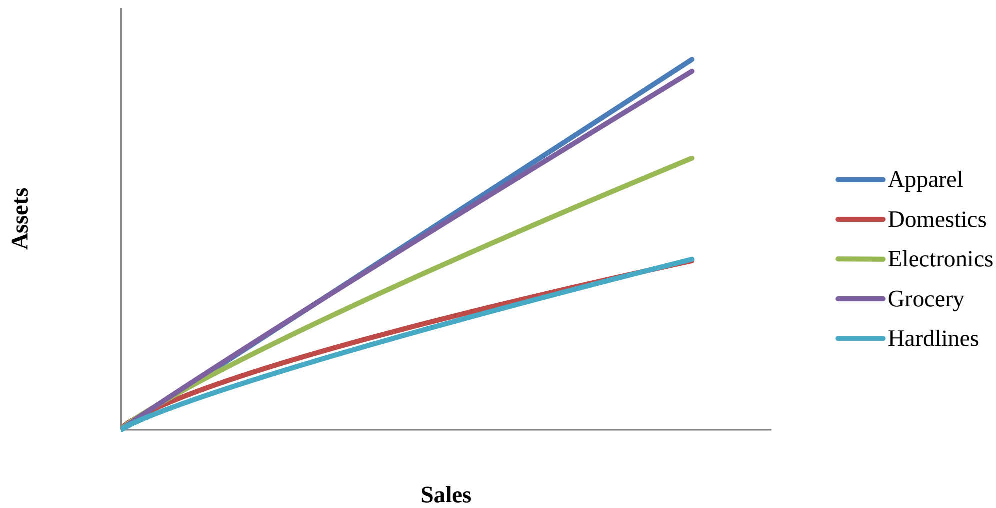
Overall then, the apparel industry seems poised to offer a significant opportunity for expanding the use of RFID. First, many retailers have piloted RFID programs and achieved substantial successes (e.g., Bloomingdale's, Dillard's, JCPenney). Others such as American Apparel and Walmart are in the midst of implementing its widespread use. Collectively these retailers are in a position to not only drive RFID adoption but also increase the supply chain benefits of RFID use by apparel manufacturers, such as through collaborative efforts to create significant standardization in its usage and processes across the industry. Second, apparel has exceptionally high read rates, often reaching 99.9% accuracy. Such a high degree of accuracy yields reliable data that can be used to enhance supply chain benefits for all partners.

Ultimately, apparel manufacturers may have more to gain than any other set of manufacturers, considering the operating efficiencies of other manufacturing industry segments today. To estimate the operating efficiency levels of various consumer product manufacturing segments, we collected publicly available data that spanned the apparel, domestics, electronics, grocery, and hardline segments, with sales and assets by quarter for each firm. The sample was taken over an 11-year period, from 1999 to 2009, and resulted in 44,047 firm–quarter observations. From these data, we estimated efficiency frontiers[13] for each industry segment. In Figure 3, in which we depict the resulting efficiency frontiers (i.e., estimated required total assets necessary to generate sales), apparel manufacturers are the least efficient. From Figure 3, it thus is clear that in general, apparel manufacturers require the highest level of assets to generate sales, compared with other groups of consumer product manufacturers.[14] Thus, they also offer the greatest relative opportunity to improve business processes through the use of RFID.

[13] In this specific meaning of the phrase "efficiency frontier," if a firm is using its assets as efficiently as the average firm in the industry for its given level of sales, then it would be on the efficiency frontier. So, in comparing these industries we get a sense of how efficiently each industry uses its assets to generate sales. The relationships we estimate are nonlinear to allow for economies of scale.

[14] Let $S = Sales$, and $A = Assets$. We estimated the functional form $A = \alpha S^{\theta}$ for each industry in the Figure. To estimate this, we first took the natural log of both variables to get $lnA = ln\alpha + \theta lnS$. We then used ordinary least squares (OLS) regression to estimate $lnA = \beta_0 + \beta_1 lnS + \epsilon$ where ϵ is the random error term. Once this was estimated, then we found α by exponentiation of $\widehat{\beta_0}$, that is $\alpha = e^{\widehat{\beta_0}}$; and we found θ directly from the estimate of $\widehat{\beta_1}$, that is $\theta = \widehat{\beta_1}$. In $A = \alpha S^{\theta}$, α can be thought of as the scale parameter, and θ can be thought of as the shape parameter. The most important parameter is the shape parameter, θ, because it describes how efficiently assets are used in driving sales. Across all industries in our sample, $\theta \in [0.74, 0.99]$, with the apparel industry having the highest estimate. This means that, of the industries examined, apparel is the most inefficient at using assets to generate sales. All five models were significant (p<.001) and had R^2 levels ranging from 0.79 to 0.95. In particular, the model of the apparel industry had an $R^2 = 0.92$.

Figure 3: Efficiency Frontiers of Consumer Product Manufacturers



3. METHODOLOGY

The use cases we gathered included concepts and ideas that pertained to the potential benefits of RFID to suppliers. We solicited the use cases from a wide range of branded apparel manufacturers and apparel retailers in a variety of forums, including relationships formed through organizations such as the American Apparel and Footwear Association (AAFA), GS1 US, and Voluntary Interindustry Commerce Solutions (VICS), as well as retail supplier collaboration groups. The use cases ranged from actual implementations to concepts that had been piloted to conceptual ideas. They were compiled to achieve results that would provide deep insights into where the apparel industry collectively found business value for RFID in its supply chain.

4. APPAREL BUSINESS USE CASES

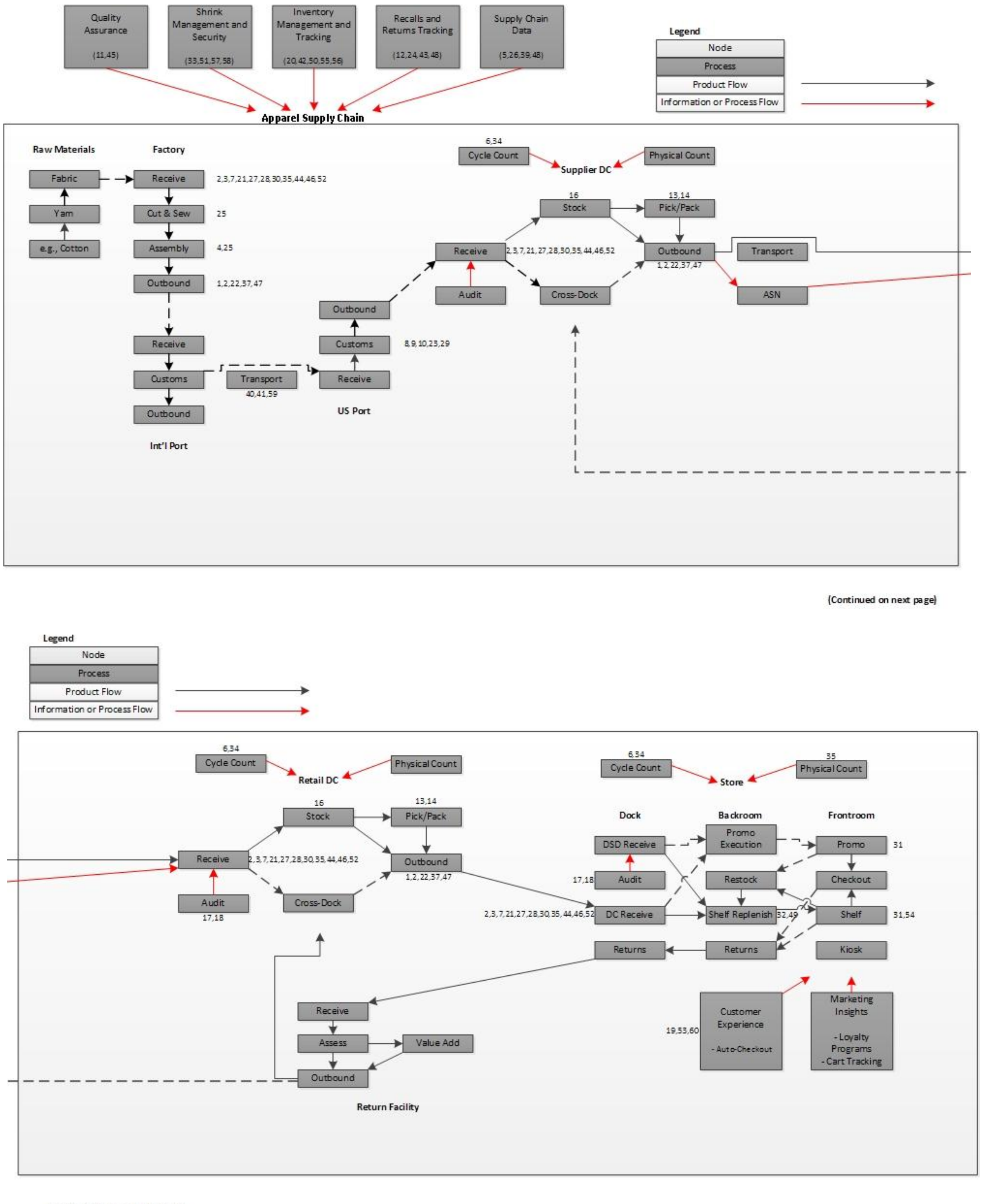
In this section, we present business use cases collected from apparel manufacturers and retailers. We define a business use case as a business problem that could be solved using RFID. As mentioned, these use cases were solicited from a wide range of companies and thus should reveal where the industry collectively believes the greatest RFID benefits reside. Over a period of several months, we collected more than 60 use cases, many of which overlap in nature or seem virtually identical. Instead of collapsing identical use cases, we refer to each as its own use case, because it is important to understand the potential benefits of RFID that exhibit higher levels of saturation across the sample of use cases in the form of higher frequency.

These business use cases spanned events from the raw material to store levels. In this section, we present the cases by overlaying them on a map of the apparel supply chain. Specifically, we map the business use cases according to the locations the participants indicated that RFID could create benefits within their supply chain. The apparel process map thus represents a generalized view of an apparel supply chain, from raw material locations to the retail store. It also includes the significant nodes in most apparel supply chains, where raw materials are sourced and finished goods are produced, on an international basis. Finished goods then get shipped to the United States for sale through the retail channel, which consists of a manufacturer DC, a RDC, and the retail store.

Product flows on the map are indicated by dashed and solid lines that proceed from one supply chain node to the next and from process to process within the specific nodes. We thus can follow a product to the factory from the point where its raw materials are received, then to the cutting and sewing stations, to assembly, and finally to an outbound process by which the finished goods get transported to the port for shipment to the United States. Because it is possible for inventory to flow through different paths within a particular node, the solid and dashed lines indicate different flows from process to process. For example, inventory may flow from the receiving process of the brand owner's DC to either a stocking (put away) location or through a cross-docking process, depending on the brand owner's processes or the type of product considered.

In addition to nodes within the apparel supply chain and the major processes underlying those nodes, we identify a set of additional processes or areas that could benefit from RFID. These processes or areas, such as quality assurance, shrink management and security, inventory management and tracking, recalls and returns tracking, and supply chain data, all apply broadly to the apparel supply chain. That is, they apply to more than one or all of the nodes on the map. Thus, we present them across the top of the figure, such that they are meant to apply across the entire apparel supply chain.

Figure 4: Apparel Supply Chain Map



Each of the collected business use cases are listed by number in Table 1; the numbers then can be applied in the apparel supply chain map according to the node(s) or processes to which each specific use case applies.

Table 1: Collected Business Use Cases

No.	Apparel Use Cases	No.	Apparel Use Cases
1	Outbound automation	31	Plan-o-gram compliance
2	Inbound and outbound audit processes	32	Shelf replenishment
3	Electronic proof of delivery	33	EAS consolidation
4	Right tag on product	34	Reduce cycle count time
5	Supply chain data quality	35	Receiving accuracy
6	Could eliminate audits & manual inventory	36	Eliminate physical inventory counts
7	Smart inspect	37	Carton accuracy
8	Country of origin	38	3rd party consolidation efficiency
9	FTZ (Free Trade)	39	Increased store PI accuracy
10	Trade agreements	40	Country specific shipping documentation
11	Traceability through supply chain	41	Country specific care labels and placement
12	Track deffectives & recalls	42	Inventory tracking within DC
13	Pick/ pack speed	43	Prodcut recall
14	Pick/pack accuracy	44	Electronic proof of delivery
15	Detail of available data	45	Counterfiet tracking
16	Item level data	46	Inbound quality
17	Claims accuracy	47	Outbound quality
18	Potential to eliminate claims	48	PI accuracy
19	Brand visibility in store (integrated)	49	Shelf replenishment
20	Speed and accuracy	50	Dormant inventory reduction
21	Inbound quality	51	Reduce shrink
22	Outbound quality	52	Electronic proof of delivery
23	FTZ and first sale	53	Shopper item interest vs. purchase
24	Track returns	54	Density and space planning
25	Tracking through processing areas	55	Multi-channel inventory management
26	Drive accurate costing	56	Inventory tracking
27	Vendor pack accuracy	57	Security and shrink reduction
28	Case pack accuracy	58	Shrink due to employees
29	Source validation	59	Accurate export documentation
30	Shipping validation	60	Store to store transfers

The business use case mapping process allows a particular use case to appear at multiple locations on the supply chain map, because certain business problems for which RFID may solve or create benefits can occur at multiple points in the supply chain. For example, electronic proof of delivery [3][15] might apply to the factory, supplier DC, RDC, and retail store levels, because RFID can benefit each node by creating an electronic proof of delivery upon receipt.

Further examination reveals that the business use cases should enhance multiple business processes at each node in the supply chain. Of particular note, due to the level of saturation of use cases in this area, the apparel process map indicates that apparel brand owners and retailers believe RFID will enhance receiving and outbound processes at each node along the supply chain. These cases include increased inbound and outbound accuracy, electronic proof of delivery, and improved audit processes, among others. Also, a high concentration of use cases occurs in the international shipping area of the process map, where RFID seems likely to

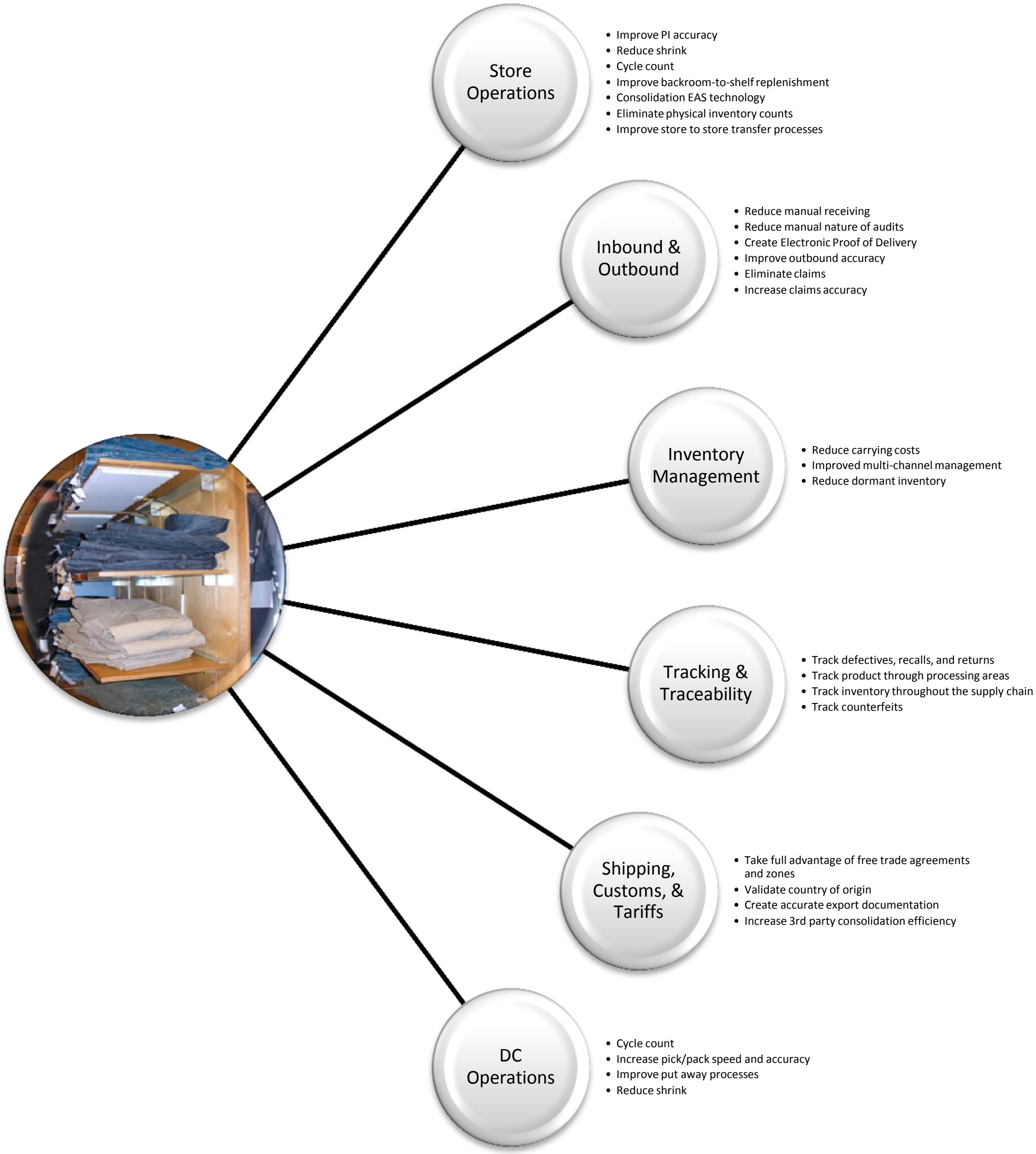
[15] Note the "[x]" is a reference to Table 1, Use Case "x."

enhance an apparel brand owner's ability to capitalize on free trade agreements and determine countries of origin. Finally, the use case map shows that stakeholders believe that RFID will enhance brand owners' and retailers' ability to manage and track inventory, track recalls and returns, and reduce shrinkage throughout the supply chain.

Through comparisons with use cases in other retail industry segments, we realize that these concentrations of business cases in the apparel industry are quite similar to those in other segments. Other segments also focus on using RFID to improve their inbound and outbound quality, as well as minimize their shrinkage and manage their inventory. Studies in other segments also indicate additional areas of benefit that do not emerge extensively in the current set of use cases. In particular, a concentration of use cases occurs in other segments around the area of quality assurance, because RFID can significantly reduce the amount of counterfeit products on the market through authentication processes and the maintenance of supply chain integrity. Other segments also seem to concentrate on the benefits of RFID for store execution processes. For example, shelf replenishment and promotional execution through RFID have critical benefits for the retail supply chain. Finally, the use of RFID in the form of cart tracking and consumer loyalty programs, as a means to gather marketing insights, is a key benefit for many segments.

To better understand the business use cases we collected from the apparel industry, we categorize them into higher-level groupings: store operations, inbound and outbound processes, inventory management practices, customs, shipping and tariff issues, tracking and traceability, and DC operations. In Figure 5, we distribute the collected business use cases into these higher-level categorizations.

Figure 5: Categorization of Business Use Cases



5. STORE OPERATIONS[16]

According to Figure 4, several of the business use cases we collected pertain to improved store operations processes, and two of these processes—improved backroom-to-shelf replenishment (reporting movement) and improved perpetual inventory (PI) accuracy (reporting quantity)—likely have the most benefits for apparel manufacturers (Delen et al. 2007, Gaukler, Seifer, and Hausman 2007; Hardgrave et al. 2008). The primary benefit to apparel manufacturers is the potential improvement in top-line sales. That is, as retailers implement RFID and create visibility regarding the inventory on the shelf, as well as align backroom-to-shelf replenishment processes, shelf product availability should rise. One manufacturer declared that its entire business model pivoted on PI accuracy and that improvements in this metric alone would drive significant overall benefits throughout the supply chain.

Store PI error is a significant and well-recognized problem for retail stores (Heese 2007; Nachtmann, Waller, and Rieske 2010), and by implementing RFID, retailers significantly increase PI accuracy and may reduce out-of-stock (OOS) events by up to 50%.[17] Those outcomes do not even consider the impact on manufacturers. Retail shelf OOS rates have remained stable at around 8% in recent years (Gruen and Corsten 2007), and retailers that implement store-level RFID may see an up to 30% reduction in shelf OOS (Hardgrave, Waller, and Miller 2006). When faced with a shelf OOS, consumers react in a variety of ways, but the two most detrimental to apparel manufacturers are when they decide not to purchase (11%) or substitute a different brand (22%) (Gruen and Corsten 2007). Furthermore, the collective 33% negative reaction that these two options represent does not include any future implications for the apparel manufacturer, such as a long-term loss of brand loyalty among these consumers.

If an apparel manufacturer experiences an average 8% shelf OOS rate across its retail locations and each of those retailers reduces its shelf OOS rate by 30% through RFID implementation, then the minimal improvement in top-line sales is approximately 1%. This improvement at first glance may seem "minimal," but we should consider the potential dollar value before we dismiss it. For example, if a U.S. apparel manufacturer reports annual net sales of $4 billion,[18] the 1% improvement in sales due to the implementation of RFID at the store level represents more than $30 million more in annual top-line sales.

Furthermore, on-shelf availability, reductions in OOS events, and in-store visibility are all factors that increase the volatility of the bullwhip effect, as we discuss in more detail in the next section on demand signals.

6. DEMAND SIGNALS

To achieve high ship-to fill rates, apparel manufacturers need accurate order forecasts. In the short term, which often encompasses the time needed for suppliers to produce and distribute,

[16] Seemingly benign supplier decisions can have profound effects on retail store operations (e.g., Waller et al. 2010; Waller, Williams, and Eroglu 2008; Waller, Tangari, and Williams 2008).
[17] See "A Great Fit for the Apparel Industry." GS1 EPCglobalUS, pp. 1-2.
[18] This estimate came from the annual report of a single, publicly traded, branded apparel manufacturer.

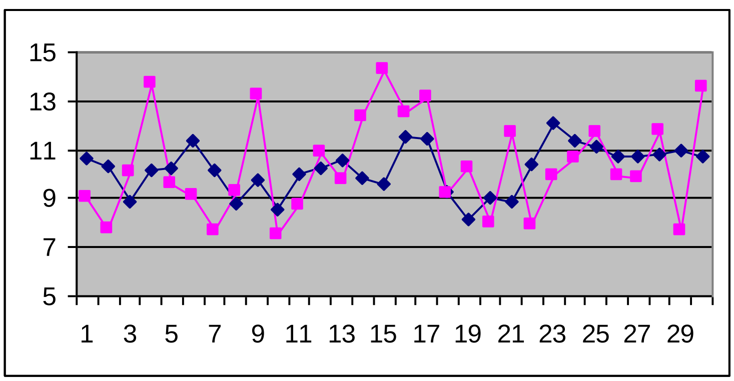
suppliers must make tactical decisions, such as how to position inventory effectively throughout the distribution network. Generally, suppliers have customer service targets to meet at each of the retail DCs, because each DC functions as an individual ordering node.[19]

To meet these targets, suppliers periodically forecast DC orders and position their inventory throughout the distribution network. In addition, the supplier must schedule transportation capacity and warehouse labor for its DC. Because these decisions pertain to each DC, they must be based on local DC order forecasts, not made on the basis of aggregate demand forecasts.

What characterizes the orders placed with a retail DC? When placing an order to receive from a retail DC, retail stores look to accomplish two primary objectives: (1) fulfill consumer demand and (2) maintain inventory targets. When the retail DC places an order with a supplier, it similarly has two primary goals: (1) fulfill anticipated orders from the stores it serves and (2) maintain its inventory target.

Because DC orders reflect consumer demand plus changes in each echelon's inventory, few supply chains adopt point-of-sale data as their primary data source to forecast DC orders.[20] In this case, POS offers an indirect data source and a measure of consumer demand that does not directly contribute to DC orders. Furthermore, DC orders contain more volatility than the aggregate POS of the stores served by the DC, so they are difficult to forecast, and the lack of accurate order forecasts has severe consequences for the supply chain (Williams and Waller 2010a, 2010b). This impact constitutes the well-known bullwhip effect.[21]

Figure 6: Illustration of the Bullwhip Effect



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[19] This is referring to the apparel supplier's DC. Within a given company's supply chain, a DC may not actually be an independent ordering node if the company is using a multi-echelon inventory management methodology or a cross docking methodology. However, for an apparel supplier's DC, serving a number of customer DCs, typically inventory is managed from a single echelon inventory management methodology.

[20] To make a comparison between POS and DC orders to forecast future orders, we might contrast the mean absolute deviation (MAD) of POS data–based forecasts (*PMADijk*) with order data–based forecasts (*OMADijk*). We denote this difference Δ*MADijk*, where *i* refers to the particular item, *j* refers to the specific forecast methodology used, and *k* is to the forecast horizon. Then, Δ*MADijk* = *OMADijk* – *PMADijk*.

[21] Bullwhip can be described with respect to information and/or inventory. With respect to inventory, if the variance of shipments at one echelon is higher than the variance of shipments at a lower echelon, then bullwhip exists. With respect to information, if the variance of orders at one echelon is higher than the variance of orders at a lower echelon, then bullwhip exists.

In Figure 6, the horizontal axis is time and the vertical axis is number of units. The blue line is POS and the pink line is orders from the retailer. You can see that the orders are more variable in Figure 6 than POS. This is an illustration of the meaning of bullwhip.

Error with regard to the bullwhip effect is common, and in most cases, it is assumed that additional variability in DC orders is random or cannot be explained. This explanation is likely true for a portion of the additional variance in DC orders, but it cannot explain the majority of additional variance. The single most important factor in explaining additional variability in DC orders, and therefore improving DC order forecast accuracy, is the inventory level at various stages of the retail echelon.

Changes in inventory levels at the store level eventually affect the inventory level of the DC and ultimately influence the DC order. A lack of visibility persists with regard to this issue. Perpetual inventory might be used in addition to POS as a second, indirect source of information that measures changes in inventory throughout the retail echelon. However, perpetual inventory at even the best retailers reaches only 50% accuracy. Thus, incorporating perpetual inventory information into the DC order forecast is not feasible and likely would introduce even more variability into the DC order forecasts.

Similar to POS and perpetual inventory information, RFID is an indirect data source that provides visibility for both components of DC orders: consumer demand and changes in inventory levels. The improved accuracy of store-level PI due to RFID means that RFID essentially reduces the variability of the upstream demand signal and thus allows a manufacturer to better forecast orders and reduce excess inventory throughout its system.[22]

7. INVENTORY MANAGEMENT

Several of the collected business use cases suggest that item-level RFID source tagging has potential benefits for managing inventory throughout the apparel supply chain. Most notably, the use cases frequently indicated that a key benefit of RFID would be the reduction of inventory and subsequent carrying costs.

In particular, RFID-enabled business processes can reduce inventory levels throughout the supply chain. Each node in the supply chain maintains inventory, so reductions are possible at each node. The magnitude of these reductions depends on its current processes and the type of facility. However, to understand the business impact of inventory reduction due to RFID-enabled strategies, we have to clarify the costs associated with carrying inventory.

In general, a firm or node can calculate its inventory carrying costs by estimating its average inventory dollars and then factoring the average inventory dollars by the inventory carrying cost

[22] Errors in PI can result in items appearing to be out of stock when, in fact, they are in stock. In those situations, orders are placed too early, resulting in excess inventory. Those early orders cause error in the forecasting systems at higher echelons in the supply chain, causing them to overestimate demand. Errors in PI can also result in items appearing to be in stock when, in fact, they are out of stock. In those cases, orders are placed too late, causing higher echelons to underestimate demand.

percentage. Thus, any deduction in either the average inventory dollars carried or the inventory carrying cost percentage yields business value.

Two primary sources of inventory held throughout the apparel supply chain are likely to be affected by RFID-enabled business processes: cycle stock and safety stock. Cycle stock refers to the average amount of inventory required to meet demand between replenishments. That is, it equals the amount of inventory a particular node expects to sell during a replenishment cycle. Thus, the amount of cycle stock carried by a node is a function of the item's rate of sale and the time between replenishments. This time between replenishments in turn is driven by ordering costs, which include more than just the cost of placing an order. They also entail the costs triggered as a result of an order, such as the cost of placing the order and other such factors. For example, each time an order is placed; it creates the potential for an invoice match error and many other types of errors that relate to the creation and fulfillment of a purchase order. Because a RFID-enabled process would reduce the probability of each type of error, the ordering cost would also be reduced.

Specifically, RFID-enabled processes likely reduce ordering costs by minimizing the errors, and thus the costs, of shipping and receiving an order. As mentioned previously, RFID can reduce the manual nature of both inbound and outbound processes, which likely reduces their overall cost. As ordering costs diminish due to RFID business processes, the time between orders also decreases, even as the frequency of orders increases. When the time between orders or replenishments declines, the associated cycle stock is reduced.[23]

To illustrate this reduction in cycle stock, as in Figure 7, consider a node in which the order cost has been reduced, which then reduces the time between replenishments. The order-up-to level, or amount of inventory required to be on hand at the time of replenishment, therefore drops, so the cycle stock carried by the node is decreased.

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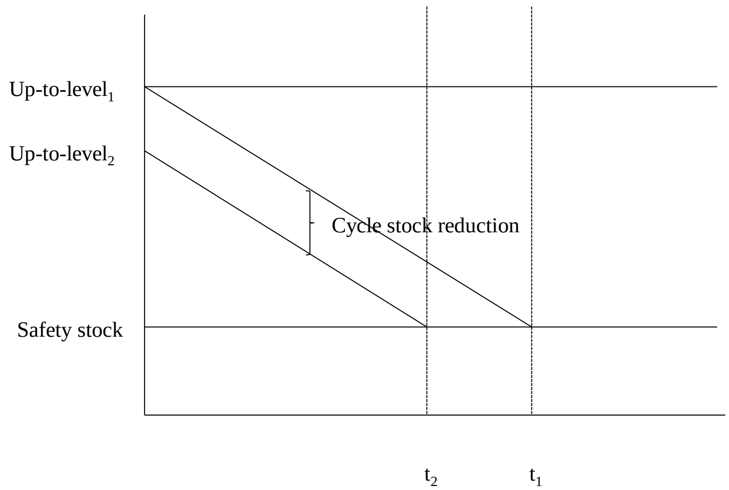
[23] For example, consider a continuous replenishment process with a fixed order quantity and reorder point. It is well known how to estimate the optimal order quantity. The optimal order quantity is $Q = \sqrt{\frac{2\, Demand * Ordering\ cost\ per\ order}{cost\ of\ carrying\ one\ \ unit\ of\ inventory}}$. Clearly from this we can see that the optimal order quantity decreases as the ordering cost per order decreases. A common estimate of average cycle stock is given by $\frac{Q}{2}$. The frequency of replenishment is a function of $\frac{1}{Q}$ and the time between replenishments is estimated by $\frac{Q}{forecast\ of\ sales}$. The Figure gives the view of this relationship from the perspective of a periodic review inventory management system.

Figure 7: Cycle Stock Reduction



To estimate the cycle stock reduction associated with the reduction of order costs and the time between replenishments, we consider the example of an apparel DC that replenishes socks to its RDCs. The time between replenishments for a particular sock stockkeeping unit (SKU) is 7 days, but using RFID reduces the associated ordering costs, such that the optimal time between orders is 5 days. If the daily forecast for this sock SKU were 10,000 units, then the node's cycle stock would be reduced by almost 30%. The manufacturer then would need to carry only around 50,000 units of cycle stock, rather than 70,000.

Of course, the implications of such changes in a multi-SKU environment may be less straightforward. However, this example can represent an average outcome for an SKU. In reality, a firm's or node's inventory policy is greatly influenced by constraints such as transportation capacity. For example, an apparel firm may have a policy that it will send only full containers to its U.S. DCs from an offshore production facility. The policy could stay the same, regardless of any associated transportation efficiencies, but the benefits in our example remain pertinent, because the overall mix of SKUs per shipment would likely change. Therefore, each container might have smaller quantities of a greater number of SKUs per shipment, which again would reduce the overall cycle stock.

A second main source of inventory reduction entails the safety stock held at each particular node. Safety stock is the expected number of units that a node keeps on hand, just before the replenishment arrives and becomes available for use. Safety stock mitigates the uncertainty in demand and supply; in a traditional sense, safety stock specifically protects against lead time, replenishment interval time, and demand uncertainty. For example, uncertainty or error in the perpetual inventory creates demand variability, and errors ultimately become manifest as stockouts. However, stockouts can be mitigated with additional safety stock, such that additional safety stock can reduce the probability of stockouts associated with PI inaccuracy. For a given level of safety stock, if PI uncertainty declines, the in-stock level increases.

Similar to the case for cycle stock, RFID likely allows specific firms or nodes to reduce their levels of safety stock. This reduction results from the reduction in the underlying variability of supply and demand.

Even as the RFID processes reduce inventory, they also might reduce the cost of carrying inventory by reducing the effective inventory carrying cost percentage (i). This cost factor describes the annualized cost of carrying inventory. Although rules of thumb, such the prime rate plus 3% to 5%, often serve to estimate the carrying cost percentage, the inventory carrying cost percentage likely differs for various SKUs, nodes, or firms. Yet the principal components of the inventory carrying cost percentage are common across SKUs, nodes, and firms and include the costs of capital, storage, risk, and service.

The collected business use cases reveal clearly that RFID-enabled processes have the potential to reduce the cost of carrying inventory for a node or firm, because they can reduce inventory risk. Inventory risk is a broad category of inventory costs that encompasses both shrinkage and obsolescence. The business use cases suggest that RFID could reduce inventory shrinkage at each node throughout the supply chain. At the retail store level, RFID might reduce shrinkage due to customer and employee theft. Furthermore, shrinkage due to employee theft at DCs and production facilities, as well as in transit, could be mitigated by the use of RFID.

To understand the dollar impact of reductions in shrinkage, a company needs only its current inventory carrying cost percentage and the subsequent reduction in this percentage. That is, the percentage reduction in inventory carrying cost can be estimated as $(i_1 - i_2)/i_1$, and the reduction in inventory carrying cost then is

$$\text{inventory reduction} = \text{average inventory \$} \times (i_1 - i_2),$$

where i_1 is the company's inventory carrying cost percentage prior to implementing RFID, and i_2 is the company's inventory carrying cost percentage after implementing RFID.[24]

To illustrate the potential business impact, consider the $4 billion apparel manufacturer we mentioned previously. It likely carries approximately $1 billion in inventory on average. Before

[24] The technical reader might notice an issue here about the claim that RFID will reduce inventory costs when considering the idea of it reducing the inventory carrying cost factor. A lower inventory carrying cost factor will make carrying inventory less expensive, thus increasing the optimal order quantity. So, reducing the inventory carrying cost factor has two effects, (1) it increases the optimal order quantity and (2) it reduces the cost of holding inventory. Which effect dominates? It depends. If a continuous review inventory management process is used and the assumptions of the economic order quantity model hold, then the net effect is that inventory holding costs decrease, even when the increased order quantity is taken into account. Let $cc = the\ average\ cost\ of\ holding\ cycle\ stock$, $D = demand\ per\ unit\ of\ time$, $S = ordering\ cost\ per\ order$, $c =\ unit\ cost\ of\ the\ item$, and $i = inventory\ carrying\ cost\ factor$, then $cc = \left(\frac{1}{2}\sqrt{\frac{2DS}{c}}\left(\frac{1}{\sqrt{i}}\right)\right)ic$. Taking the first derivative we have $\frac{\partial cc}{\partial i} = \frac{1}{4}\sqrt{\frac{2DSc}{i}}$, which is positive, implying that the net effect of a decrease in the inventory carrying cost factor is to reduce the cost of carrying inventory in optimality.

implementing RFID, this manufacturer estimated its inventory carrying cost percentage to be 23.25%. In this case, the manufacturer's annual cost of carrying inventory was estimated to be $232.5 million. The collected use cases indicate that this manufacturer could experience reduced shrinkage if it implemented RFID. We conservatively estimate that shrinkage accounts for 1% of its current inventory carrying cost percentage and RFID would reduce shrinkage in the supply chain by half. The estimated business impact then is

$$\text{inventory reduction} = \text{average inventory } \$ * (i_1 - i_2)$$
$$\text{inventory reduction} = \$1 \text{ billion} \times (23.25\% - 22.75\%) = \$5 \text{ million.}$$

8. DC OPERATIONS

Material handling involves a network of flows, all of which require speed and accuracy. By eliminating the line-of-sight constraint of barcodes, RFID increases both speed and accuracy in material handling operations. For example, mobile readers mounted on forklifts in an apparel DC can determine the routing and location of stored pallets without requiring the forklift driver to scan the pallet and can alert a driver who picks up the wrong item. Furthermore, RFID readers accurately tally thousands of items per hour with far less labor required.

These abilities to count items faster and more accurately than humans represent considerable potential benefits of RFID implementation. Several of the collected use cases confirm that RFID would significantly improve cycle counting in these two dimensions of speed and accuracy. With cycle counting, the firm draws a sample of inventory within the DC to count, then infers the inventory count of the entire DC on this basis. In its current state, DC cycle counting is still labor intensive though, because these methodologies currently require DC staff to scan at a carton level. When the zone or items to be cycle counted are selected, the DC laborer must scan each carton's barcode. However, RFID could dramatically increase the speed of such cycle counts and thus decrease the labor required; it has been shown to reduce the labor involved in cycle counting by up to 95% in some settings.[25] Furthermore, RFID might improve cycle counts through increased accuracy. The benefits of RFID thus would increase if the potential for error is higher; for example, because they leave more to count, RFID offers greater benefits for SKU- or item-level measures. Faster access to more accurate inventory levels in turn trims inventory levels and associated costs while maintaining high fill rates.

The collected use cases also indicate that RFID can have a substantial impact on pick/pack operations in an apparel DC. For most apparel manufacturers, pick/pack operations are labor intensive: The DC employee must pick the correct item and then pack the item, during which process the DC employee scans each barcode on each item and scans the carton to associate the items with the carton. The use cases suggest that the manual nature of these operations imply the potential benefits of RFID, particularly with regard to auditing outbound pick/pack cartons. That is, a key advantage of RFID is its ability to audit each outbound pick/pack carton quickly, even as it ensures a high degree of outbound accuracy and the potential to induce necessary upstream process adjustments dynamically.

[25] "Auto-ID on Delivery: The Value of Auto-ID Technology in the Retail Supply Chain," Accenture report, November 1, 2002.

Some materials appear to be better candidates for RFID than others. For example, slower moving, lower volume items with higher value benefit more from the reduced shrinkage potentially offered by RFID. Such items also often have higher margins, so their OOS generally mean significant damage to the bottom line.

With this consideration, we add that though RFID architecture usually refers to tags moving through an environment that contains readers, the inverse process could be equally useful. Tags, or select location tags in the environment, can remain stationary while the reader travels, constantly reading location tags and providing a wealth of metrics, including routes, dwell times, pallets moved, and various other efficiency measures of the person or asset that holds the reader. In this sense, we can think of the reader as a computer mouse pointer moving across a spreadsheet. The reader always knows which "cell" it is in and the cells to which it is adjacent. The amount of time the reader spends in each cell and the amount of data in that cell (e.g., inventory, asset tags being read) can be captured constantly, which implies the capture of true, GPS-like data.

The ability to update any alterations to assets within the cell positions dynamically is also critical. Inventory often is associated with a particular asset, such as racks or shelving or any other type of placeholder. Beyond the floor footprint, the location of these assets constitutes the most significant factor in describing factory or DC layouts or planograms. If these assets are tagged, in addition to the grid of "cells," then a reader moving throughout the area can dynamically update their locations and contents and keep the planogram current.

9. INBOUND AND OUTBOUND PROCESSES

Many of the business use cases we collected focused on the potential improvements offered by RFID to inbound and outbound processes. These processes are required for any location through which inventory flows in the supply chain, and at each stage of the supply chain, they have the potential to affect manufacturers.

For example, several of the business use cases focused on the inbound processes at apparel DCs. These generally manual processes require a great deal of labor: As trucks deliver cartons from a production facility, an apparel DC receives the shipment by unloading and scanning a barcode placed on the carton at the production facility. The DC laborer must search for and scan the barcode to receive the carton. The carton is then sometimes temporarily set down on the receiving floor until it is handled once again to build a pallet. Thus, each carton is handled at least twice prior to appropriate routing.

By implementing RFID, scanning can take place as each carton crosses the dock door, which could reduce the number of touches per carton by half. Because in apparel DCs, labor accounts for the largest portion of the facilities' variable cost, RFID implementation could represent a significant reduction in DC labor cost. The RFID implementation also might have a substantial impact on the speed of the DC receiving process for similar reasons. This benefit may be particularly important in periods in which DCs build seasonal inventory and experience higher incoming volume.

By reducing the number of touches per carton through the use of RFID, the supply chain reduces the time associated with receiving and minimizes time spent waiting in the DC for incoming shipments. In addition, several use cases suggest that the audit processes for shipments incoming to DCs could benefit from the use of RFID. With item-level RFID tagging, the need to open and perform an item-level audit of carton contents can be eliminated or reduced, thus minimizing the time and labor associated with the DC receiving process.

The collected business use cases further indicate that a significant opportunity exists for RFID to enhance the outbound quality of apparel DCs. Ultimately, suppliers seek to deliver perfect orders, including shipments with the correct product, on time, in the right quantity, delivered to the right place. Unfortunately, the perfect order requires DC operations to be perfect. Even if DC performance is high in each category, the cumulative probability of at least one type of error is likely higher than expected. For example, consider a DC that sends the correct items on a shipment 97.5% of the time and sends the correct quantity of each item 97.5% of the time. Assuming that the errors are independent, the retailer receives the correct items in the correct quantity only 95% of the time.[26]

Because DC operations contain several sources of error, the level of error likely depends on multiple factors[27]. In particular, the type of DC is an obviously important factor: Is the facility primarily a cross-docking operation? Does it hold inventory? Does it perform pick-and-pack operations? As the operations become more complex, the likelihood of error increases. This point is particularly relevant for DCs that conduct redistribution/rework activities, such as pick-and-pack, or that create customized packaging and displays for specific retail customers.

Several of the suppliers we visited had dedicated large portions of their local DC to rework operations. Pick-and-pack efforts require creating a product, built from the multitude of mixed inventory available in the DC. It is a retailer-driven, labor-intensive process that changes often enough to prevent efficiencies, which makes it prone to higher error. Pick-and-pack functions also reflect the retailer's desire to offer competing products. For example, if retailer A offers a 6-pack of men's undergarments in three different colors, retailer B may choose to offer a 4-pack in four different colors. These two different products require separate packaging, labels, case sizes, and cube-out capacities. Thus, pick-and-pack operations depend on manual labor, which makes them susceptible to error that can spread throughout the supply chain. The higher cost of manual labor at the DC level, as opposed to the manufacturing facility for example, also results in a potentially higher cost per error.

Item-level RFID tagging offers apparel manufacturers the ability to audit the contents of each carton being shipped to their retail customers through an automated scan process. Therefore, the apparel DC can find errors in the redistribution process prior to those errors being found by the retail customer. This shift ultimately reduces the deductions or chargebacks demanded by the manufacturer's customers. Such deductions are a significant issue in the apparel supply chain. A

[26] If the correlation between these two types of errors is zero, then this is the result. If the correlation between these two types of errors is 1.0, then the accuracy stays the same. If the correlation between these two types of errors is negative, then the accuracy will be less than 95%.
[27] Not included in this list is the correlation in errors in each of these sources of errors.

retailer can charge the supplier for a perceived failure to comply with one or more of the retailer's requirements. There are many root causes of such deductions, including some inaccuracy in the shipment received by the retailer, whether that shipment contains the wrong quantity of an item or additional items not ordered by the retailer.

Although the extent of chargebacks varies by supplier and retailer, some suppliers have indicated that it is not uncommon for them to be approximately 1% of an apparel manufacturer's sales. Upon the receipt of a chargeback, the manufacturer may accept or dispute the retailer's claim. The cost of deductions thus is not limited to the dollar amount of the chargeback itself. Suppliers spend a significant amount of time and effort reviewing and challenging deductions claimed by the retailer, and several suppliers in our use cases indicated that they assigned multiple staff members to tracing, analyzing, and challenging retailer deductions, which reflected a significant cost to the business. The effort associated with disputing claims was often worthwhile though; for example, one manufacturer noted that approximately one-half of its claims were eliminated as a result of the dispute process. In this setting, RFID implementation might reduce the total number of claims and significantly reduce the costs of the dispute process as well.

Even if a manufacturer is successful in eliminating half the claims on 1% of its sales, consider the overall impact of outbound shipment quality on the manufacturer's business. If retailer claims are equivalent to 1% of sales and the undisputed claims are approximately equivalent to 0.5% of sales, then the impact for our $4 billion apparel manufacturer would be approximately $20 million. At 10 cents per tag, $20 million covers 800 million 4-packs—more than three times the annual throughput of some facilities we visited and almost double the annual throughput of $4 billion manufacturer.

10. TRACKING, TRACEABILITY SHIPPING, CUSTOMS, AND TARIFFS

Currently cost savings associated with tracking and traceability through RFID at the store level have been better explored than those at other echelons throughout the apparel supply chain. However, some cost reductions and quality improvements could be associated with the supplier.

With the extent of tracing we have described, the supply chain could determine, for example, if one bale is associated with weak cotton that results in more tears in garments, then traced back to that bale. Perhaps bales from one vendor or with some particular type of fiber consistently have quality problems. Such tracing benefits future quality improvement efforts and ultimately should result in fewer return-related costs or the potential for quantitatively verifiable cost negotiations with the responsible material providers. For companies that practice continuous improvement in quality management, RFID-enabled tracing and tracking may be a necessary condition for making such improvements. At the same time, RFID-enabled tracing and tracking should result in breakthrough improvements in quality management. When garments are returned, their RFID and database information could be used to correlate with their yarn, dying, fabric, cutting, sewing, and finishing processes.

A key step in quality management is determining the root cause of the problem. Without tracing and tracking, it is quite difficult if not impossible to take this step. Many quality problems occur in the apparel supply chain, and there are probably many different root causes of these problems.

If it were known which causes were driving which quality problems, then Pareto analysis could be used to determine which root causes to address first. Pareto analysis creates frequency counts of quality problems, their categorization, and their sources. The idea is that a relatively small percentage of root causes drives the preponderance of quality problems, so Pareto analysis reveals which are the most salient root causes. Root cause and Pareto analysis are not possible without tracing and tracking, which means that quality management is not occurring in the apparel supply chain to the degree that it could be. Tracing and tracking, coupled with quality management tools such as root cause analysis and Pareto analysis, enable feedback and learning. In essence, without tracing and tracking, feedback and learning are stymied, and productivity improvements, cost reductions, and service all suffer in turn.

The lack of quality control and management in the apparel supply chain as a result of an inability to trace and track could drive different costs and service issues throughout the supply chain. Excess inventory is a result of poor quality management; if a node expects quality problems, it holds additional inventory. In the apparel supply chain, this practice can be quite costly, considering the magnitude and frequency of markdowns. In addition, excess inventory causes normally smooth inventory management processes to go awry, such that the frequency and cost of misplacing/damaging inventory increases.

As another example of the benefits of tracing back to the bale, consider the simple example of white cotton t-shirts. Often small fragments of fabric of other colors in the garment must be removed. Removal is a tedious process, such that a worker uses a needle and picks at the fragment to remove it. If bundles of garments were tagged, those shirts that need to go through this process could be associated with particular bales, leading to the possibility of preventative action. The fabric manufacturer will not improve if it does not know that it is creating an issue. If nodes further down the chain can identify the total time a certain bale cost them, they could initiate a feedback loop with the fabric manufacturer, improve quality, and reduce costs.

This discussion highlights the possible need for a study of the quality management opportunities associated with tracking and tracing. First, we would need to identify the sources of quality problems and the frequency of occurrence, collect returned items from some set of SKUs from a set of key retailers to study the problems, and scientifically determine the source of the problem in terms of the points of the supply chain at which the problem occurred. While this effort would be costly, if applied to all SKUs going forward, it would help estimate the size of the opportunity. Second, we would need to calculate all return-related costs as a percentage of the cost of the item across many different SKUs. Third, using both these values, we could estimate the size of the benefit of tracking and tracing from a quality management perspective.

It is possible that in the future consumers will demand information about the sources or origin of everything in a garment. Currently garments include one point of origin on their label, but products we eat must list all of their nutrients, and eventually, there will probably be some sort of sustainability index associated with consumer products. More detailed information about the sources of yarn, fabric, dye, cutting, assembly, and finishing would fit this progression. If one company does it, it may give that firm a marketing strategy and competitive advantage.

Another benefit of tracing back to the bale relates to CAFTA—the Central American Free Trade Agreement. Free trade agreements in Central America eliminate duties between the United States and Central America if and only if the yarn was made in the United States. Thus, tracking back to the bale would allow for verification of the source of the fabric and where the yarn came from that made the fabric.

Apparel manufacturers also ship fabric to a country for just one part of assembly, such as adding buttons. Depending on various trade agreements, they pay tariffs only on the labor cost added in that country. Because RFID-tagged garments could provide a precise allocation of labor, the tariffs assigned to them could be more accurately based on how much actual labor went into that particular SKU. For example, two SKUs, with the same number of units, might have had buttons added at a particular facility. The total labor cost was $100,000. Without an RFID capability, the cost might be equally assigned to each SKU, whereas the RFID data might show that 90% of the labor cost actually was associated with one of the SKUs. For that SKU, which demands more labor to attach the buttons, it might be more economical to send the items to a more distant country that offers lower labor costs. Without this cost information, such optimal supply chain decisions would not be possible. In other words, RFID can enable real-time, activity-based costing. Of course, such a scenario might be possible without RFID, but it would take longer and be more labor intensive, involving, for example, a time motion study. With RFID, the data can be collected in real time as the buttons get applied.

When RFID tags get applied to bales, readers would see them when received; then after the bales were cut, each stack of cut pieces would get a new RFID tag. In the database, the identification of each bale would be associated with this new RFID tag. The stacks of cut pieces then move to the staging area, where the system makes sure everything is staged properly and put into the right truck. When the pallets are received at the sewing factory, its system receives all the pieces accordingly. When a bundle moves to a workstation, that workstation knows the bundle is there, because the RFID tag has been read, which also indicates the other stacks of pieces that are with it. A new RFID tag could be applied to the finished garment at the sewing factory, embedded in the garment; otherwise, it could be added at the laundry facility. Because it is not unusual for a cut to have over 30 different parts, this process makes it unnecessary to keep counting inventory during the process, yet it still increases accuracy levels.

In some countries in which customs requires a packing list, RFID tags could enable rapid packing list creation. A reader could be placed over the loading door after the container door is shut, and then a packing list could be printed. This capability would remove the need for manual counting or manual bar code scanning. Customs offices could even begin implementing RFID-enabled business processes themselves. For example, each trailer might have an RFID tag, and when the container gets loaded and sealed, its RFID tag would summarize the contents of that container. The customs office could use this information, such that as the trailer moves through customs, the office can simply read the RFID tag.

Another potential usage would create an automated shipping notice (ASN) based on (1) the products in the container and (2) the time of departure of that container. A reader at the shipping gate could take a read as soon as the container leaves, then trigger the transmission of the ASN. When the container arrives at the destination, the read on the trailer should confirm it is in the correct location; the reader over the door can verify the freight shipped is the same as the freight ordered. These readings also facilitate the payment process, because payment requires matching orders, shipping documents, and receiving documents. An invoice would not even be required from a business process perspective, because payment could be issued based on the receipt. Upon delivery, a proof of delivery would be sent automatically to the carrier and shipper, which then would enhance deduction management.

Finally, the apparel supply chain could tag some critical assets with RFID, namely, sewing machines. Each sewing machine in a sewing facility should be tagged, so if the machines are moved outside of a given zone, an alarm would issue. In addition, workers at stations might sport tags on their badges so that common reads of workers and sewing machines could be associated in the database. Statistical inference then could identify workers that are more likely to be associated with machine breakdowns, to eliminate the need for unnecessary worker training on proper machine handling and use.

11. TRANSPORTATION[28]

There are many causes of poor transportation utilization that could be addressed by the information created by the use of RFID in the apparel supply chain. One source involves outbound transportation from a fabric cutting facility. In this case, rules exist to minimize confusion on unloading, such that only one type of cut per pallet might be allowed. Thus, even if the truck is filled with pallets, these pallets might not be filled to capacity. However, if each of the pieces (stacks of plies for one cut, commonly known as bundles) were RFID tagged, then the bundles could be identified more easily as they got pulled, and a simple display could specify which bin they should be placed in for production staging. In this way, the pallets could be filled to capacity prior to shipping.

Because RFID-enabled business processes could lead to improved inventory accuracy, fewer unnecessary shipments would occur. Examples of these shipments include transshipments between facilities and additional but unnecessary shipments to various nodes. The reduction in the overall supply chain's inefficiency would have far-reaching sustainability and lean manufacturing implications that are difficult to value currently.

More than one supplier expressed interest in investigating RFID-enabled consolidation of shipments. Consolidating shipments allows competing suppliers to lower their transportation costs by cubing out truck or container space when disparate quantities of product travel similar routes. Sharing transportation space requires accurate and timely visibility in load capacities. The visibility and velocity provided by RFID offers the beginnings of such transportation gains.

The University of Arkansas's RFID Research Center often receives questions about how the kind of RFID being used by apparel suppliers to tag items could be leveraged in yard management

[28] The modes of transportation in the RASC based on our observations include the following: ocean carriage, truckload, less-than-truckload, parcel, and air. Better forecasting would probably have the greatest impact on costs associated with the most expensive modes, namely, parcel and air, as a result of fewer emergency shipments and transshipments. However, the above effects on inventory-related costs may shift some freight toward more expensive modes due to the reduction in inventory levels. The net effect is difficult to predict.

applications. During cyclical seasonality peaks, some apparel suppliers utilize third-party warehousing, in the form of trucks and/or containers stored at or near one of their facilities. At a DC, for example, these containers house inventory locations similar to bay locations in steel warehouse racking. Much like a giant, sliding, block board puzzle, the containers get moved and repositioned every time a pick requires product from a container that is not easily accessible.

The ongoing use of RFID should enable verification of an entire container manifest, without needing to unpack the container. However, the kind of RFID suppliers are currently using cannot take readings through container walls and has an average read range of only about 25 feet. This limitation means they cannot simply scan the yard and instantly know just where the desired product is. However, some yard management projects aim to use this same sort of RFID to identify and locate each truck or container, as well as time of arrival or departure, using static or mobile readers, or both. In addition, the frequency and duration of each pickup and drop-off of a container moved within the yard can be measured, as well as its proximity to other known locations or assets, which would provide reasonably accurate inferences about possible and appropriate locations. Furthermore, RFID can build automatic timing into a load manifest to describe the approximate fore-to-aft location of a product within the container. Layering these two uses of the technology would allow for virtual GPS-like product tracking.

12. VISIBILITY

Up to this point we have not explicitly discussed the value of visibility that RFID can bring to the apparel supply chain. One of the reasons for this is that the term visibility is often used and assumed to provide benefits without explaining how it will bring benefits. Visibility is a capability that allows a company to (1) *locate* inventory, (2) *trace* inventory to its origin, (3) *measure* important attributes of the inventory such as costs, lead times and pedigree, and (4) *foresee* the path to the destination. That is, visibility is a collection of information about inventory (locate, traces, measures, and foresees) that is dynamic and current.

There are degrees of visibility. You cannot manage a supply chain without visibility. Without visibility, costs increase and service decreases. Visibility allows for management of costs and service and it substitutes for assets. As we saw in Section 2, the apparel industry has the most room for improvement in terms of asset utilization.

Visibility can reduce cycle stock because it can, for example, decrease the ordering cost due to lower costs associated with invoice match rate failures. Lower ordering costs reduce the optimal order quantity or the optimal time between orders, thus reducing cycle stock.

Visibility can reduce safety stock because it allows you to reduce demand uncertainty and lead time uncertainty. Having visibility to the extent product can be *located* in real time helps reduce uncertainty around lead time and to make decisions that can facilitate lead time. Having visibility to the extent that inventory’s future path can be foreseen, it can be re-directed to satisfy demand as demand changes. Having visibility at a more granular level allows for more information and, thus, more accurate forecasts. Aggregation in general removes information.

Visibility can reduce promotional stock because it allows for improved management of promotional display execution. Inventory for promotion at the store level is periodically not brought to the store floor in correlation with the timing of the promotion. Having visibility to store level data that differentiates between what is in the store and what is in the backroom can allow for management of promotional stock so that the stock is delivered to the floor in correspondence with the promotion.

Visibility can reduce in-transit inventory because of a reduction in the percentage of transshipments. When product ends up at nodes where it is not needed when, in fact, it could have been re-routed in-transit had visibility been available, then it may eventually be transshipped. In-transit visibility enables in-transit re-routing, which, in turn, reduces the need for transshipments.

Visibility can reduce the inventory carrying cost by reducing the inventory carrying cost factor through a reduction in the inventory risk factor reduction. Visibility can reduce shrink, for example, a salient element of inventory risk. When this is reduced, that portion of the inventory carrying cost factor is reduced, thus reducing the cost of carrying inventory.

It can also reduce the inventory carrying cost by reducing the amount of investment, in terms of labor and transportation, for example, which go into the inventory. For example, with visibility there is less searching for misplaced inventory, fewer mis-picks, and other labor intensive items that increase the amount of money wrapped up in the inventory.

Visibility can reduce transportation costs by reducing transshipments and expedited shipments. We have already explained the logic behind transshipments and transportation. Regarding expedited shipments, when product is tracked and its future path foreseen, it can be managed rather than being moved based upon reactions to events.

We could continue this list but it is clear that visibility can improve asset utilization, which is, as mentioned before, in need of improvement in the apparel industry. One key enabling factor to visibility is standardization around identification of information, capturing information, and sharing information.

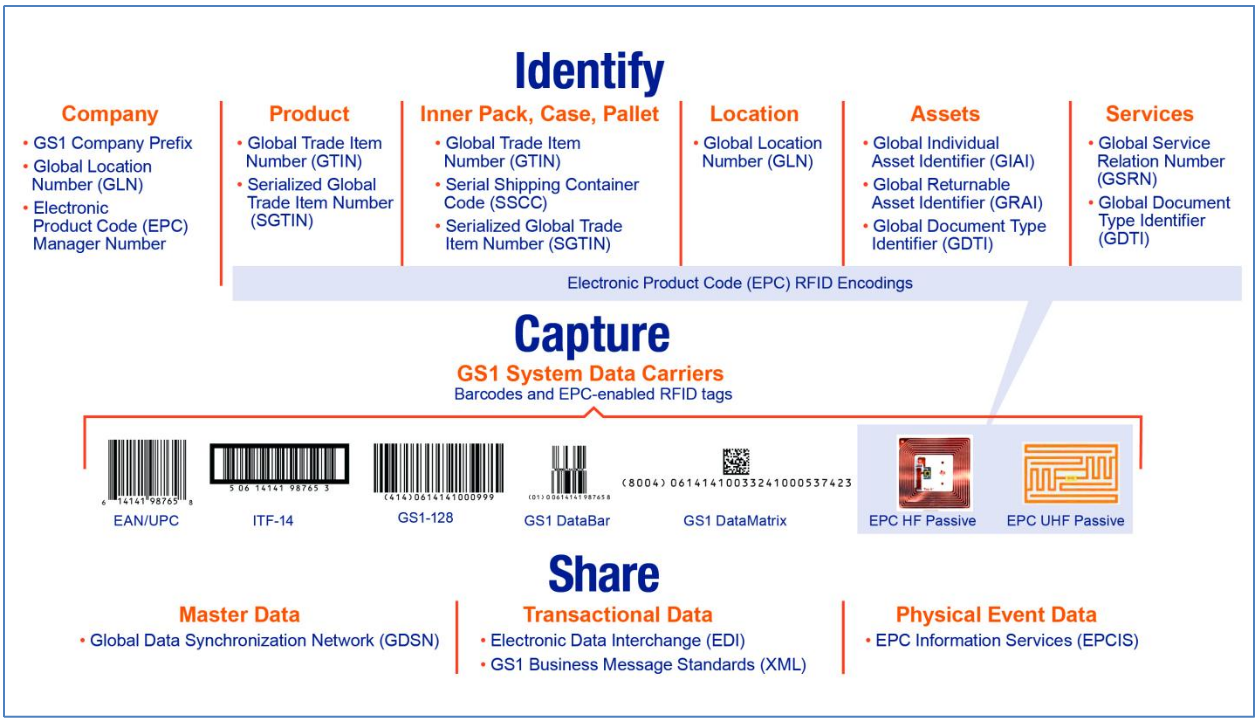
Figure 8 shows the GS1 US Visibility Framework[29] which is a collection of standards that will facilitate visibility within functions of an organization, between functions, and between companies. These standards have the potential to increase the speed of adoption of technology that will enhance true visibility. This will, in turn, enhance firms' abilities to implement the logistics concept and the supply chain management concept.

Recall that logistics is the management of the flow of inventory such that total costs are minimized and customer service targets are achieved. Today most of the flow of inventory cannot be managed because firms do not have visibility to it. Also, today, total costs cannot even be measured due to lack of visibility.

[29] GS1 US's White Paper, "The GS1 US Visibility Framework."
http://www.gs1us.org/DesktopModules/Bring2mind/DMX/Download.aspx?EntryId=2969&Command=Core_Download&PortalId=0&TabId=73

You will also recall that supply chain management is about integrating business processes between functions within an organization and between companies. One key element of business process integration is information sharing. Electronic Product Code Information Services (EPICS) is an example of a standard that makes it currently possible to share data that could be secured through RFID. One important aspect of such a standard is its independence from specific technologies used to capture the information. EPICS has such an aspect. Such standards create economies of scope in adding additional partners to the information sharing process. Without such standards, each time a new partner is added, they must work together to decide how the data will be shared. Without these standards, the ability of supply chain management to deliver value will be limited.

Figure 8: The GS1 US Visibility Framework



If you look at Figure 8, you can see that under the Capture part of the framework are both barcodes and EPC-enabled RFID tags. Currently a great deal of information is captured with barcodes but sharing is still difficult, making implementation of supply chain management difficult. We recommend that industry consider not waiting until EPC-enabled RFID tags are fully implemented to begin implementing sharing standards around physical event data. There are two reasons for this: (1) data is already available and not fully utilized, and (2) when EPC-enabled RFID grows in adoption, the benefit of the additional data that is captured through it can be realized more quickly.

13. SUMMARY

The findings of this exploratory study show that the potential benefits of item-level RFID in the apparel supply chain reach beyond the retailer to include apparel production and distribution. Improved backroom-to-shelf replenishment and greater perpetual inventory (PI) accuracy are potentially most beneficial to apparel manufacturers, because these improvements offer the opportunity to increase top-lines sales.

Other use cases we collected suggest a significant opportunity for apparel manufacturers to improve operations throughout the supply chain. In this sense, RFID offers manufacturers the opportunity to improve inbound and outbound operations at all echelons. By implementing RFID, the supply chain can undertake scanning as each carton crosses the dock door at any location, which should substantially decrease the number of touches per carton. Because labor accounts for the largest portion of variable costs in an apparel distribution network, RFID is quite promising in this regard.

Item-level RFID tagging also offers apparel manufacturers the ability to audit the contents of each carton being shipped to its retail customers through an automated audit process, such that the apparel manufacturer can find errors in the redistribution process prior to those errors being found by the retail customer. This step ultimately reduces the deductions or chargebacks from the manufacturer's customers.

In addition, RFID can reduce inventory-related costs throughout the apparel supply chain by reducing ordering costs in the form of (1) reduced shipping and receiving costs and (2) fewer errors associated with shipping and receiving. As the ordering costs decline due to RFID business processes, the optimal time between orders shortens, and the optimal frequency of orders increases. Thus, cycle stock is reduced. Furthermore, RFID improves PI accuracy, which means that it reduces stock safety levels throughout the supply chain.

Our use cases also suggest that is it reasonable to speculate not only that RFID could reduce safety stock and cycle stock but also that it would reduce the cost of carrying inventory per se, through the reduction of inventory risk, due to lower levels of shrinkage and obsolescence.

Furthermore, the use cases suggest it is conceivable that tracking and tracing due to RFID will enable continuous quality improvement and thus result in fewer return-related costs and markdowns. By enabling tracking and tracing, RFID also might reduce the cost of compliance with free trade agreements and improve customs processes.

Overall, our analysis of these use cases suggests that the broad-scale use of item-level RFID tagging in the apparel industry will yield substantial benefits to apparel manufacturers. The collection of data also indicates that manufacturers will experience benefits throughout the supply chain, beginning at the source with quality improvements and control, all the way to yielding increased sales at the retail shelf. Along the way, supplier manufacturers are likely to enjoy significant operational benefits as well.

13. NEXT STEPS

In this exploratory study, we have focused on identifying and exploring the potential use cases of RFID in the apparel supply chain. For some of them, we proposed methods for estimating the benefits, through developing accurate estimates of generalizable benefits requires large-scale field studies and experiments. Such efforts were not the purpose of this exploratory study, but this investigation reveals some obvious potential experiments and field studies. As next steps, we propose that studies should be conducted to clarify the benefits of RFID in the apparel supply chain. Large-scale field studies and experiments might investigate the value and business processes needed to take advantage of RFID; they will require the cooperation of retailers, brand owners, trade associations, standards organizations, and academics. Our discussion of needed research into the full-scale adoption and implementation of RFID in the retail supply also is not exhaustive.

When initiating a new category of RFID research at the University of Arkansas's RFID Research Center, the traditional modus operandi is a three-phase procedure: Conduct a feasibility study, conduct a pilot study, then follow and measure adoption patterns and behaviors.

Terms such as "feasibility study" and "measure patterns" may sound somewhat scientific, but this study aligns with all prior research performed by the University of Arkansas's RFID Research Center and is therefore more focused on the business aspects than the technical aspects of any supplier's interaction with RFID. In prior research, the Center has worked with several major retailers to understand potential RFID use cases, then tested them in a controlled setting before initiating examinations in real-world settings at American Apparel, Bloomingdale's, Dillard's, Macy's, Walmart, and so on. The results from these studies revealed four primary and common use cases: inventory accuracy, out-of-stocks, locating products, and loss prevention. Inventory accuracy consistently captured the principal focus.

In the first phase, the feasibility study normally involves a joint look at the technicalities of readability and laboratory imitations of reading practices and procedures intended by the end-user. For apparel, it required months of testing different tag types applied to apparel in different ways, emulating supply chain read scenarios, and measuring read rate success though various metrics. However, the first phase of this study—gathering potential supplier RFID use cases—was performed in the field, not a lab setting.

Phase II of this study will require listing the prioritized use cases produced in Phase I and determining which of them will be beneficial to examine through pilot studies. The greatest benefit to the industry as a whole will derive from pilot studies with use cases that are most common to the largest cross-section of suppliers. Those suppliers already engaged in tagging efforts, as well as those interested in investigating green-field deployments, are well positioned for involvement in Phase II. The results of Phase II will describe in measurable, quantitative terms the potential differences, whether positive or negative, between RFID and non-RFID processes.

Phase III of the study will address how RFID affects individual parties within a many-to-many architecture. For any benefits of Phase II to be realized in practice, they must be studied in their natural environment—that is, a many-to-many system where suppliers provide RFID-tagged apparel to multiple retailers through a multitude of methods and channels and where retailers receive tagged apparel from a host of different suppliers using similarly disparate methods.

Phase III therefore will seek to understand the impact of RFID in this environment. Questions examined in Phase III will include whether RFID positively contributes to and facilitates supply chain and logistics best practices in areas such as demand management and forecasting, inventory holding costs, tracking and traceability, counterfeiting and security, customs clearance, labor and handling, ordering and warehousing costs, and the cash-to-cash cycle.

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