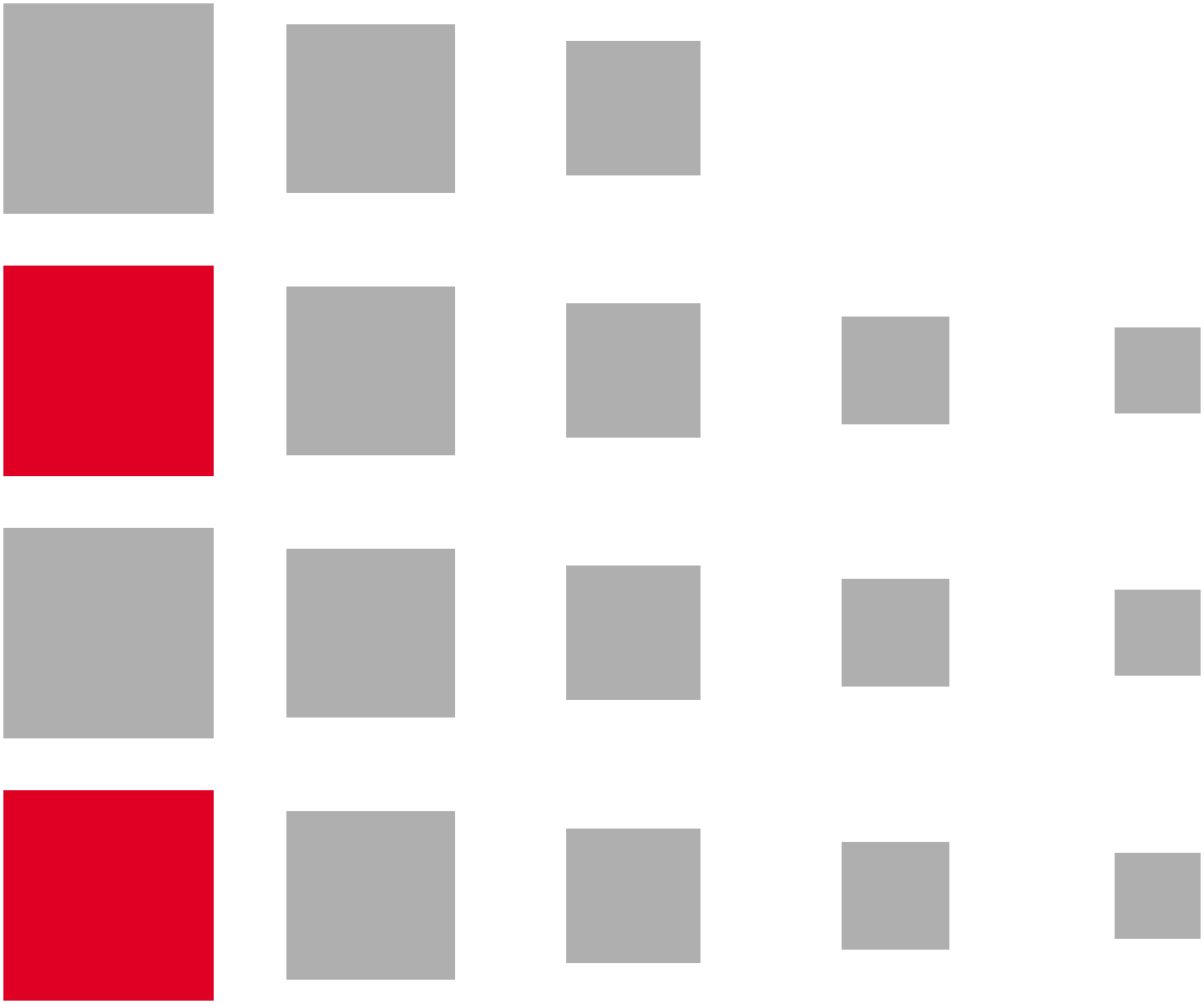
METRO Group
Future Store Initiative

RFID: Uncovering the Value

Applying RFID within the Retail and Consumer Package Goods Value Chain



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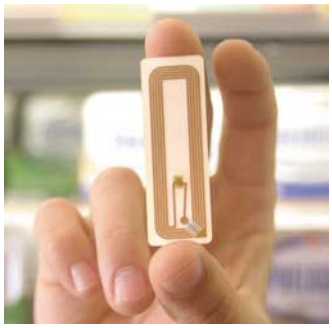
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01

Introduction



The use of RFID (Radio Frequency Identification) in the retail supply chain holds much promise to revolutionize the process by which products pass from manufacturer to retailer to consumer. Through increased accuracy, the ability to gather information at new points in the supply chain, and new collaborative sharing of information between retailers and manufacturers, RFID has the potential to significantly reduce the costs of bringing products to consumers in stores.

The basic idea of RFID is that barcodes will be replaced by tiny computer chips that are read with a radio beam instead of a laser. Since no line of sight is required, products can be identified automatically and simultaneously, for example by passing a pallet of goods through a portal, rather than requiring that every item be individually scanned by a barcode scanner. This allows retailers and manufacturers alike access to an unparalleled quantity and accuracy of information about the flow of product through their factories, warehouses, and stores.

The potential for RFID is virtually limitless. But like any transformative technology, RFID offers companies a confounding array of data standards, hardware and software choices, process changes, and new modes of collaboration. Companies evaluating RFID are often left with a simple question: Where do I begin? How can I use this new technology to improve my business?

In Germany, a group of companies under the auspices of the METRO Group Future Store Initiative have been testing a number of RFID-based applications, ranging from the manufacturing factory line all the way to the store shelf, using RFID tags on pallets, cases, and, in some cases, individual products. And although the use of RFID is at a limited scale, the involvement of multiple manufacturing partners, different classes of products and applications at the factory, warehouse, distribution center, stockroom, and shelf provide perhaps the most comprehensive look at how the use of RFID impacts the infrastructure, processes, and relationships in a retail deployment.

In this business paper, *by SAP and Intel in collaboration with Retail Forward and M-Lab*, the METRO Group Future Store Initiative presents a combination of results from real-world trials with its manufacturing partners and what we believe is the most comprehensive model of process and benefits available in the near and medium term through the use of RFID. Our goal has been to make available insights that are both tangible and flexible and to balance the genericism of a "one size fits all" approach with the simple reality that every retailer and manufacturer uses subtly – but importantly – different processes.

The use of RFID in the METRO Group Future Store Initiative has produced benefits ranging from real-time visibility of products on shelves to decreased time required to pick up pallets with a forklift. Unlike simpler technologies where one clear overriding benefit can be identified, calculating the ROI of RFID requires looking at multiple processes spanning the life of a product from the end of the factory production line all the way to the consumer's hands in the retail store. This document breaks these processes and benefits down into a model that not only shows what benefit is derived but *how* it is derived, thereby providing a roadmap for companies considering an RFID deployment to easily understand both the technology and business changes they must accomplish to take full advantage of this remarkable new technology.



02

Process and benefits model

In this chapter, a process and benefits model for using RFID on pallet and case level is presented. The process and benefits are described at a level of detail so that they become relevant to a wide variety of companies in the grocery supply chain.

This model is derived from the results of work conducted with a retailer and two CPG manufacturers.

Our aim is to provide companies considering the use of RFID in the supply chain with a more detailed and clear description of the potentials of RFID than previous studies and thereby offer insights into where to look for benefits and where to start. Finally, we provide guidance with regard to the selection of appropriate product categories to start with.

The relevant process steps are shown for:

- the current process
- the process with RFID on pallet level
- the process with RFID on case level

We look at the process from the end of the factory production line until products move onto the store floor. The supply chain that we consider consists of a manufacturing plant with a warehouse attached to it. From there, products move via a retail distribution center (DC) to a retail store.

By comparing the current process steps with the processes using RFID on pallet level and case level respectively, we can derive and describe a number of potential benefits of RFID. We link each potential benefit to changes in specific process steps in the supply chain. We distinguish between case and pallet level tracking. We also identify the impact along these lines:

- automation benefits, where RFID provides a labor cost or time savings
- new process-enabling benefits, where RFID allows a fundamentally different or new way of doing a process that is more efficient
- serialization benefits, where the introduction of new serialized data (e.g. case level serialization) leads to benefits that are dependent on serialization rather than RFID (for example, knowing which stores received products that were recalled)
- collaborative benefits, where the primary benefit is derived from the sharing of data between manufacturer and retailer or vice versa

We specifically look at differences between various product categories in the grocery supply chain. Finally, we provide some guidance with regard to the selection of appropriate product categories to start with.

2.1 Overview of supply chain

Before going into the individual process steps, we will give a brief overview of the product flow in a "typical" grocery supply chain:

At the manufacturer's plants, pallets are assembled directly after the production line and either stored in the factory warehouse or moved directly to one of the manufacturer's DCs. At this stage, only full pallets are handled. For the supply chain we consider, most deliveries of products that finally reach the store are shipped from the factory warehouse to the retail DC. In order to assemble a delivery for a DC, pallets are removed from the warehouse storage area and placed in the shipping area from where they are loaded onto trucks.

When trucks arrive at the DC, they are unloaded and the deliveries are checked. Then the pallets are stored in the DC. Some of the pallets are sent as full pallets from the DC to the stores, but the majority of pallets coming from the retail DC are mixed pallets. These mixed pallets are picked at the retail DC. Prior to shipment, the pallets belonging to an order are assembled in the shipping area. When the truck arrives, the pallets are moved onto the truck and brought to the retail store.

The store receives deliveries from more than one retail DC. Furthermore, it also receives direct store deliveries from manufacturers. The store checks in the pallets. They are placed in the backroom until moved onto the store floor. Cases that could not be placed on the shelves are returned to the backroom and stored there until shelf space becomes available.





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In some instances, the retailer (either at the DC or the store) detects interchanged or additional products in a delivery or products with quality problems. This can lead to product returns to the DC or the manufacturer that need to be administered. In some instances, additional products delivered are today simply thrown away. Another situation where products need to be returned involves product recalls.

2.2 Introduction to the process and benefits model

For our analysis, we distinguish between several process steps at each of the three entities in our supply chain. These process steps are not meant as a complete list of activities that are conducted in a grocery/CPG supply chain. In contrast, we have focused on those process steps that change with RFID on pallet and case level. These are mainly those process steps that deal with the physical flow of products. Process steps unaffected have deliberately been ignored.

In order to understand what benefits can be derived from RFID on pallet and case level and how, one needs an understanding of what the current process looks like and of what it changes with the adoption of RFID. This requires a slightly more finer level of detail than the overview given above. The current process and the processes with RFID on pallet and case level are described in the figures in Appendix A.

The process and benefits model in table 1 gives an overview of the process steps and the benefits achievable at each of the process steps, separately for case and pallet level tagging. The benefits included in the model do not provide an exhaustive list of potential benefits. In contrast, we have tried to focus on those potential benefits

- that are frequently mentioned by companies when talking about RFID on pallet and case level, or
- that we have specifically encountered in our work with the companies mentioned above

The figures in Appendix B provide a more detailed breakdown of benefits by process step and some more details on the causal link between process change and resulting benefits. These causal links are described in depth in the following chapter.

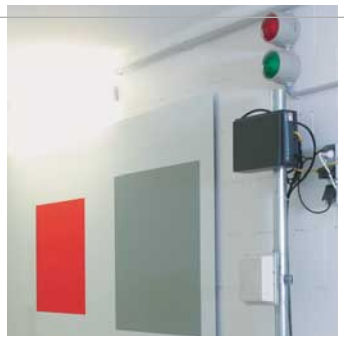
At this point, we would like to stress that we are fully aware that every supply chain is unique. Processes differ, and therefore the way in which certain benefits may or may not be realizable differ as well. Every model is necessarily limited in its capability to represent reality. However, we believe that the models presented here still provide significant value and guidance to companies thinking about implementing RFID solutions.

When looking at table 1 for the manufacturer, the retail DC and the retail store, it becomes apparent that the majority of benefits resulting from process changes at the manufacturer are related to pallet level tracking whereas for the retail store, most benefits are related to case level tagging. The retail DC is somewhere in the middle. This is mainly related to the fact that the relevant handling unit shifts from full pallets to mixed pallets and cases as we move downstream the supply chain.

This might give manufacturers the impression that the majority of benefits from case level tagging go the retailer. However, we will highlight three points that indicate from our perspective that this need not be the case.

- Some manufacturers do picking for some of their products. This means that cases also become the relevant handling unit for them. Certain benefits of case level tagging discussed for the retail DC are also relevant for the manufacturer that does picking, e.g. picking efficiency and inventory counting.
- The quantity of benefits does not say anything about their magnitude. Some manufacturers, for example, might find tremendous benefit in a more finer level of traceability for their products.
- One of the main reasons for using RFID tags on cases stated e.g. by Wal-Mart is that they believe this can help to improve product availability at the retail shelf. This offers





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Table 1: Process and benefits model

	Manufacturer		Logistics/ 3PL	Retailer	
	Factory	Warehouse	Distribution Center	Store Stockroom	Store Floor
	Pallet assembly	**Goods receipt**	**Shipment receipt**	**Order receipt**	**Shelf restocking**
	Cases are assembled into pallets and EAN-128 assigned	Pallets are scanned into warehouse and inventory is marked as transferred	Truckloads are received in warehouse and order accuracy is confirmed	Pallets are received from the DC	Goods are moved from storeroom to shelf
Pallet	Automated scans save X seconds per pallet	Automated scans save X seconds per pallet	Automated scans save X seconds per pallet	Automated scans save X seconds per pallet	
Case	Case validation ensures complete pallets		Automated check of delivery accuracy saves X minutes per pallet	DSD case deliveries confirmed automatically	Separation of stockroom and floor inventory leads to improved replenish-ment from stockroom
		Warehouse staging	**Pallet staging**	**Pallet staging**	**Returns pickup**
		Each pallet is placed into the warehouse	Pallets are moved into either storage (full) or for picking (open)	Pallets are stored until broken into cases	Goods to be returned are moved to stockroom
Pallet		Automated scans save X seconds per pallet	Automated scans save X seconds per pallet		
Case		Pallets can be stored randomly (optimized) in warehouse			
		Truckload assembly	**Pallet breaking**	**Breakdown and routing**	
		Individual truckloads are assembled prior to truck arrival	Full pallets are moved from storage to picking area	Cases of goods are removed from pallet and either stored in stockroom or staged to the floor	
Pallet Case		Truckload assembly and loading in one step save time and space	Automated scans save X seconds per pallet		
		Truck loading	**Mixed pallet picking**	**Case breakdown**	
		Orders are loaded onto trucks	Cases are moved from picking area pallets onto mixed pallets	Full cases are broken for stocking of individual items	
Pallet		Automated scans save X seconds per pallet			
Case			Automated confirmation of cases picked saves X minutes per pallet		
			Higher picking accuracy leads to fewer missing or unsaleable products at store		
			Higher picking accuracy elimi-nates need for random checks		
		Returns/Recall processing	**Order assembly**	**Returns processing**	
		Goods returned to manu-facturer are processed	Orders for each store are assembled and staged	Damaged and unsellable goods are staged for return to the DC	
Pallet		Less handling effort for returned products	Automated scans save X seconds per pallet		
Case		More targeted recalls to retailers and consumers		Less handling effort for returned products	
				More targeted search for products recalled	
			Truck loading		
			Orders are loaded onto trucks		
Pallet Case			Automated scans save X seconds per pallet		
			Returns/Recall processing		
			Goods returned to manufacturer are processed		
Pallet Case			Less handling effort for returned products		
			More targeted recalls to stores		

Automation
Optimization
New process
Serialization

potential benefits not only for the retailer but also for the manufacturer. The logic why RFID tags on cases can lead to improved product availability and what this means for the manufacturer is discussed in more detail in chapter 2.3.2

The majority of benefits result from automating process steps that are currently conducted manually. Often, these process changes eliminate manual confirmation and checking procedures or the need to scan barcodes. In a few instances, RFID leads to an optimization of current processes or to new processes. In order to realize most of the benefits on case level that we consider, serialized data is not required. (Barcodes on pallets generally already contain a unique identifier, e.g. a SSCC number.) In the applications that we consider, a unique identifier for cases is only needed for recall and returns processing.

From a high-level financial perspective, most process changes and resulting benefits lead to cost reductions (see Appendix B). We do not envision that RFID on pallet level can lead to higher sales. On case level, RFID can increase sales for both the manufacturer and retailer by improving product availability at the retail store.

2.3 The benefits in detail

In this part, we will look to at the benefits that we have derived in more detail. We will separately discuss the benefits for pallet and case level tagging. The benefits are discussed along the supply chain described above. For some process steps, there is more than one relevant benefit (e.g. warehouse staging on pallet level). Also, some changes in certain process steps lead to benefits at later process steps (e.g. mixed pallet picking).

Not all benefits are discussed at the same length. Benefits resulting from automating certain work steps are discussed more briefly as we believe they need less explanation than those benefits resulting from new processes, optimization, or serialization.

2.3.1 Benefits of pallet level tagging

Manufacturer factory and warehouse:

- Pallet assembly:
  After pallet assembly at the factory, a barcode label is usually attached that is manually scanned in order to associate the barcode with the pallet. The magnitude of the benefit that can be achieved by automating this process step depends on the time that is needed for an operator to identify the pallet and the number of pallets received. The manufacturer may still decide to attach a barcode label to provide additional human-readable information on the pallet and a barcode for those supply chain partners that do not already use RFID.
- Goods receipt:
  With RFID on pallet level, the step of manually scanning the barcode on the pallet to create a storage request can be automated. In addition, acceptance of the delivery can be automatically confirmed to the trading partner.
- Warehouse staging:
  There can be different benefits at this process step. Firstly, RFID tags can eliminate the need for manually identifying a pallet when it is stored in or removed from the storage area. Furthermore, the storage location can automatically be verified if the storage locations are also equipped with RFID tags. This saves labor time. (Sometimes it is argued that RFID can help reduce the number of misplaced pallets in a warehouse. We have not considered this, since the companies we worked with stated that this is not an issue for them.)
  Secondly, RFID tags on pallets can lead to a process change that allows optimizing the storage of pallets in the warehouse. We found that companies often assign a fixed storage location to a pallet some time before the pallet actually arrives. The location is then printed on the pallet label. However, the optimal storage area might change and companies may find a benefit from assigning storage locations dynamically only at the point when a pallet arrives. When the RFID tag on the pallet is read, the warehouse management sys-

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tem determines the storage location and transfers this information to the forklift driver. (Although this benefit could also be achieved with barcodes, we have included it in our discussion as we feel that switching to RFID makes companies think about their current processes and might also lead to discussing potential improvements that are not always strictly related to RFID.) The financial impact of these benefits can e.g. be assessed by determining whether this process change can lead to a reduction in time to store and retrieve products or to less storage space being needed.

- Truckload assembly:
  Instead of assembling pallets to be shipped prior to the arrival of the truck, the pallets may be provided on a just-in-time basis and moved directly onto the truck. This would mean creating a new process in which requests for removal of pallets from the warehouse are assigned dynamically based on the trucks arriving. This process can also be realized based on barcodes. RFID tags, however, may enable this process as otherwise there would still be some time needed for manually verifying the pallets before they could be moved onto the truck. This new process can lead to a reduction in working time for assembling a truck load and may as well free up some of the shipment area that can then be put to other use.
- Truck loading:
  In order to verify the delivery, the barcodes on all pallets that are moved onto a truck are often scanned. RFID tags on pallets can automate this step, as has already been mentioned above, and save labor time for each pallet. This automated verification process may or may not be realized in conjunction with the new process for truckload assembly.

Retail DC:

- Shipment receipt:
  At the receiving area in the DC, pallets are identified manually when a truck is unloaded, and the physical delivery is checked against the delivery note and the order. RFID tags on pallets allow automatic identification of a pallet, thereby saving the labor time for identifying a pallet in the receiving process.
- Pallet staging:
  The improvements here are very similar to the improvements for the warehouse staging process. Automatic identification of the pallet and storage location can again free up some labor time.
- Pallet breaking:
  In DCs, there is often only one pallet available in the picking area that needs to be substituted when it is empty. Similar to the staging process, labor time is saved when pallets are identified automatically.
- Order assembly:
  After a pallet has been picked, it needs to be ensured that it is put in the right place in the shipping area. Currently, companies frequently use barcodes to mark specific sections in the shipping area. With RFID tags to mark those sections, the time to manually scan the shipping area barcode can be saved.
- Truck loading:
  As for the manufacturer, barcodes on shipping labels are usually scanned to verify a delivery. Eliminating the manual scanning process can free up time for the warehousing personnel.

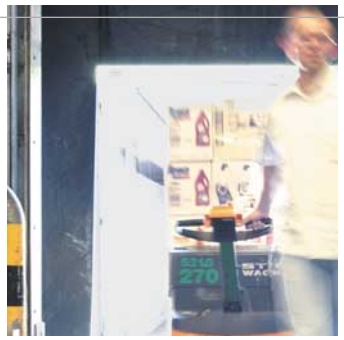
Retail store:

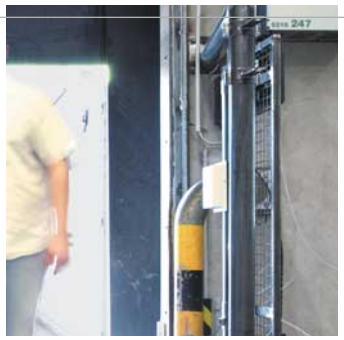
- Order receipt:
  At the retail store, pallets received are usually manually identified, and the physical pallets delivered are compared with the delivery note and the order. With RFID tags on pallets, the step of identifying the pallets can be automated which can save the store personnel some time.

2.3.2 Benefits of case level tagging

Manufacturer factory and warehouse:

- Pallet assembly:
  By reading the RFID tags on cases that are being put onto





a pallet, the manufacturer can automatically control that pallets are complete. This might reduce the need for manual rework at later process stages. This is also the point in the process where it might be most appropriate for the manufacturer to record the serial numbers of the cases that are put onto a specific pallet.

- Returns/recall processing:
  Retailers make returns when they detect products with quality problems in a delivery or products that have not been ordered. These returns need to be handled at the warehouse. RFID tags on cases can save some of the handling effort, as the cases being returned can be registered automatically.
  Furthermore, manufacturers can benefit from RFID tags on cases during product recalls. Recalls are issued for various reasons. Manufacturers have to recall products that pose health risks to consumers, but they also ask retailers to return products e.g. because they are incorrectly labeled. RFID tags on cases can provide a finer level of product traceability as single cases of products instead of production charges can be tracked. Manufacturers might benefit from that in several ways. Firstly, product returns can be handled more efficiently, because the cases being returned can be identified automatically. Secondly, manufacturers might be able to issue more targeted requests to return certain products, which leads to lower costs of products being destroyed. Thirdly, knowledge that products are traced on a very granular level might increase consumer trust in the product's quality and improve sales and margin. (Ensuring consumer health and safety is one of the major reasons for establishing traceability systems in the first place.)

Retail DC:

- Shipment receipt:
  At the receiving area in the DC, both quality and quantity of the products delivered are checked. RFID tags on cases can eliminate the need to check the number of cases on a pallet. If delivery notes are available electronically, deliveries can automatically be confirmed. This saves some of the manual control effort.
- Mixed pallet picking:
  RFID tags on cases can allow exact determination which cases have been picked. This can have two effects. Firstly, it saves the picker time that is usually needed to manually confirm the number of cases picked. Secondly, it can eliminate the need for any additional accuracy checks at later stages. For example, some retail DCs conduct sample counting of pallets after the picking process is finished in order to monitor picking accuracy. (Picking accuracy also has an impact on retail store operations. This impact is discussed below.)
- Returns/recall processing:
  Returns processing can become more efficient with RFID tags on case level. The cases to be returned can now be automatically identified. This saves time compared to manually recording the products that are returned and can help to automate the creation of a return receipt.
  In case of product recalls – provided that the retail DC has detailed information on the serial numbers of cases to be returned and to which stores these cases have been shipped – the DC can determine which stores might be affected and issue more targeted information to stores. (This aspect has an impact on how the store handles recalls and is discussed below.)
- Inventory counting:
  Much of the effort for inventory counting in DCs goes into checking the number of cases on the pallets that are placed in the picking area. If it becomes possible to determine exactly how many cases of a product are on a pallet by reading the RFID tags on the cases, the manual counting effort can be drastically reduced.

Retail store:

- Order receipt:
  In contrast to deliveries from retail DCs, which are often not

checked at the retail store, the shop personnel checks all direct store deliveries received from manufacturers. Provided that the RFID tags on all cases that are on a pallet can be read, the time for manual checks is reduced. Furthermore, by automating the checking process, the retail store might detect errors in deliveries that previously remained undetected. This avoids being billed for products that have not been delivered.

- Effect of changes to mixed pallet picking process at retail store:
  Increased picking accuracy at the retail DC does not only lead to benefits there but also has an impact on store performance. Firstly, a higher accuracy means fewer missing products in a delivery which can increase product availability. This depends on whether the products are actually required for shelf replenishment in order to avoid an out-of-stock situation before the next delivery can arrive.
  Secondly, if errors in a delivery are not detected, they also lead to a misalignment between inventory information in the inventory management system and physical inventory in the store. Some stores use computer systems to automatically generate order recommendations. If these recommendations are based on inaccurate information, too many or too few products may be ordered. In the first case, this leads to excess inventory. In the latter, this can lead to out-of-stock situations. It has been estimated that about one-third to half of out-of-stock situations are caused by store ordering and store forecasting processes [Source 1].
  Thirdly, sometimes there are products in a delivery from a DC that have not been ordered. If the products are listed in the store, this leads to additional inventory in the store. This causes some additional inventory holding cost. But these costs are likely to be negligible compared to the case when products are delivered that are not listed. These products can be returned to the DC, but as the cost for administering returns is rather high, some retailers tend to simply throw away the products.
- Shelf restocking:
  RFID on case level enables the separation of store inventory into backroom inventory and inventory on the store floor. This separation does not exist at the moment and can help to reduce out-of-stock in two ways.
  Firstly, visibility of backroom inventory can help employees to determine whether there might be products in the backroom that they are not aware of. Employees can then look for those products. If this process does not work, products go out of stock on shelves although they are in the store. Recent research suggests that in about one-third of out-of-stock situations, products are actually in the store but not on the shelf [Source 2].
  Secondly, the separation of store floor and store inventory can help to generate a rough estimate of the number of products still on the shelf. This estimate can be generated e.g. by combining the information on the number of cases moved onto the store floor (gathered from case level tracking) with sales data from the point-of-sale (POS) system. (This estimate will never be entirely accurate as theft, damage, incorrect scans etc. lead to inaccurate inventory data.) If an out-of-stock situation is approaching and there is still inventory in the stockroom, a request to replenish products from the backroom can be triggered automatically.
  Not all out-of-stock situations necessarily lead to lost sales. Estimates vary, but on average customers tend to buy a different product in about two out of three cases [Source 3]. This needs to be taken into account when estimating the impact on store profit.
  The manufacturer can also benefit from increased product availability, since fewer consumers switch to competing brands when a product is out-of-stock. For the manufacturer, it is less important whether the consumer buys a different product in the store; however, ist is important to know whether he/she in the end buys another product from the same manufacturer, the same product at a different retail outlet or a competing brand (or no product at all).





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There is also a negative impact of low product availability on customer loyalty both with regard to retail store and product brand, but this impact is hard to quantify.

To clarify, we do not want to argue that RFID tags on cases (or even on items in the future) can eliminate out-of-stock situations completely. But RFID tags can affect a few of the root causes for inventory inaccuracy. Figure 1 gives an overview of some of the causes for out-of-stock and highlights those that can be improved by RFID on case level and have been discussed by us.

- Return/recall processing and pickup:
  There are two aspects that need to be addressed here. The first one is related to the process of physically handling the products. RFID tags on cases can help to make the process of recording the cases to be returned more efficient, regardless of whether the products are returned because of a recall or because the store has detected that products have been delivered that were not ordered or are damaged.
  The second one is related to identifying the products that need to be returned in case of a recall. If the retail store receives a request to return certain products, store personnel start to look for these products in the store. At the moment, the store cannot determine whether the specific cases are still in the backroom or already on the store floor. A separation of backroom and store floor inventory can reduce the effort for locating these products in the store.
  Furthermore, based on the serial numbers of cases, the DC might be able to inform only those stores that have actually received products that are affected instead of all stores. This means stores that did not receive any of the products do not need to spend time searching for them.
  Whether this benefit is achievable depends on the retailer's policy with regard to product recalls. For example, in case of potential health risks, retailers tend to remove all products from the shelves even if they know that only certain charges are affected. This is done because retailers do not want to take any risks and also want to make it clear to consumers that they have taken action (as consumers tend not to distinguish whether all or only a few products are affected).

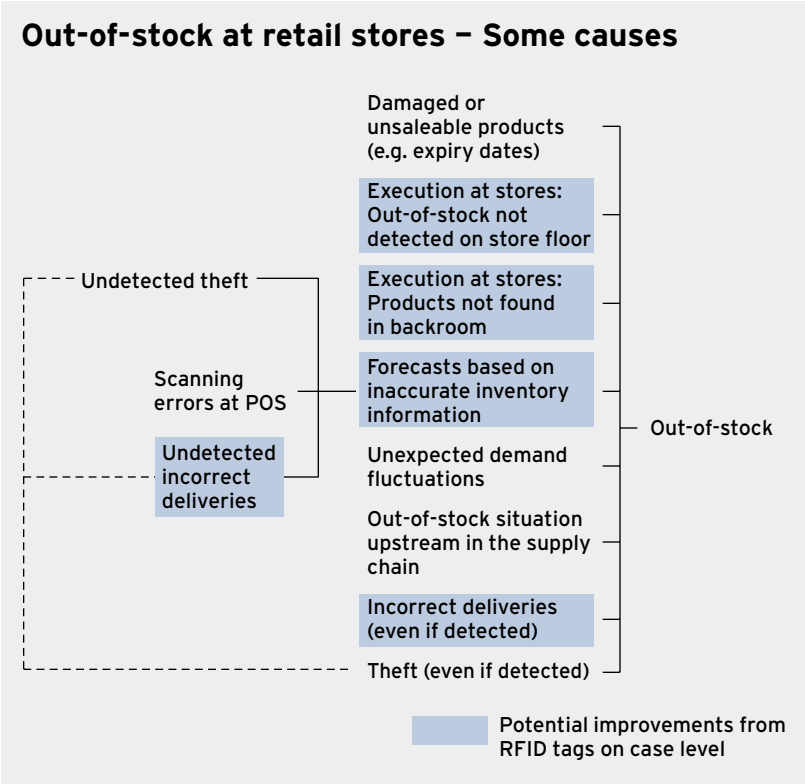


Figure 1: Selected causes for out-of-stock at retail stores

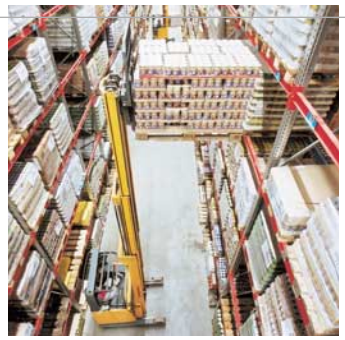
2.4 Impact of different product categories and supply chain characteristics

At the end of this chapter we will discuss whether the potential benefits are "sensitive" to certain parameters of a grocery supply chain, especially product categories. We first look at which differences between supply chains and product catego-

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ries are relevant when applying RFID on either pallet or case level. Differences can exist e.g. with regard to the current level of efficiency within the supply chain, the number of relevant work steps in the supply chain, the physical properties of the product, product-specific issues (e.g. theft, demand level, seasonal demand patterns, product promotions) and attributes (e.g. limited shelf life), and its price.

- Level of efficiency in the supply chain:
  Supply chains differ in their level of efficiency. Potentials for applying RFID can be higher when supply chains face problems, e.g. with regard to product visibility in the supply chain. The companies we talked to already use rather sophisticated processes and heavily rely on barcode-based solutions. Some potential benefits of RFID that are being discussed were therefore not relevant for these companies. For example, errors in inventory data that lead to products becoming unsaleable or high search cost were not mentioned as relevant issues in our sample. These issues might of course pose significant problems in other supply chains.
- Number of relevant work steps in the supply chain:
  There are supply chains that do not consist of only the three entities, warehouse, DC and store. Supply chains can involve additional entities, e.g. DCs operated by the manufacturer for cross-docking products produced at different locations. In these instances, there are additional process steps (e.g. receiving, storing, and shipping in the cross-docking warehouse) that RFID can help to improve.
  In some other supply chains, benefits might be lower. For examples, especially large supermarkets receive direct store deliveries of full pallets for some product categories. In these instances, the benefits e.g. related to an improved picking process are not relevant, since no picking takes place.
- Physical properties of the product:
  This aspect is especially relevant for case level tagging. It is less of a problem for pallet level tagging. The product's physical properties can have an impact on the type of tag that is needed and how it is attached. Liquids and metal can make it hard to achieve acceptable read rates.
- Product-specific issues (e.g. theft, product promotions) and attributes (e.g. limited shelf life):
  This list of product-specific issues and attributes is not meant to be exhaustive. However, the issues mentioned here might be of specific relevance for some products.
  Theft: Some products are stolen more often than others. Gillette, one of the companies very active in the area of RFID, is facing very high levels of theft for some of its products, e.g. razor blades. They see RFID as a potential to detect and reduce theft. In contrast, for many products, theft – especially on case or pallet level – is not an issue.
  Product promotions: For other products, there are frequent promotions. According to our interviews, promotional items can make up a significant part of the inventory in store backrooms. Using RFID to improve the replenishment process from the backroom can potentially have a bigger impact on product availability for those products than for others that are usually not found in the backroom.
  Limited shelf life: For products with limited shelf life, a first-in-first-out inventory policy for moving cases onto the store floor needs to be ensured. Serialized data on case level can help to monitor this policy. This issue is less critical for products with long shelf lives.
- Product price:
  Product price is frequently stated as one of the main determinants for the use of RFID. However, this is more relevant when it comes to item level tracking. For an item that costs 1 EUR, for example, it might be harder to find savings that warrant the use of RFID tags than for an item that costs 5 EUR. Product price is less of an issue on case and pallet level, since a lot of the benefits are derive from automating certain steps in handling the physical unit. This handling effort and the resulting savings depend on the number of handling units, not on their price.







03

Case studies

In this chapter, we will provide some examples for the process changes and potential benefits for the companies that were involved in the study.

In each case study, we describe the process changes that lead to a specific potential benefit and give an indication of the financial impact of this benefit for the retailer, the manufacturer, or both. We also discuss important issues from our perspective that need to be addressed in order to realize the benefit. Each of the following case studies contains the following elements:

- Brief background / relevant context information
- Current process
- Process with RFID
- Indication of potential financial benefit
- Issues that need to be addressed in order to realize the benefit

We examine several case studies separately for pallet and case level tracking. The specific numbers presented at certain points have been altered to protect the confidentiality of study participants but still give an accurate reflection of the benefits and costs of RFID deployment.

3.1 Background on companies

Before going into the detailed process steps, we will provide some general information on the three companies considered.

Global Foods Inc. is an international manufacturer of packaged food products with annual sales exceeding 20 billion EUR. It has several dozen different brands, some of which are global whereas others are only available in selected countries. We specifically look at one of its brands that manufactures and sells a wide variety of convenience food products. Products come in cans, bottles or cardboard packages. The products can be stored for several months without refrigeration. At the specific plant we were looking at, about 200 different products are produced. The plant is located in Central Europe. From there, products are sent to about 300 distinct delivery points in several European countries. The warehouse receives and ships around 300,000 pallets per year.

Food Manufacturers Ltd. is a large producer of a wide variety of food products that is active worldwide. Similar to Global Foods Inc., the company sells consumer products under different brand names. We looked at one of its production facilities, which produces chocolate and related products that are sold under one brand name. The production capacity at the plant is around 50,000 tons per year. Next to the plant is a warehouse in which products are stored. 75% of products are shipped internationally as full pallets to Food Manufacturers' regional distribution organizations. Of the remaining 25% designated for the national market, about 50% are mixed pallets. The picking for these pallets is done in a designated area in the warehouse.

Retail International Corp. is an international retail company that has operations in more than 20 countries. It has different distribution lines, some of them focusing on electronics, others on grocery products. The company has centralized purchasing and logistics operational units that serve several distribution lines. We looked at one distribution line that operates medium-sized supermarkets and focuses on dry goods. Due to their medium size, the supermarkets receive more than 80% of dry food products from Retail International's DCs. There are different DCs involved, depending on whether we are talking about dry goods, fresh products, frozen products etc., and whether products are A, B or C products. From the DC that we consider, the store receives three deliveries of between 8-12 pallets a week. The DC receives and ships around 330,000 pallets a year. Almost all shipped pallets are mixed pallets.

3.2 Potential benefits of pallet level tracking

3.2.1 Use of RFID tags on pallet level

There are several ways in which RFID tags can be used on the pallet level. For the use of RFID in the supply chain that we have examined, we assume that pallets are equipped with





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Electronic Product Code (EPC)-compliant RFID tags that contain a unique number. The EPC number on the tag is used as an identifier for the pallet as it moves through the supply chain. The SSCC number currently used on barcodes on the pallet can be stored directly on the tag, either embedded directly within the EPC, or alternatively, in a separate memory area on the chip. If random EPCs or non-EPC tags are used, a two-column link table would be required to map the tag IDs to SSCC numbers.

As not all companies will switch to RFID at the same time and there is also a need to have some kind of safety mechanism in case of unreadable tags, we assume that the manufacturer will still put a printed label with some information on the pallet.

3.2.2 Truck loading at Food Manufacturers

- Background and current process:
  To assemble a delivery, forklift drivers remove the pallets to be shipped from the storage area and place them in the shipping area prior to the arrival of the truck. The trucks are owned and operated by a third-party logistics provider. Loading pallets onto the truck is done by the truck driver, supervised by warehouse personnel. All pallets are scanned in order to ensure that the correct pallets are put on a truck.
- Process with RFID:
  Food Manufacturers does not want to rely on the third-party truck driver to ensure that the right pallets are put on a truck. Scanning a barcode is still a manual task which makes it error-prone. Truck drivers might e.g. be tempted to skip scanning any barcodes at all if they are in a hurry. By using RFID tags on pallets that are read when the pallets are moved onto the truck, one can automatically check the identity of the pallet. A signal (light or sound) can be used to indicate that a pallet (a) has been read and (b) actually belongs on this truck. RFID on pallet level might enable Food Manufacturers to eliminate the need for warehouse personnel supervising the entire loading process.
- Potential financial benefit:
  There are about 15 trucks leaving the warehouse every day. For every truck, we expect that about 10 minutes of supervising time could be saved. Assuming 250 working days a year and 25 EUR labor cost per hour, Food Manufacturers would save 16,000 EUR per year at this one warehouse. Per pallet, this would mean savings of about 20 EUR-Cent. Figure 2 shows a way how the potential financial impact of this benefit is calculated.
- Issues to be addressed:
  With RFID, the current process of loading trucks is not only automated, but to some extent a new way of doing the loading process is enabled. There are two main issues that need to be addressed. One, it needs to be ensured that read rates are at (or close to) 100%, which should not be a problem on pallet level. This is required, since any misread is likely to lead to manual intervention from warehouse personnel and cut into the savings. As truck drivers are not employed by Food Manufacturers, it is unlikely

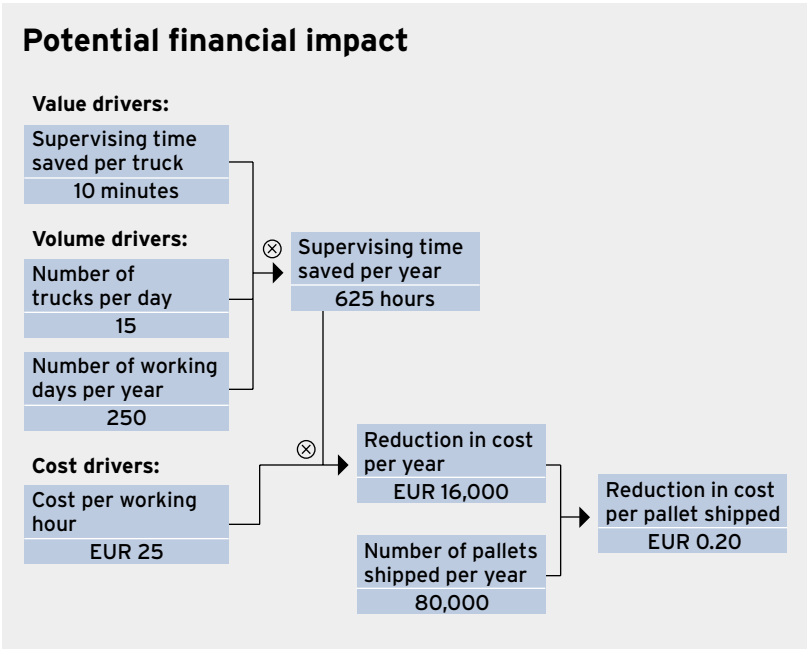


Figure 2
Truck loading at Food Manufacturers: Potential financial impact

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that they will be sufficiently trained to resolve these issues. Secondly, it needs to be ensured that the new process is understood and accepted by the third-party logistics provider and its employees.

In addition, the response time of signals (lights) must be reasonably short, if we expect the worker to adhere to these signals. If he has to wait for several seconds, it would be unacceptable and unworkable from an operations' perspective. However, it is still important to record anything that went wrong, since it is impossible to guarantee 100% what the workers are actually doing.

3.2.3 Truckload assembly and truck loading at Global Foods

- Background and current process:
  As at Food Manufacturers, pallets to be shipped are assembled in a special shipping area before the truck arrives and from there moved onto the truck. In order to verify that the correct pallets are placed on a truck, the barcode on the pallet is scanned. Forklifts usually move two pallets that are stored on top of each other at the same time.
- Process with RFID:
  Global Foods envisions using RFID tags to enable a new process for loading trucks that are shipped directly from the factory warehouse. Instead of assembling pallets prior to the truck's arrival, they should be provided just in time when the truck arrives and should be loaded directly from the forklift onto the truck. There are two types of benefits. The first one comes purely from eliminating the need for manual barcode scans, the second one from redesigning the entire process, which can lead to further reductions in labor needed as well as freeing up storage space that can be used otherwise. (At the moment, Global Foods rents additional storage space at a separate location, because there is not enough space available at the factory warehouse.)
  The second benefit is realized by changing the warehouse management system so that it can assign orders based on the arrival of trucks. Terminals with a wireless connection are needed inside the forklift cockpit that can display the actual order.
- Potential financial benefit:
  We will look separately at those two types of benefits. With regard to the first type of benefit (i.e. automating the current process of barcode scanning when a pallet is moved onto the truck), Global Foods expects to save approximately seven seconds per pallet shipped this way. Of the 300,000 pallets shipped by the warehouse, one third is affected. (The other two-thirds are transferred to Global Foods' DC adjacent to the warehouse.) With 25 EUR per hour for labor cost for warehouse personnel, we get a benefit of 5,000 EUR for this warehouse alone. Breaking it down for a pallet, we get 5 EUR-Cent per pallet.
  With regard to the second type of benefit (i.e. optimizing the loading process by just-in-time assembly of pallets), Global Foods expects to save 30 seconds per pallet. Assuming 30 EUR per hour for a forklift driver, we get a savings potential for labor cost of 25,000 EUR per year or 25 EUR-Cent per pallet. Furthermore, we expect that Global Foods could gain 500 square meters of storage space. Assuming 50 EUR per square meter and year for rented storage space, we get another potential of 25,000 EUR. (This calculation ignores the current cost of moving products to and from the rented storage space.)
- Issues to be addressed:
  Regarding the first type of benefit, the issues are very similar to the example given above for Food Manufacturers. We will therefore focus on the second type of benefit. As already mentioned, there are changes to the current warehouse management system required, and forklifts need to be equipped with terminals. Furthermore, a mechanism is needed in order to let the system know that a specific truck has arrived.
  Additionally, the effect of this new process on the third- party logistics provider needs to be examined. For example, al-



though it might be more efficient for Food Manufacturers to assemble the delivery just in time, the overall time for loading a truck might increase. This would essentially mean that warehouse processes improve at the expense of the logistics provider as unproductive truck waiting times increase.

3.2.4 Goods receipt at Retail International's DC:

- Background and current process:
  When a truck arrives at the DC, the pallets are unloaded. As products come from a third party, all deliveries are checked manually for accuracy and against delivery note and initial order. Retail International currently does not receive dispatch advices from its suppliers. Furthermore, quality is checked. Then a label is attached to each pallet containing information in human-readable format (article number, supplier number, number of items per case, picking place, receiving time and week, etc.) as well as a proprietary barcode. The barcode is scanned, and the content of the pallet is associated with the barcode. The barcode scan also creates a storage request.
- Process with RFID:
  Retail International can use the RFID tag on the pallet to identify and track the movement of the pallet in its DC. By reading the RFID tag, the pallet is automatically identified. In combination with a dispatch advice, the DC can determine automatically what should be on the pallet. Delivery accuracy and quality still need to be checked manually.
  The printed label attached by the manufacturer can remain on the pallet and allows for manual identification of a pallet when needed.
- Potential financial benefit:
  We estimate that the process of identifying a pallet, attaching the barcode to the pallet, and associating the barcode with the pallet's content takes about 10 seconds per pallet. The DC receives approximately 1,300 pallets per day. Assuming 20 EUR per hour labor cost, the DC could save around 18,000 EUR per year or 5.6 EUR-Cent per pallet.
  Printing a label (including hardware cost on a pro-rata basis) costs around 2 EUR-Cent. If there is no label attached at the DC, there is another savings potential of roughly 6,500 EUR.
- Issues to be addressed:
  With RFID, the current process of unloading and identifying pallets and their content is automated. There are several issues that need to be considered.
  Firstly, as for other applications, read rates of as close to 100% as possible are required. Again, this should not be a problem on pallet level. Also in this application, signals can be used to inform personnel whether a pallet has been read successfully and could be associated with a position in a dispatch advice (if relevant).
  Secondly, in the target process described, we assume that Retail International can automatically associate the pallet identifier with the pallet's content based on the information contained in an electronic dispatch advice. For Retail International, this requires additional collaboration with the manufacturer. If a dispatch advice is not available, the potential savings would decrease, since this association would still require manual effort.
  Thirdly, the label currently attached at the DC contains not only a barcode but also information on picking location, week of arrival etc. If this label were still needed (instead of using the label attached by the manufacturer), this would reduce the benefit.
  Fourthly, it is likely that not all manufacturers use RFID and dispatch advices starting on day one and that not all pallets contain EPC-compliant RFID tags. Therefore, the new and old process may have to coexist for a while. This might cause additional cost. Retail International has to find a way to deal with this issue.

3.2.5 Pallet staging at Retail International's DC:

- Background and current process:
  In the DC, full pallets are moved by forklifts. The pallets are

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usually stored in the upper rows of the storage shelves in proximity to the picking location for the specific product. Picking places are located on the ground floor and fixed for each product. They have been determined in order to minimize picking routes. To store a pallet, the forklift driver approaches a pallet in the receiving area and scans its barcode. Based on the number stored in the barcode, the warehouse management system assigns a storage place. The storage place is assigned based on rules that take e.g. driving and elevation times into account. This information is displayed on a terminal in the cockpit. To confirm that the pallet has been stored correctly, the forklift driver enters the checking number for the storage location.

- Process with RFID:
  The pallet is automatically identified when the forklift approaches the pallet in the receiving area. For this, an RFID reader on the forklift is needed. When placing a pallet, the reader on the forklift reads the RFID tag for the storage location in order to verify that the pallet has been stored in the right place. In both instances, labor time is saved.
- Potential financial benefit:
  In this process step, RFID can help to automate the current process of manual barcode scans. We estimate that RFID saves five seconds for identifying a pallet and a storage location each. With 1,300 pallets stored each day, this means labor cost savings of approximately 18,000 EUR per year or 5.6 EUR-Cent per pallet, assuming 20 EUR per hour labor cost for a forklift driver. (In the long run, this might also lead to fewer forklifts being needed which would reduce the capital tied-up in equipment.)
- Issues to be addressed:
  As for the receiving and shipping process, signals can be used to indicate whether a pallet or storage location has been identified correctly. This would allow to correct these so-called false negative reads (i.e. a tag that should be read is not read), e.g. by manually identifying a pallet based on the label attached.
  However, in this application one potentially also has to deal with false positive reads (i.e. tags that should not be read are accidentally read). For example, when a forklift driver approaches a pallet or a storage location, the reader might not only read one tag but additional tags belonging to other pallets and storage locations respectively.

3.2.6 Order assembly at Retail International's DC

- Background and current process:
  Most of the pallets being shipped from the DC are mixed pallets that have been picked at the DC. At the end of the picking process, the picker places the pallets in a designated row in the shipping area, attaches a new proprietary barcode label and scans it in order to associate the barcode with the pallet. The correct row is ensured by scanning a barcode that identifies the row. This activity also terminates the picking processes, and the pallet becomes available for shipment.
- Process with RFID:
  As discussed above, we assume that RFID tags are integrated into pallets and are used to identify and track pallets as well as the content on the pallet. Furthermore, we assume that the hand lift trucks used for picking are equipped with an RFID reader. (There are also other possible options in which e.g. hand lift trucks do not contain a reader but an RFID tag.)
  The pallet is identified at the beginning of the picking process and associated with the picking order. When the last case has been picked, the pallet is moved to the shipping area. An RFID tag for each row is read in order to ensure that the pallets are placed correctly.
- Potential financial benefit:
  RFID in this case helps to automate the current process of manually attaching and scanning a barcode label on the pallet and the scanning of the barcode for the shipping row. We estimate that RFID saves five seconds for attaching and scanning the barcode label on the pallet. As

the barcode that identifies the row is usually scanned while the picker is on the move, we do not assume any time savings here. With 1,300 pallets picked each day and 20 EUR labor cost per hour for a picker, we can estimate savings at approximately 9,000 EUR per year or 2.8 EUR-Cent per pallet. (The barcode label attached to the pallet in the shipping area is much simpler and cheaper than the one attached during the receiving process. Therefore we do not consider any savings in printing cost.)

- Issues to be addressed:
  As the rows in the shipping area are directly next to each other, there is the risk of false positive reads. Signals can be used to indicate to the picker that the shipping row could not be determined accurately.
  With RFID tags on pallets, there is no need to attach a separate barcode. However, this would mean that there would be no other information on the pallet that allows identification except for the RFID tag. (In the process steps considered before, there was still a label attached to the pallet.) In case the tag becomes unreadable, it might become difficult to identify the pallet. If this might cause problems, companies may nevertheless put on a barcode as an additional safety measure.

3.2.7 Truck loading at Retail International's DC

- Background and current process:
  Similar to the truck loading process at Food Manufacturers warehouse, where the barcode on the pallet is scanned in order to ensure that the right pallets are put on the truck, the new barcode is scanned. Retail International does not entirely rely on third-party logistics providers for transportation. 60-70% of transports to stores are done by Retail International, the remaining capacity is bought from third parties (e.g. to cover peak demand).
- Process with RFID:
  The tag on the pallet is scanned when the pallet is moved onto the truck. This eliminates the need for manual barcode scans.
- Potential financial benefit:
  Scanning the barcode takes about three seconds per pallet. With 1,300 pallets per day and 20 EUR per hour labor cost for shipping personnel, this gives approximately 5,500 EUR per year or 1.7 EUR-Cent per pallet.
- Issues to be addressed:
  As already mentioned above, any misreads would lead to manual intervention, which would reduce the benefit. Therefore, a read rate of close to 100% is desirable.

3.3 Potential benefits of case level tracking

3.3.1 Use of RFID tags on case level

RFID tags on cases may either be already integrated into the packaging material or are attached sometime during the production process e.g. as part of a printed label. Except for pilots, we do not expect RFID tags on cases to be reused on a large scale.

The tag may either contain an essentially random EPC number or a specific number (e.g. a GTIN) plus a unique serial number. In contrast to pallets where a SSCC number already allows identifying a pallet uniquely, currently two cases containing the same product cannot be distinguished by reading the barcode.

When random EPCs (instead of EPC numbers containing e.g. a GTIN plus serial number) are used, the EPC number for each case needs to be known as otherwise the case cannot be identified at all. Companies may need to change their legacy systems so that they can deal with these random EPC numbers or maintain long tables that link each of the random EPC numbers to a GTIN. With a GTIN plus serial number, a company can simply ignore the serial number and still identify the case. We regard the latter alternative as the likely one to be realized.

3.3.2 Shipment receipt at Retail International's DC:

- Background and current process:
  There are two types of checks conducted when a delivery





is received at the DC. Firstly, the amount delivered is verified; secondly, product quality is checked (e.g. are any damaged cases or products in the delivery?). The first check involves two steps: (a) Checking the delivery note against the underlying order (i.e. are all products that have been ordered listed in the delivery note?), and (b) checking the physical delivery against the delivery note (i.e. are there any missing, additional or interchanged cases in the actual delivery?). The check of the physical delivery is conducted manually, and any differences that are detected are manually adjusted. As mentioned before, Retail International does not receive dispatch advices from its suppliers at the moment.

- Process with RFID:
  With RFID on case level, there is the potential to automatically collect information on the actual products contained in a delivery. This would make step (b) much faster, since it eliminates the need for manually counting the cases on a pallet. Furthermore, if a dispatch advice is sent in advance, step (a) can be completely automated. To realize the benefit of automatic counting, serialized data is not necessary.
  As for the receiving process on pallet level, signals can be used to inform personnel whether all expected cases on a pallet have been read successfully or if unexpected cases were read. This requires however the availability of a dispatch advice with the information what cases were packed onto which pallet.
  The quality check is assumed not to change, since EPC does not allow checking whether a case or product is broken or damaged. (For the companies we talked to, management of expiry dates was no issue in the warehouse or DC, because a first-in-first-out inventory policy is applied, and inventory turns are sufficiently high.)
- Potential financial benefit:
  For full pallets, the current process of checking a pallet takes about three minutes, including quality checks and label attachment. Some savings can already be achieved with RFID on pallet level (see above).
  We assume that by eliminating the need for manually counting the number of cases, one could save another half a minute per pallet. Automating the comparison between physical delivery and delivery note based on the tag reads and the dispatch advice could lead to savings of another 10 seconds. With 18 EUR per hour for warehouse personnel and an average of 80 cases per pallet, this would lead to savings of approximately 72,000 EUR per year or 0.3 EUR-Cent per case.
  Automatically comparing the delivery note against the order (step (a)) could lead to additional savings, but as these savings are not directly related to RFID, we have not considered them.
- Issues to be addressed:
  A high read rate of cases on a pallet is absolutely critical to reduce the effort for manual counting in step (a). This might be achievable for some products, but at the moment this is unlikely to be achievable for all types of products (e.g. those containing liquids and metal).
  It is likely that not all manufacturers will use RFID on case level and send dispatch advices starting on day one. Therefore, the new and old process may coexist for a while. If the manufacturer does not send dispatch advices, Retail International can still reap some benefits, since the manual step of counting the cases on a pallet could be automated. In this case, the employee would need some kind of display that shows the number of cases and could then manually compare this figure with the delivery note.

3.3.3 Mixed pallet picking at Retail International's DC

- Background and current process:
  The DC receives electronic orders from the store. Based on these orders, picking orders are generated and forwarded electronically to pickers. The pickers use hand lift trucks, which contain a terminal to display and confirm

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the different steps of the picking process. Usually two pallets that belong to the same order are filled by one person at the same time. Each mixed pallet consists of 80 cases on average. There are dedicated picking locations for each product. The picker sees the information where to go next on his terminal. After picking the indicated number of cases of a certain product (or less if the product is not available), the picker enters and confirms the number of cases picked.

Picking is not error-free. In some instances, the picker accidentally picks more cases, forgets to pick cases or picks the wrong product. These picking errors roughly amount to 0.5% of cases picked.

As both the DC and the store belong to the same holding company and checking is too labor-intensive, Retail International does not check all pallets but accepts some picking errors.

The company conducts tests in order to get statistical data on picking errors. 1% of all pallets that have been picked are counted by separate personnel in the shipping area. If an error is detected, the worker who has picked the pallet needs to correct the error.

Picking errors causes costs not only at the DC but also at the store. (The impact of picking errors on store performance has already been discussed above. Here, we want to briefly repeat this discussion augmented with details about the specific situation we are looking at.)

Firstly, missing products can cause out-of-stock situations at the store, even if detected at some point in time in the store. (The store we consider orders and receives deliveries three times a week. Therefore, errors can usually not be corrected for until the next delivery arrives.)

Secondly, if products are delivered that are not part of the store's assortment (different distribution lines have different assortments), these products need to be returned or are simply thrown away.

Lastly, undetected picking errors are one reason for inaccurate store inventory data. Inaccurate inventory data can have a negative impact on the quality of orders (e.g. products are not ordered although they are needed, or more products are ordered than needed) as the store forecasting system bases its decision on an assumed number of products that differs from the number of products actually in the store.

- Process with RFID:

  With RFID tags on each case, one can now record exactly the number of cases picked. Every time a case is picked and placed on a pallet, an RFID reader (e.g. on the hand lift truck) records the case identifier of the picked cases. By automating this activity, one saves time, because there is no longer a need for the picker to confirm the number of cases being picked. Furthermore, the number of picking errors can potentially be reduced, since the picker can get a signal when he picks a product that does not belong to the delivery, or picks too many or too few cases. By reducing the number of picking errors (at best to zero), Retail International hopes to be able to eliminate the need for manually counting 1% of deliveries.

  Furthermore, an increased picking accuracy also leads to fewer resulting costs at the retail store.

- Potential financial benefit:

  There are about 1,300 mixed pallets picked each day. On average, picking a pallet takes 35 minutes. We assume that about 4 minutes per pallet could be saved by eliminating the manual task of confirming the cases picked. This would lead to potential labor cost savings of 430,000 EUR or 1.7 EUR-Cent per case.

  Eliminating the sample checks could save 75 minutes per pallet checked. With 1% of pallets checked, potential savings in labor cost amount to roughly 81,000 EUR per year or 0.3 EUR-Cent per case.

  The benefit for the store from more accurate deliveries is hard to quantify. The issue of out-of-stock resulting from inaccurate deliveries is considered below when we look at

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shelf restocking. At this point, we only want to focus on the issue of additional products that are not part of the assortment and might be thrown away. As the store we consider only carries about one-half of the products of the larger stores that are also served via the DC, we assume that 50% of the additional products (0.15% of all cases) are unsaleable. The store receives approximately 90% of products from Retail International's DCs. This means approximately 240,000 cases per year (this figure is for dry products only). In total, the store would receive 180 cases that cannot be sold. Assuming 20 EUR per case, the savings for the store would amount to 3,600 EUR or 1.5 EUR-Cent per case (3,600 divided by 240,000 cases).

- Issues to be addressed:
  For this application, getting a read rate of very close to 100% is an important issue as well. There are different ways in which a solution for recording the number of cases picked could be implemented. One possible solution would be to place a reader on the hand lift truck above the pallets that are currently assembled. This would have the advantage that the reader would only have to read those cases that are currently put on the pallet without any additional products in between. False negative reads could thereby be avoided. There is also a risk of false positive reads that needs to be addressed. For example, cases on pallets in the picking area that are close to the picking aisle might accidentally be read.
  An alternative solution would be to equip all picking locations with RFID readers, so that they record which products are removed. However, this requires high read rates of cases on a pallet, which might be hard to achieve. This issue will be discussed below when we look at the case of inventory counting efficiency at Retail International's DC.
  If the serial numbers of cases picked are to be recorded (e.g. in order to realize traceability of single cases), it must be ensured that these numbers are adequately stored and associated with the pallet EPC number.

3.3.4 Inventory counting at Retail International's DC

- Background and current process:
  The DC currently conducts an annual inventory counting. The main effort goes into manually counting the cases on pallets in the picking area.
- Process with RFID:
  Retail International might equip every picking location with a reader with at least one or several antennas. Assuming that all cases can be read, an accurate inventory figure would be available any time. This would potentially eliminate the need for a manual inventory count.
- Potential financial benefit:
  One inventory count takes about 1,800 hours, resulting in a savings potential of approximately 36,000 EUR per year.
- Issues to be addressed:
  Ensuring a read rate of 100% for cases on a pallet might not always be achievable. Alternatively, one may simply use the data on picked cases. As picking accuracy is likely to increase with the use of RFID on case level, this might give a rather accurate picture of the inventory in the picking location.
  At the moment it cannot be determined whether the data gathered is sufficiently accurate. In the end, a manual inventory count may still be necessary.

3.3.5 Shelf restocking at Retail International's store

- Background and current process:
  There are specific time windows in which the store receives deliveries. The pallets are first placed in the stockroom. The same day after the store is closed, employees hired from a third party move the pallets onto the store floor and replenish the shelves. Full cases that could not be placed onto the shelves are returned to the stockroom. Retail International intends to keep as low a stockroom inventory as possible. Therefore, for most products there are only a few or no cases in the stockroom and large parts of the inventory consist of promotional products or





non-food products. Product availability on shelves is constantly monitored by store employees. Products that go out of stock frequently are monitored more closely. If a stock-out is approaching for a product, employees are encouraged to replenish products from the backroom as soon as possible (if possible). In order to determine whether there might still be products in the stockroom, they rely on their memory. The current stock-out rate is 4%. The store estimates that it loses 1% in sales from stock-outs.

- Process with RFID:
  Currently, there is no system in place to record which cases have already been moved to the store floor and which ones are still in the stockroom. By placing a reader between stockroom and store floor, it can be detected which cases move from stockroom to store floor (and potentially back again), assuming a sufficiently high read rate of cases on a pallet. If empty cases are moved through the same door as full cases, there needs to be a procedure in place to determine which cases are empty and which are returned to the backroom. The RFID tags of empty cases can be registered e.g. when they are thrown away. Store personnel can now get a rather detailed picture of stockroom inventory. This can increase the chances of successfully replenishing products from the backroom, since employees do not need to rely on their memory to find out whether there might still be products in the backroom.
- Potential financial benefit:
  There is no empirical data available on the actual effect of RFID tags on case level on product availability. Retail International estimates a 50% reduction in out-of-stock. (This would mean a 2%-point increase in product availability.) This effect is not only reached by a separation between stockroom and store floor inventory, but also by more accurate deliveries to stores due to fewer picking errors (see above for a discussion of the resulting benefits). For the retail store, this could mean an increase in sales of 0.5%. Assuming a price of 2 EUR and a gross margin of 25% on each additional product being sold, Retail International's profit would increase by 0.5 EUR per additional item. (According to the Food Marketing Institute (FMI) in the US, supermarkets achieved a gross of 28.4% in 2001.) These figures can be translated into a potential benefit per case. With 20 items per case, an increase in product availability can generate an additional profit of 5.0 EUR-Cent per case or 12,000 EUR per store. Increased product availability at the shelf also has a positive effect on sales for the manufacturer. (We do not assess the potential impact on brand loyalty.) Assuming that the consumer buys a different brand (or no product at all) in one out of three stock-out situations, increasing product availability by 2%-points would lead to additional sales of 0.7% for the manufacturer. (For all calculations, we assume the same margin on the substitute.) As the margin for the manufacturer tends to be higher than for the retailer, the benefit for the average manufacturer might be in excess of the 5.0 EUR-Cent calculated for the retailer. But assuming the same gross margin of 25% for the manufacturer as for the retailer, the benefit for the average manufacturer can be estimated at 7.0 EUR-Cent per case. For Food Manufacturer's production site, this could amount to a savings of more than 1 million EUR per year.
- Issues to be addressed:
  Read rates of close to 100% on case level are less important here than in a lot of the previously discussed applications. Even if the information on backroom inventory is not entirely accurate, it still gives more visibility than previously available. If employees are to be able to check backroom inventory remotely to determine whether replenishment from the backroom is possible, they might need to be equipped with handheld devices that can remotely access the store inventory management system. In order to accomplish a separation between stockroom and store floor inventory, the store inventory management system needs to be updated.





While it is difficult to pinpoint which of the benefits generated by the use of RFID is *the* killer application, it is clear that tagging makes financial sense today for both retailer and manufacturer. As the case story summary chart below illustrates, applying a tag to a pallet may result in a benefit of € 0.50 to the manufacturer and € 0.16 to the retailer. In this model, tagging individual cases did not generate direct financial benefit for the manufacturer. However, the manufacturer can gain indirectly from higher product availability at the store which is estimated at € 0.07 per case. For the retailer, tagging at case level has the potential to result in a € 0.09 benefit. These numbers can be regarded as baseline benefits. Not included, for example, are any savings in labor at the retail store from more efficient store operations. An Auto-ID Center white-paper estimates that these savings might be even bigger than the savings from improved on-shelf availability [Source 4]. With tag costs rapidly declining, companies will see immediate benefits at the pallet level and should see per-tag benefit at the case level by the time systems are deployed.

		Pallet Tagging			Case Tagging		
			€ per year	€-Cent per pallet		€ per year	€-Cent per case
Manufacturer		Truck loading at manufacturer	16,000	20.0	Increased profit from better on-shelf status	1,280,000	7.0
		Automating barcode scans at warehouse	5,000	5.0			
		Just-in-time order assembly	25,000	25.0			
Retailer	DC	Receiving goods at distribution center	18,000	5.6	Labor reduction in receiving goods	72,000	0.3
		Staging pallets at distribution center	18,000	5.6	Labor reduction in picking mixed pallets	430,000	1.7
		Order assembly for store shipments	9,000	2.8	Elimination of sample checks	81,000	0.3
		Truck loading for store shipments	5,500	1.7	Reduction of inventory counts	36,000	0.1
	Store				Reduction of mispicked cases	3,600	1.5
					Increased profit from better on-shelf status	12,000	5.0
		Total benefit to manufacturer		**50.0**	**Total benefit to manufacturer**		**7.0**
		Total benefit to retailer		**15.7**	**Total benefit to retailer**		**8.9**

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04

Roadmap

Preparing the Enterprise for EPC-RFID

Despite offering both retailers and manufacturers significant advantages, deploying RFID-based solutions at scale poses immense and complex challenges on both the business transformation and technology infrastructure fronts. Many areas of benefit – ranging from decreased out-of-stocks to improved handling of returns – require not only an internal process change but new methods of collaboration between retailers and manufacturers as well.

Business Transformation: Manufacturers

Beyond pilot projects, such as the METRO Group Future Store Initiative, where retailers are affixing RFID tags at the distribution center level, most envisioned RFID scenarios begin with a tag being applied to the finished good as it moves off the factory production line. This allows the manufacturer, retailer and associated third parties (such as logistics companies) to share in the benefit of tagged tracking as the product moves through the supply chain.

But this also creates the essential paradox of RFID deployments: although both manufacturers and retailers have similar costs to deploy readers and associated infrastructure, the manufacturer alone bears the ongoing cost of affixing tags to products. Since the benefits are shared and accrued by multiple partners, it stands to reason that the cost would also be shared with retailers in some way as well.

Past experiences at "collaboration", however, have evolved far more slowly than a common sense "win-win" understanding would imply. Even sales data, gathered via the 25-year-old method of scanning a barcode at the point of sale, is not shared universally between retailers and manufacturers, despite the overwhelming evidence that sharing this data improves the ability of both parties to match supply with customer demand.

While it is possible for a manufacturer to achieve modest cost savings through the raw automation benefits provided by RFID (such as the reduction in time a forklift operator needs to move a pallet if the forklift itself "scans" the pallet), the majority of RFID benefits to manufacturers is only possible when a collaborative relationship exists with retail partners, and collaboration with trading partners is the most important – and by far the most difficult – element of business transformation facing manufacturers wishing to capitalize on RFID investments.

Many of the examples of collaboration between manufacturer and retailer are simply examples of best practices of existing initiatives such as EDI, CPFR and sharing of POS data. But what is clearly different about collaboration using RFID data is that, in many instances, the collaboration itself is in real time. If an RFID system alerts a distribution center that pallets in a shipment are missing cases, a real-time resolution between the retailer and logistics company is implied. To truly take advantage of RFID, companies must begin approaching collaboration not as a planning tool but as a way of doing business in real time.

The Production Line

Although several categories of manufactured goods will benefit from the use of RFID technologies during their manufacture and on the assembly line, the supply chain implications truly begin when the tag is affixed to the finished product. One of the first challenges that manufacturers will face is restructuring the process of assembling, shrink-wrapping, and tagging pallets of finished goods.

In the pilots to date, tags have been manually affixed to the cases and pallets. In scale deployment, the production line will have to be retooled to accommodate the automatic affixing of tags. Once fully integrated into the production process, current concerns about the location of the tag and the readability of barcodes in a "hybrid" tag will be allayed.

Of course, the affixing of RFID tags to products becomes a virtually moot point if the tags are incorporated fully into product packaging, but this requires the active collaboration





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of packaging suppliers and logistics companies (see below). Since collaborative solutions inherently require dramatically longer roll-outs than single-company initiatives, manufacturers wishing to capitalize on RFID in the short term must address the issue of physically attaching the tag to cases and pallets.

The Warehouse

The manufacturer warehouse illustrates perhaps the most intriguing benefit of moving toward an RFID-based identification system – but ironically, this benefit has little to do with the core RFID solution itself.

Historically, warehouses have relied heavily on the eyes of forklift drivers to determine where a product is staged and stored. This has resulted in the evolution of a system where like items are stored near like items. So a warehouse may have a tall stack of one product (necessitating a more complex storage or retrieval procedure) adjacent to an empty area with no pallets in it. This results not only in an inefficient use of physical space but also in routes to fill individual orders that may have the forklift driver going back and forth multiple times past the same product.

What would break through this efficiency barrier is the ability to store pallets without reference to what the pallet contained; in other words, if every pallet is stored in a specific location based on its physical dimensions and the available space (rather than on a forklift driver's ability to put all pallets of product type X in a particular location). But to do this requires that every pallet – not just every pallet *type* – have a unique identification number, and that every pallet *space* similarly be uniquely identified.

At its heart, this is, in fact, simply serializing every pallet and location. There is no doubt that this information could be contained in a barcode, and, in fact, EAN-128 addresses many of these issues. Although many manufacturers and retail distribution centers have either already gone this route or are in the process of deploying serialized location-based warehouse schemas, the deployment process for infrastructure and new warehouse management systems is sufficiently painful, so that many others have chosen to continue relying on human perception as the best organizing principle for warehouses.

Perhaps the most key element of business transformation for manufacturers – and retailers alike – is beginning the transition from today's "human-centric" business process to a future where processes are built around computer-optimized decisions. Using data – any data – to drive optimized processes is absolutely a prerequisite for taking full advantage of new data sources like RFID. For example, rather than using a historical audit of shrinkage to gauge the effectiveness of shipping solutions, manufacturers will create business rules to check of the contents of each and every pallet – scanned via RFID – at shipment and destination and allow the manufacturer, shipping company, and retailer to resolve any exceptions in real time.

The human element in warehouse operations is impossible to ignore. In one RFID test conducted by Wal-Mart and the Auto-ID Center, an inexplicably inaccurate read step was found to be caused by forklift drivers deviating as little as six inches from their designated route – literally "cutting corners." While theoretical solutions such as boosting the range of readers, forcing drivers to follow a narrower path, or better training of the drivers all *could* solve the problem, the fundamental fact remains that no technology solution will be successful until it addresses the fundamental change that computer-directed activities entail.

Collaboration

Manufacturers looking to deploy RFID-based solutions in hopes of achieving positive business results must look carefully at the success of other technologies that have promised dramatic ROI – but at the cost of "everyone has to do it." It took decades for the use of barcodes to become universal at the retail point of sale (and barcodes have zero incremental

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cost over printing packaging without them, unlike RFID). And even today, many manufacturers bemoan the dearth of sales data that their retail "partners" provide them. Some large CPG manufacturers report that they see POS sales data on less than 40% of the products they produce.

And POS data is not an isolated example:

- EDI: Electronic data interchange offers immense benefits if all parties agree to exchange information using standardized formats, but many retailers still cope with hundreds of manufacturers using manual processes, which in turn inhibits their ability to move to a completely electronic solution.
- CPFR: Despite the promise of greater efficiency for both retailers and manufacturers, mutual distrust has kept collaborative planning, forecasting and replenishment from taking off.
- Trading exchanges: Several years (and several hundreds of millions of dollars) after their creation, public exchanges are handling only a tiny fraction of the trading volume of their founders.

So what do these all have in common with RFID? Many of the collaborative benefits of RFID require that manufacturers and retailers share data that they already have today but have chosen for business reasons not to share. While many retailers and manufacturers participate in pilot projects sharing data gleaned through RFID, many don't translate this sharing attitude into their day-to-day business dealings with the same partner.

In order to make RFID work at scale, manufacturers will have to collaborate with:

- Retailers. Many of the business processes practiced by both retailers and manufacturers are antithetical to the collaborative benefits of RFID: trade promotions, loyalty programs (in their present incarnation), forward buying, returns allowances, etc. Before the full benefits of RFID can be realized, the benefits of sharing dramatically deeper information between retailer and manufacturer must be realized first.
- Logistics providers. Several of the examples cited in the benefits model require an active collaboration between the manufacturer and logistics providers. For example, in order to accurately schedule the arrival of trucks (a necessity if a manufacturer moves to "just-in-time" assembly of orders without a staging area), the logistics provider must provide much more information about the movement of its fleet. Similarly, in many instances, the logistics provider itself may be best positioned to both tag and track the flow of pallets. Companies like intelligent pallet provider CHEP would receive a double benefit from installing permanent tags onto pallets: not only would they enable manufacturers and retailers to track pallets on their own, but serializing pallets and sharing the infrastructure to track them would dramatically reduce the loss of pallets in CHEP's ecosystem of client companies.
- Packaging manufacturers. Many of the experimental technologies that are being explored to drive the cost of RFID tags down to five cents – or even lower – require innovative manufacturing processes that may ultimately preclude the affixing of a separate tag at the point of manufacture of a finished product. Printing RFID antennas with conductive ink directly on packages is one such technology, but before this can be used, an active collaboration between the packaging manufacturer and the goods manufacturer must share the cost – and benefit – of requiring additional work by the packaging company. While early pilots will continue to focus on tags that are applied separately in the process, long-term RFID solutions will integrate the tag into the packaging much as the barcode moved from a printed label affixed to a good to an integral part of the printing process.

Of all the elements of business process change, collaboration offers the greatest challenge and the greatest reward. While manufacturers can certainly re-engineer certain parts





of their production lines and warehouse operations to gain "inside the four walls" benefits from RFID deployment, these benefits will at best barely outweigh the cost deployment. To achieve significant bottom line improvements, manufacturers must look outward and assess the degree to which they are capable of collaborative business practices that take advantage of RFID data.

Business Transformation: Retailers

One of the ironies of RFID is that once the level of tagging is moved from pallet to case – or especially to item level – the benefit derived by manufacturers dramatically decreases (as the quantity of goods they ship means they care most about pallet quantities) while the benefit derived by retailers dramatically increases.

Retailers struggle with both an exponentially more complex warehousing situation (receiving shipments from hundreds of vendors and assembling shipments to hundreds of stores) and, historically, processes that have been resistant to technology impact for years. Retailing is often referred to as a mix of art and science, usually in the context of explaining why technology won't solve a given problem.

First and foremost, taking advantage of the incredible quantity and quality of information provided by RFID requires that retailers shift their thinking about their business to admit that 21st century retailing is 90% science and 10% art. In other words, to thrive with technologies like RFID, retailers must first accept that data-driven decision-making is inherently more successful and profitable than using such soft measures as last year's demand, a store manager's hunch, or the intuition of a fashion buyer.

Distribution Center

For retailers, the overwhelming majority of process benefit and change is in the distribution center. With even the promised five-cent tag, the cost of tagging (and tracking) individual items puts many of the in-store benefits of RFID out of reach of retailers deploying RFID at scale. So in the short and medium terms, the fundamental question that will impact the retail distribution center is whether tags are affixed at a pallet or case level.

- Pallet level tagging. The process impact of the use of RFID at a pallet level is minimal in the retail distribution center. Although it does offer some significant automation benefits (such as allowing a forklift driver to skip the step of scanning a pallet before picking it up), the benefit of RFID is focused exclusively on the receiving of goods into the distribution center and the tracking of mixed pallets that are subsequently shipped out to stores. As shown by the virtually non-existent misplacement rate of pallets in the Metro distribution center (4 pallets misplaced each month out of 75,000 shipped, a rate of 0.005%), the accuracy gains afforded by even a multiple-reader RFID solution would be minimal and the impact on process similarly minimal. To take advantage of the automation benefits of RFID at a pallet level, retailers must simply replace barcode scanners with RFID readers and reap the (small) benefit of automating the read process.
- Case level tagging. Taking advantage of RFID at the case level requires a much larger shift in infrastructure (see below), but the process implications are not quite as dramatic and in many cases also involve a corresponding reduction in labor time. If RFID tags are applied to all cases in a retail DC, not only can the process of picking be enhanced both in speed and accuracy during the pick, but the existence of tags on the cases allows multiple check points for accuracy prior to the picked pallet exiting the DC. The process remains fundamentally the same, save for the change in the physical workflow around moving a case to the trolley and moving a pallet into a truck.

In both pallet and case level tagging, the process implications for collaborative steps still rely on changing the relationship between DC and logistics provider. If the retailer is using its own fleet for delivery of goods, this process change can be





minor. But retailers working with third-party logistics companies to deliver goods to the stores must develop new processes that address both the timeliness and accuracy of information. For example, many "best practice" retail DCs already schedule the arrival of trucks in a narrow time window (e.g. 20-minute blocks). Those that haven't already mastered that collaborative step will find it very difficult to achieve ROI based on RFID-enabled processes until they have already developed best-practice relationships using the data that is available today.

Store receiving

The implications for process change for stores receiving goods tagged at a pallet level are virtually non-existent; the tag replaces the same barcode that would be scanned or visually accounted for during existing goods receiving processes. At the case level, however, RFID tagging enables retailers to do an instant check of the contents of every pallet, address any discrepancies that arise, and immediately identify the location of goods that are urgently needed to address impending stock-outs on the floor.

For the purpose of this white paper, we have focused on a stockroom architecture that assumes a single portal at the entryway through which goods pass into the stockroom. This would provide store personnel with a "snapshot" of goods entering the stockroom. As such, the process implication is again mostly in the collaborative resolution of exceptions with the logistics provider and the more immediate reporting of misdelivered or underdelivered shipments to the retail DC. The impact on store personnel is minimal.

One possible exception to this would be the use of handheld RFID readers to locate cases within the stockroom itself. While many goods are unloaded almost immediately onto the store floor, others languish in the stockroom until they are needed. Industry statistics have shown that some 35% of the time, products out of stock on the shelf in grocery stores are actually in stock in the back room. A simple system by which sales data from the POS triggers a message to a handheld informing the store associate of the EPC number of a case that needs to be pulled out of backstock and brought to the floor can provide reduction in "in-stock out-of-stocks" without a major investment in smart-shelf infrastructure.

Store floor

Virtually all of the real process changes on the store floor involve the use of smart shelves that require item-level RFID tags on products on the shelf and alert staff when replenishment is necessary. Although a powerful concept in pilot, three major barriers stand in the way of this becoming mainstream in the short and medium terms.

- Tag cost. While five-cent tags are (theoretically) just around the corner, even at a five-cent cost, the low margin on most grocery and CPG goods means that affixing even a five-cent tag would not generate sufficient benefits to justify the investment. High-theft items such as razor blades, batteries, DVDs, etc. may create a compelling business case, but it is unlikely that affixing RFID tags to individual cans of soda or packages of candy will be economically viable in the short and medium terms.
- Infrastructure cost. Beyond the tag cost, smart shelves are expensive and because of that are again only viable for high-theft, high-cost items. Blanketing the store with an infrastructure capable of reading every tag every few seconds is not only prohibitively expensive but would generate an astronomical quantity of data to sort as well. This combined infrastructure cost far outweighs the benefits of universal item-level tagging in the future.
- Process change. In many instances, replenishing the shelf on an item-by-item basis, rather than a full case at a time, not only fails to generate substantial business value but also would require massive process changes. Rather than stocking a shelf once a day or several times a day, store associates would have to constantly disrupt the flow of cus-

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tomers to put items on the shelf, and backroom stock could no longer be counted in cases but instead would have to be accounted for also at an item level.

Customers

While much media attention has focused on the implications of RFID for consumers, its use in the retail supply chain doesn't touch the customer directly. Items shipped in RFID-tagged cases and pallets still arrive on the store shelf with only a barcode on them. So, as retailers and manufacturers deploy RFID at the pallet and case levels, consumers simply enjoy better availability of their favorite products on the store shelf.

But as companies begin tagging individual items, they must be cognizant of both the real and perceived interaction between consumers and those tags and take steps to ensure that the impact on consumer privacy is minimal. Where item-level tags are used in the METRO Group Future Store Initiative, signage clearly identifies the use of the tag to consumers so that they are aware of the existence of both the tag and reader.

Tech transformation

Just as the successful adoption of RFID requires both process and structural changes on the business level, its impact on the technology infrastructure is equally profound. The raw quantities of data generated – much of it in new forms and gathered at new points – strain even the conceptual capacity of the vast majority of enterprise systems today. Many processes are tracked with an "assumptive conclusion": for example, a signature on a shipping manifest at the store is assumed to mean that the entire contents of the shipment arrived intact. Tracking the flow of products using RFID means a dramatic reduction in the inaccuracies inherent in assumptive systems, but at the price of a dramatic rise in the quantity and locations of data flowing through the system.

Most retailers and manufacturers deploying RFID do not have the luxury of a greenfield installation where an entirely new architecture is put in place. Significant investments both in enterprise software and in the customization of that software to particular ways of doing business make it impractical to assume that a new architecture will quickly or easily materialize that supports RFID's requirements to gather and use data at multiple points in the supply chain.

Similarly, the benefits of RFID adoption span multiple enterprise applications, and as virtually all companies use enterprise applications from multiple vendors, the simple reality is that even if perfect support for RFID technology were available from one – or several – vendors, companies relying solely on the enterprise application layer for RFID support would have significant gaps in their ability to successfully use RFID until all vendors offered equal support, a practical impossibility.

So the solution for companies wishing to deploy RFID in the near term is to begin with a separate technology layer that handles the primary tasks of gathering, filtering, and acting on RFID data gathered from multiple readers in the enterprise. This infrastructure is possibly the most important, but least understood, components of a successful RFID system, and understanding its role in the transformation of the enterprise technology architecture is critical to the success of any scaled RFID deployment.

It begins with the actual process of reading the tag and interpreting the data. A tag scan is nothing but a series of bits until the reader determines what those bits mean and what to do with that information. Turning that tag read into a message that can be interpreted by other software systems is the fundamental purpose of the RFID Reference Architecture, or RRA. See Appendix C.

New Architectural Requirements

Getting started with RFID can be as simple as replacing a barcode scanner with an RFID scanner and gathering the exact same data with no change to an existing process. The technical requirements at this point are simply replacing a pe-

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ripheral; the other hardware, applications, and data structures remain the same. At the other end of the spectrum, continually monitoring the location of every item in a warehouse using hundreds of linked readers and hundreds of thousands of tags would involve changes to every part of an existing technology infrastructure. Most companies will choose a path between the two extremes, and, in doing so, must address the architectural implications of RFID:

Since RFID requires extending the enterprise architecture into multiple new dimensions (physical space, scalability of data, and multi-company collaboration), a new architecture is required that encompasses the layer of hardware, software and data structures that essentially resides between the readers and both individual enterprise applications and the enterprise application integration (EAI) level. To illustrate the role of this new architecture, imagine the process of a pallet of RFID-tagged cases arriving at a retail distribution center. The RRA's role is to:

- Gather data. When the pallet crosses through the entry portal, multiple RFID readers would read any tags that enter their range. Since even the best readers don't achieve 100% accuracy, multiple readers in the same portal allow an instant check on the accuracy of the scan and ensure that all the tags on the pallet have been read. The RRA would compare the results of the multiple readers to derive a "single view of the truth" as to what tags were actually scanned at the entry portal.
- Filter data. Instead of a paper manifest accompanying the truck driver, the shipped pallet is accompanied by an electronic transmission of the shipped contents of the pallet. In other words, the retailer's distribution center is alerted by the manufacturer's warehouse management system that this specific pallet should be expected to contain these specific case ID numbers. The RRA system would receive this electronic notification, scan all tags passed through the entry portal, and identify when the expected shipment had been received.
- Generate events. The RRA is not in and of itself an enterprise application, but it is capable of communicating with other applications through events and messages. If the

Technology challenge posed by RFID	Solutions requirement
Multiple physical environments require new hardware	Secure wireless network ubiquity and standardized architecture throughout the enterprise
Harsh physical environments for technology (e.g. warehouses, distribution centers, store backrooms, etc.)	Ruggedized hardware and attention to total-cost-of-ownership (TCO)
New points of data gathering (e.g. portals, "smart shelves," etc.)	Scalable architecture that allows rapid expansion of technology in new physical environments
Massive influx of new data as cases are serialized or tags are scanned repeatedly	Distributed application architecture that allows data to be filtered close to the tag read
Data must be shared between multiple applications	Enterprise applications must be integrated and Web services enabled
Data must be shared between multiple companies	Solutions must be deployed on a common, open, standards-based architecture that allows seamless transfer between enterprises

tags scanned upon arrival match the expected contents of the shipment, the retailer's systems – as well as the manufacturer's WMS – are notified of the event. If an exception occurred, such as a missing case, the RRA reports this to the appropriate applications rather than attempting to resolve the exception itself. Ideally, this data is filtered out at the reader or controller level. Only the appearance of new tags or the disappearance of known ones is reported to the higher-level AII.

- Locally act on events. Part of the value of an RFID-based system is its ability to shift management of products from a historical view of "what happened" to a real-time view of "what is happening." In order for the exception to offer the ability for any real-time resolution, local notification of personnel at the point of scan must occur. So, while the actual resolution of exceptions occurs at the enterprise application layer, notification and an interface that allows local personnel to see that an exception is occurring in real time are core functions of the RRA.

Effects of the RFID Reference Architecture

Although in an abstract diagram the RRA appears quite simple, its effects on the flow of information through the enterprise are profound. Processes that are currently handled through historical reporting in a single application will soon require that real-time, accurate, and filtered data be made available to a number of applications *prior* to reaching a data warehousing level. While easy to propose on paper, most companies are still struggling to fully take advantage of historical reporting on an enterprise basis, so an infrastructure that gathers, processes, and acts on data in real time is simply out of the reach of most companies exploring RFID today. But this cannot, and should not, stand as a barrier to the gradual deployment of RFID through the enterprise. Although it is unrealistic to either scrap the existing architecture in favor of a greenfield deployment or to bring RFID to all the enterprise applications at once, a measured approach to RFID is possible, though it first requires a look at the impact of the RRA on the core layers of the technology infrastructure.

Physical (hardware) layer

Any RFID-enabled process begins with the reading of an RFID tag by a reader. The reader hits the tag with a radio beam and reads the information contained on the tag. What happens next depends on the architecture at the hardware level. Some readers are designed to simply pass the tag read along to an attached computer, relying on the computer to do validation (e.g. reading a check sum, eliminating tag collisions, etc.) Other "smart" readers have the ability to do validation and even basic filtering, embedded in the reader itself. This results in two possible architectures for the physical hardware layer: an independent reader architecture where "smart" readers are connected directly to the RRA and a controlled reader architecture where a computer controls multiple attached readers and is itself connected to the RRA.

Both of these architectures have benefits and weaknesses, and it is envisioned that a single RFID deployment into a physical location such as a warehouse might contain both independent and controlled readers. Not only that, but many different hardware vendors will offer readers that all must be interconnected – and, more importantly, maintained on an ongoing basis. A reliance on any particular proprietary solution at the hardware level will cripple companies' ability to gain benefit from RFID. Since hardware will flow into a heterogenous physical environment and fulfil multiple tasks, open architecture that supports multiple reader and controller types is critical.

It is important to note that in many cases, the deployment of an RFID system into a physical space such as a retail stockroom or manufacturer warehouse is a significant introduction of new hardware into an environment that is not generally

complementary to technology. Deploying the RRA means bringing physical technology off the desktop and into the "real world," and that carries both a substantial investment cost and significant risks to damage from real world accidents. Since many processes rely on near 100% accuracy of reads, a scalable architecture that allows near 100% uptime of the system is a must.

Data layer

Once a tag is read, the RRA is responsible for determining what to do with the information gleaned from the tag. If it is simply querying a system for what to do with the tagged item (for example, a conveyer belt that is automatically routing cases based on their destination), it can simply pass that information on to the appropriate system, receive the response, and purge the tag scan from its memory; the historical record of which case was routed where would be kept not in the AII but in the appropriate enterprise application.

But many of the applications envisioned for RFID don't simply map a single tag read to a single enterprise application. For example, one of the highest-impact applications of RFID at the case level would be reducing the error rate of cases mispicked into mixed pallets of goods. To do this, a reader on the picking trolley would be constantly scanning – say every five seconds – searching for all the tags within range (e.g. placed on the pallet). Since the data that such a scan would return is simply a series of tag numbers, an application would have to be developed that constantly evaluated the results of each scan against the expected results of the scan and alerted the operator when there were exceptions. Although the data needs of the particular application are modest (up to 200 cases on the trolley, scanned every five seconds), they are certainly more substantial than passing along a single tag read and then purging the memory.

The data problem becomes more complicated when more advanced applications are introduced. The concept of "smart shelves" that keep track of what products are on them creates an astronomical quantity of data even at a warehouse (case) level: scanning a 96-bit EPC-compliant RFID tag once every five seconds from the 500,000 cases in a retail distribution center generates 32,958 GB of data every hour. While the vast majority of this data is simply confirmation of the existence of the requisite number of cases on the shelf – and is therefore disposable – the RRA is required to filter and process an incredible amount of data in these more advanced RFID applications. Ideally, this data is filtered out at the reader or controller level. Only the appearance of new tags or the disappearance of known ones is reported to the higher-level AII.

In the near term, applications that are already able to track serialized data (such as EAN-128 numbers on pallets) should be able to easily accommodate the stream of real-time, single-tag reads coming from an RRA system. The real challenge in the near term will be preparing these applications for the more granular serialized data that comes from RFID tagging at a case level: In the Metro example, the Essen distribution center shipped 615,700 pallets to stores in 2001, each of which were duly recorded and serialized. Bringing serialization down to the case level would require that the enterprise applications handle data on 45,739,000 items, a 74-fold increase in data management and storage.

While most of the RFID applications envisioned today are built on discrete single scans of RFID tags affixed at the pallet or case level, keeping track of individual items in real time is not far off. For goods with a high theft rate at the shelf, such as razor blades, or goods with a complex inventory mix like DVDs or audio CDs, RFID provides a mechanism to keep track of exactly what is on the shelf in real time. Today's barcodes give the ability for a system to track the last point at which an object was scanned, and portal-based RFID readers that register a pallet's arrival in the warehouse simply replace the laser with a radio wave; the fundamental data architecture remains the same. But

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if systems are developed that instead track where an object is in real time (by repeatedly scanning multiple readers and reporting on everything within range), these systems simultaneously exploit more of the inherent power of RFID and generate orders of magnitude more data. While these "constant scan" applications are more complicated to develop, they offer a truly revolutionary way for retailers and manufacturers alike to monitor their supply chains: from the factory to the store floor.

Network layer

The implications of the RRA on the network are, for the most part, a direct result of the implications on the data layer. Simply put, whatever network is in place to support the RRA must be capable of moving the quantity of data generated by the tag scans. For simple applications, 10 MB Ethernet may well be sufficient; for smart shelves tracking individual items the requirements would tax even the most sophisticated Gigabit Ethernet switches. And despite the large volumes of data envisioned in advanced RFID applications, the calculation of how much network bandwidth is needed and where is straightforward and mathematical.

The other consideration that the RRA brings to the forefront is the physical location of readers and other hardware. Where many barcode-based systems in warehouses and distribution centers have relied on the scanning device to store up scanned data and transmit it to a host PC when placed in a cradle, RFID-based systems essentially demand a constant communication between reader and the RRA, which in turn essentially demands universal access to wireless networking throughout the physical facilities which employ RFID. Security protocols for wireless networking, though widely misunderstood and underdeployed by end-user organizations, are in fact quite robust and, if properly implemented, should allow retailers and manufacturers to deploy sufficient high-bandwidth wireless network connectivity into all physical spaces necessary for the RRA.

The introduction of RFID at an item level, even in extremely limited applications, onto the store floor, however, creates an additional networking and security issue that is not so easily addressed. While the traffic between readers and the store network can be secured through encryption, the standard-based information encoded on each EPC-RFID tag is by definition unencrypted. In other words, the contents of the RFID tag can be read by any reader tuned to the same frequency. While the physical logistics of scanning UPC or EAN barcodes today prevent competitive espionage, it would be far more difficult in an RFID-enabled future to prevent a competitor's employee from simply walking through the store with a handheld RFID reader and within minutes capturing an exact inventory position of the store. Even more disruptive would be a walk-through with an RFID read-*writer* and, for example, flipping the "privacy bit" that deactivated each RFID tag in the store, thus rendering the entire system inoperative.

While this potential for mischief may sound remote and far-fetched, the most important network and security implication of the RRA is that RFID blurs the line between electronic security and physical security. When there is literally a computer on every pallet, case, or item, the distinction between what is "data" and what is "product" become far less clear, and while RFID dramatically reduces the accidental introduction of error into the data, it dramatically increases the possibility of intentional corruption of the data.

Application layer

As seen in the RFID Reference Architecture, enterprise applications themselves do not need to be able to handle the raw RFID data, so in that sense the impact on them is minimal. But one absolute prerequisite to the ability to take advantage of RFID is the ability to handle messages from other applications in real time. Since the majority of RFID-enabled process changes require communication between different applications – or even different companies – in real time,

batch import or offline data transfer are simply not robust enough to allow companies to derive the benefits of RFID.
Web services offer a migration path that allows virtually any application to share data and functionality with other applications, and most vendors of enterprise applications have Web services supported in current releases. But for companies that have not yet upgraded systems to current versions, obtaining Web services functionality either from a complete upgrade or tools like enterprise application integration (EAI) is a necessary step in connecting the RRA with the functionality of existing applications.
Another major consideration is the data model used internally by enterprise applications. In addition to being able to support real-time messaging between applications, these enterprise applications also must support serialization at the appropriate granularity in their own data models. So, for example, a warehouse management system can no longer simply maintain a record showing that there were ten cases of shampoo shipped to a retailer and three more remaining in the warehouse; it must now keep track specifically of *which* cases left the building and which remained in the warehouse. While pallet data is much more routinely serialized – and therefore more widely supported in enterprise applications – case-level serialization is still relatively rare, and item-level serialization even rarer. So, companies considering a leap to RFID must ensure that their enterprise applications are capable of managing that serialized data at the same level of granularity as the RFID-enabled solution.

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Glossary

Adapted from the Auto-ID Center glossary
(part of the EPCGlobal archives)

Antenna
A device for sending or receiving electromagnetic waves.

Distributed architecture
Software that runs simultaneously on different computers distributed throughout an organization, rather than on one central computer.

EAN International
The international group that administers barcode standards in many parts of the world.

Electronic article surveillance (EAS)
Simple electronic tags that are either "on" or "off." When an item is purchased or borrowed legally, the tag is turned off. When someone passes a gate area holding an item with a tag that hasn't been turned off, an alarm sounds.

Electronic data interchange (EDI)
A widely accepted method of sharing data over a business network.

Electronic Product Code (EPC)
A global coding scheme, administered by EPCGlobal, that will identify an item's manufacturer, product category and unique serial number.

EPCGlobal
A joint venture between the Uniform Code Council (UCC) in the United States and EAN International in Europe to administer the numbering and data standards for EPC.

European Article Numbering (EAN)
The bar code standard used throughout Europe, Asia and South America. It is administered by EAN International.

eXtensible markup language (XML)
A widely accepted way of sharing information over the Internet in a way that computers can use, regardless of their operating system.

Global Trade Item Number (GTIN)
A superset of bar code standards, which is used internationally. In addition to manufacturer and product category, GTIN also includes shipping, weight and other information. The EPC is designed to provide continuity with GTIN.

Hardware
The physical, touchable, material parts of a computer or other system. Hardware for RFID systems consists of tags and readers, along with the computers required to collate, process and communicate the data generated.

Radio Frequency Identification (RFID)
A method of identifying unique items using radio waves. The big advantage over bar code technology is that lasers must see a barcode to read it. Radio waves do not require line of sight and can pass through materials such as cardboard and plastic.

Reader
Also called an interrogator. The reader communicates with the RFID tag and passes the information in digital form to a computer system.

Smart cards
A broad term used for a plastic card (usually the size of a credit card) with an embedded microchip. Some smart cards contain an RFID chip so they can identify the holder without requiring any physical contact with a reader. RFID smart cards are often called "contactless" smart cards.

Tag
The generic term for a radio frequency identification device. Tags are sometimes referred to as smart labels.

Tag collision
Interference caused when more than one RFID tag sends back a signal to the reader at the same time.

Uniform Code Council (UCC)
The nonprofit organization that oversees the Uniform Product Code, the barcode standard used in North America.

Universal Product Code (UPC)
The barcode standard used in North America. It is administered by the Uniform Code Council.

Source listing

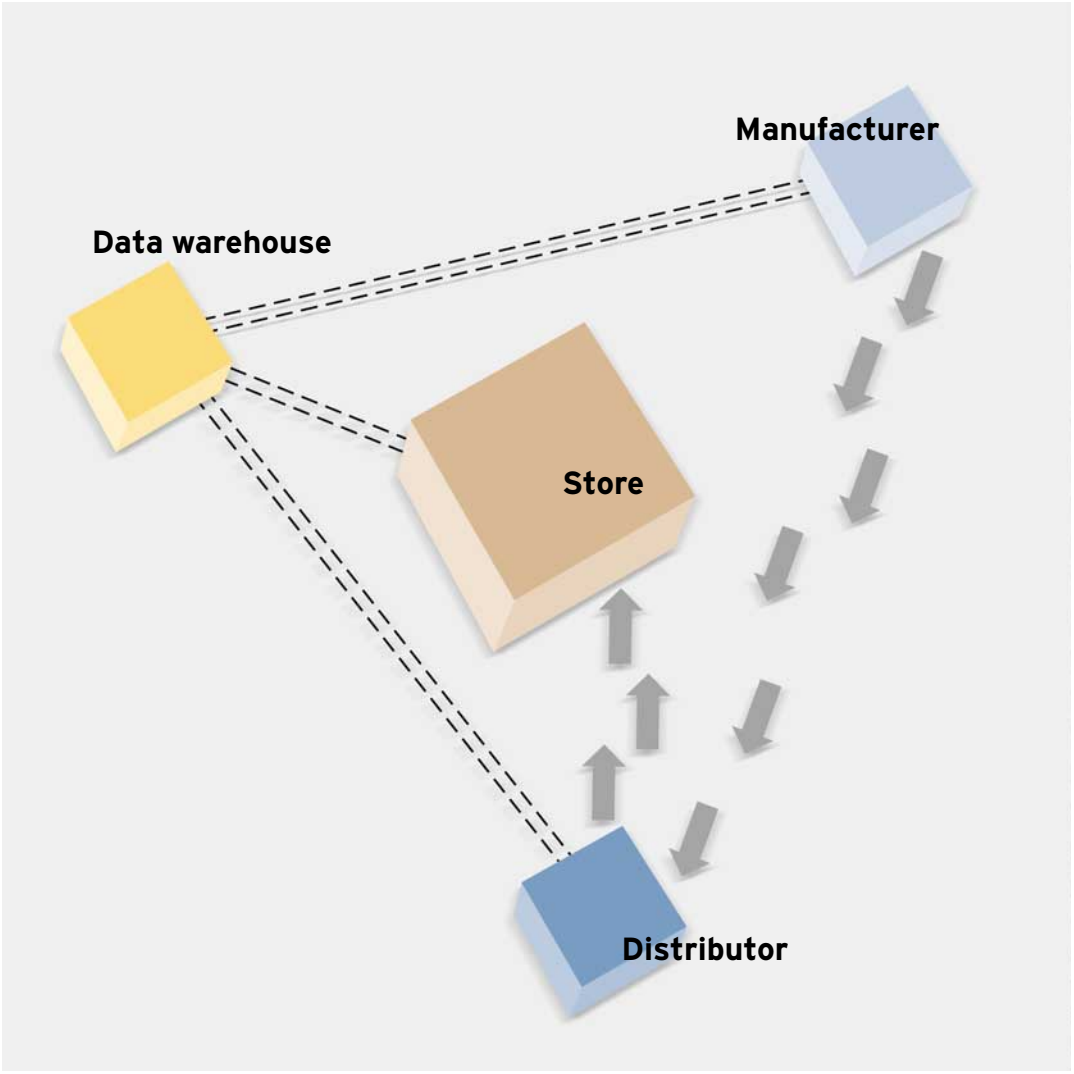
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Appendix

Figure A.1: Current process and process with RFID on pallet and case level for the manufacturer, retail DC and retail store

Current process		Changes to process with RFID on pallet level	Changes to process with RFID on case level
	Manufacturer's plant and warehouse		
Cases are put on pallet until full pallet is assembled; then, the pallet is shrinkwrapped and labeled with barcode	Pallet assembly	EPC tag on pallet is read in order to identify pallet	Serial numbers of cases are registered when put onto pallet
Barcode is manually scanned in order to associate barcode with content and to create storage request	Goods receipt	EPC number is associated with content of pallet	*No change to process with RFID on pallet level*
Barcode is manually scanned in order to identify pallet at storage and at removal; sometimes, storage location is verified as well (e.g. by scanning barcode on storage location)	Warehouse staging	EPC tag on pallet is read in order to identify pallet; EPC tag at shipping area is read in order to verify location	*No change to process with RFID on pallet level*
Pallets are placed in shipping area	Truckload assembly	Pallets are no longer assembled prior to arrival of truck; instead, requests to remove pallets from storage area are assigned dynamically when trucks arrive; EPC tag on pallet is read when pallet is moved onto truck	*No change to process with RFID on pallet level*
Barcode on pallet is manually scanned in order to verify delivery	Truck loading		
Manufacturer informs retailers and customers which product charges need to be returned /are recalled; returned products are handled manually	Returns/Recall processing	*No change to current process*	Based on tracking of serial numbers for cases, manufacturer can inform retailers which specific cases need to be returned / are recalled; cases returned can be identified via EPC numbers and registered automatically

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Figure A.2: Current process and process with RFID on pallet and case level for the retail DC

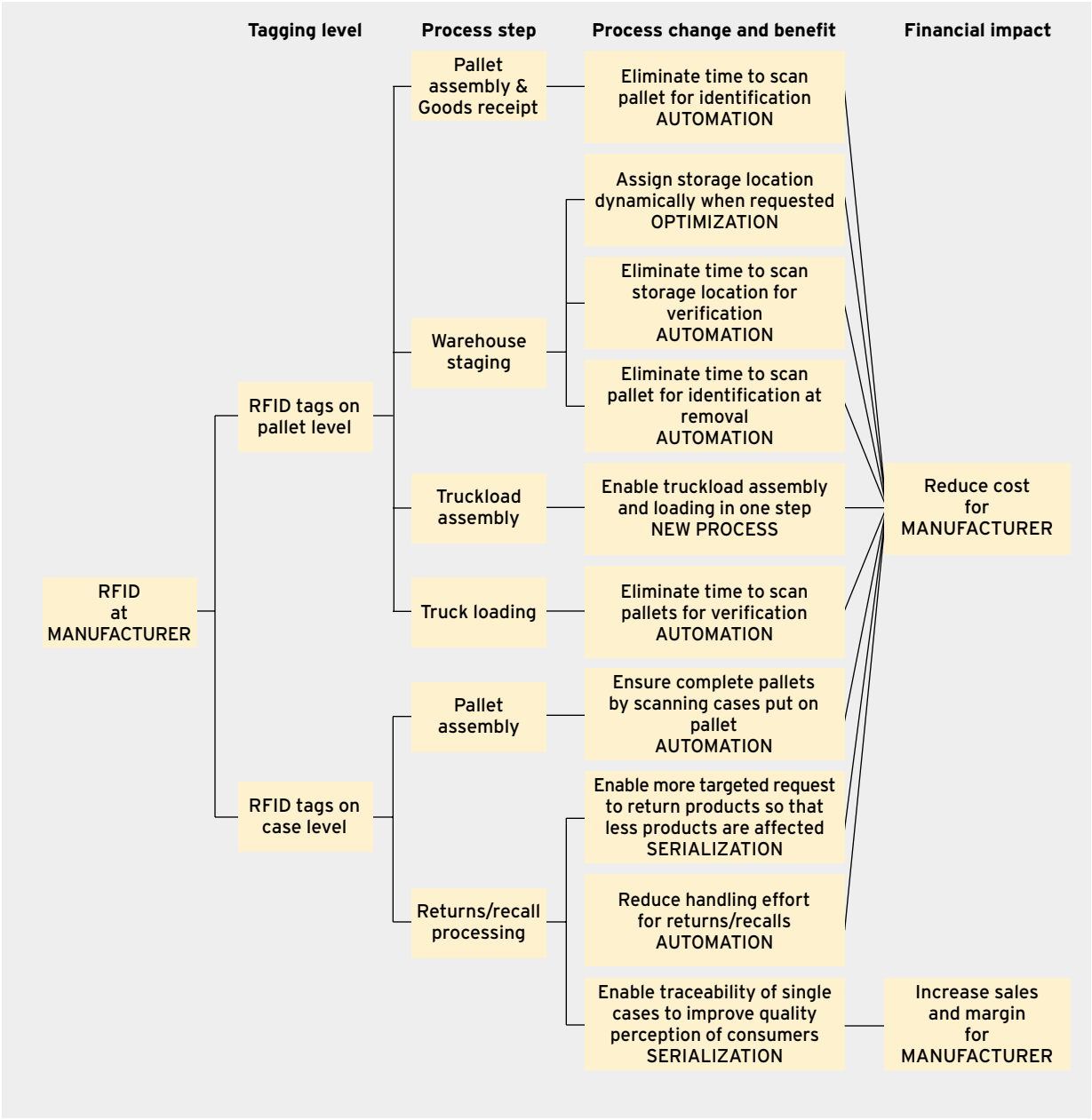
Current process	Retail DC	Changes to process with RFID on pallet level	Changes to process with RFID on case level
Barcode on pallet is read manually when pallet is unloaded; the number of cases on a pallet is manually counted to compare the physical delivery with the delivery note; furthermore, delivery note is compared with order; quality of delivery is checked (e.g. damage); new barcode label is attached	Shipment receipt	EPC tag on pallet is read automatically when pallet is unloaded; the EPC number is used to track the pallet in the DC (i.e. there is no new barcode label attached)	EPC tags of cases that are on pallet are read when pallet is unloaded; information on cases in delivery is used to automatically compare the physical delivery with an electronic delivery note (e.g. dispatch advice sent prior to arrival of delivery)
Barcode on pallet is read manually by forklift driver to identify pallet; pallet is transferred to storage location and placed there; storage location is verified e.g. by reading barcode at storage location	Pallet staging	EPC tag on pallet is read automatically when forklift arrives to identify pallet; EPC tag on storage location is automatically read in order to verify the location	*No change to process with RFID on pallet level*
Barcode on pallet is read manually by forklift driver in order to verify pallet identity; pallet is transferred to picking area and placed there	Pallet breaking	EPC tag on pallet is read automatically when forklift arrives in order to verify pallet identity	*No change to process with RFID on pallet level*
Picker picks indicated number of cases from picking location; types in number of cases picked for verification	Mixed pallet picking	*No change to current process*	EPC tags on cases are read in order to record and verify the number of cases picked
Assembled pallets are moved to shipping area and shrink-wrapped; new barcode label is attached and associated with pallet content; shipping area barcode is scanned in order to verify location; sample countings of picked pallets in order to check picking accuracy	Order assembly	EPC tag on pallet is read and associated with pallet content; shipping area EPC tag is read to verify location	As picking accuracy has already been assured in the picking process by reading the EPC tags of the cases picked, there is no longer a need to conduct sample countings any longer
Barcode on pallet is manually scanned in order to verify delivery	Truck loading	EPC tag on pallet is read in order to verify delivery	*No change to process with RFID on pallet level*
DC informs retail stores which product charges need to be returned / are recalled; returned products are handled manually	Returns/Recall processing	*No change to current process*	Based on tracking of serial numbers for cases, DC can determine which stores have received products to be returned / recalled and inform those stores; cases to be returned can be identified via EPC numbers and registered automatically
Inventory in picking areas is regularly counted manually	Inventory counting	*No change to current process*	EPC tags of cases that are on pallet in the picking area are read regularly; this eliminates need for manual inventory counting

Figure A.3: Current process and process with RFID on pallet and case level for the retail store

Current process		Changes to process with RFID on pallet level	Changes to process with RFID on case level
	Retail store		
Pallet is manually identified; for deliveries from retail DC, there is no additional quality and accuracy check; for direct store deliveries, the number of cases on a pallet is manually counted to compare the physical delivery with the delivery note, the delivery note is compared with the order, and the quality of the delivery is checked (e.g. damage)	Order receipt	EPC tag on pallet is read automatically when pallet is unloaded in order to identify pallet	For direct store deliveries, EPC tags of cases that are on pallet are read when pallet is unloaded; information on cases in delivery can be used to automatically compare the physical delivery with an electronic delivery note (e.g. dispatch advice sent prior to arrival of delivery)
Pallets are stored in backroom until moved onto store floor for replenishment	Pallet staging	*No change to current process*	*No change to current process*
N/A	Breakdown and routing	N/A	N/A
N/A	Case breakdown	N/A	N/A
Cases are moved between backroom and store floor; there is no information whether products contained in cases are still in backroom or already on store floor	Shelf restocking	*No change to current process*	EPC tags on cases moved between backroom and store floor are read; store inventory management system is used to realize a separation between inventory in backroom and on store floor
Employees in retail stores start to look for products; due to lack of information whether products to be returned / recalled are already on the store floor, they might remove and return all products	Returns pickup	*No change to current process*	Only those stores that have actually received products to be returned / recalled need to look for those products; stores affected can determine whether products are already on the store floor based on tracking of serial numbers for cases and separation of backroom and store inventory
Returned products are handled manually	Returns/Recall processing	*No change to current process*	Cases to be returned can be identified via EPC numbers and registered automatically

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Figure B.1: Process changes and benefits from pallet and case level for the manufacturer



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Figure B.2: Process changes and benefits from pallet and case level for the retail DC

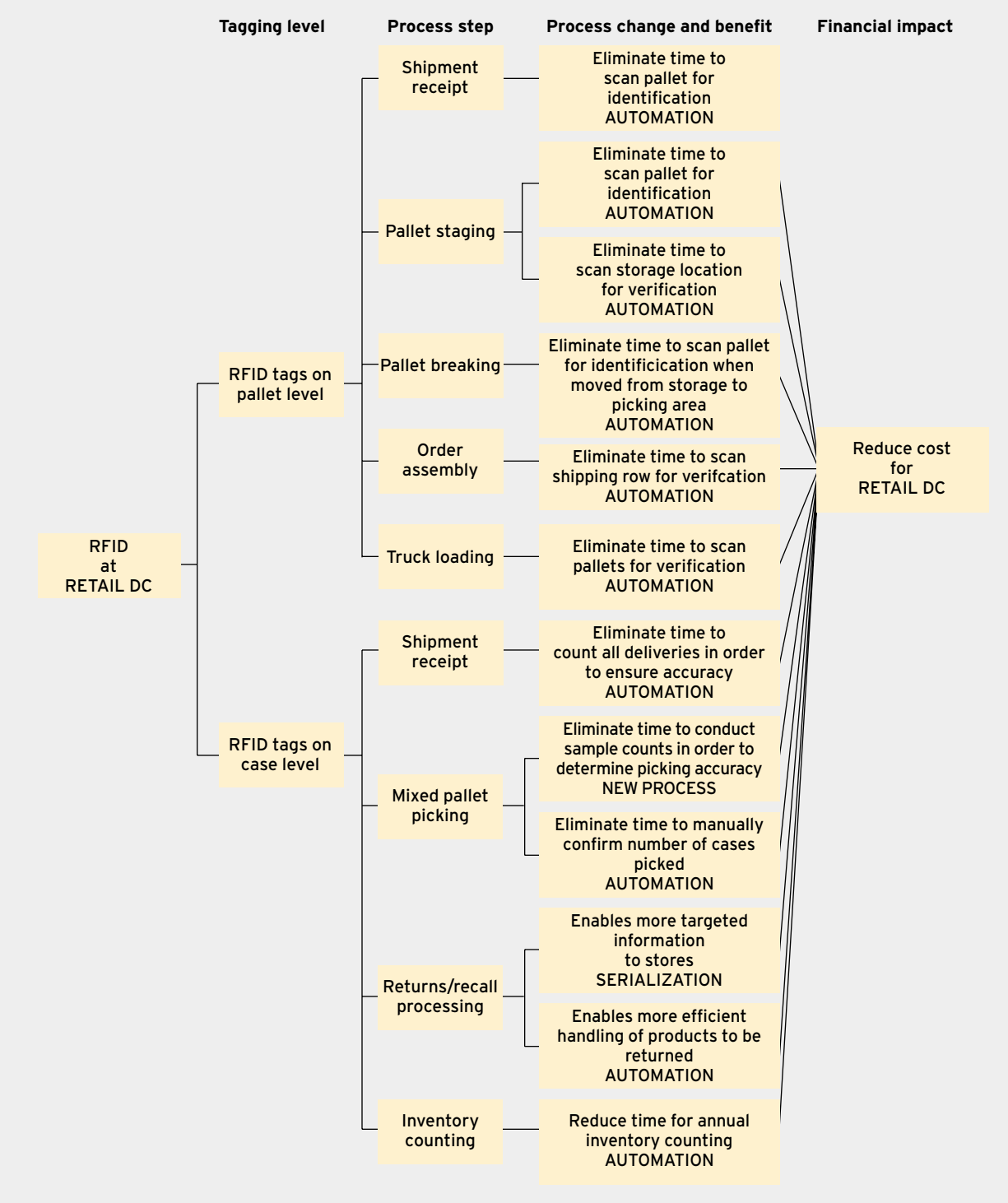
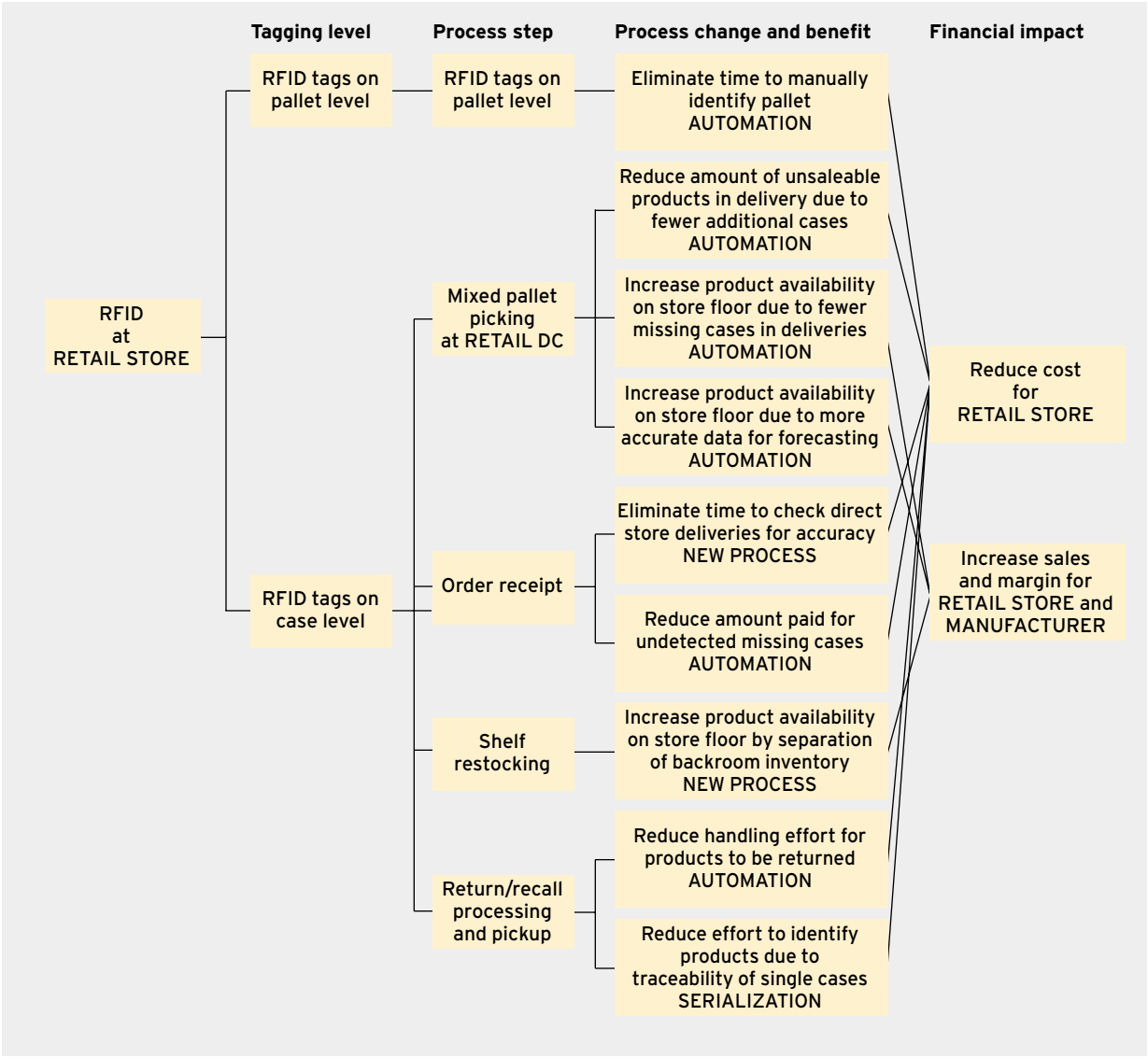
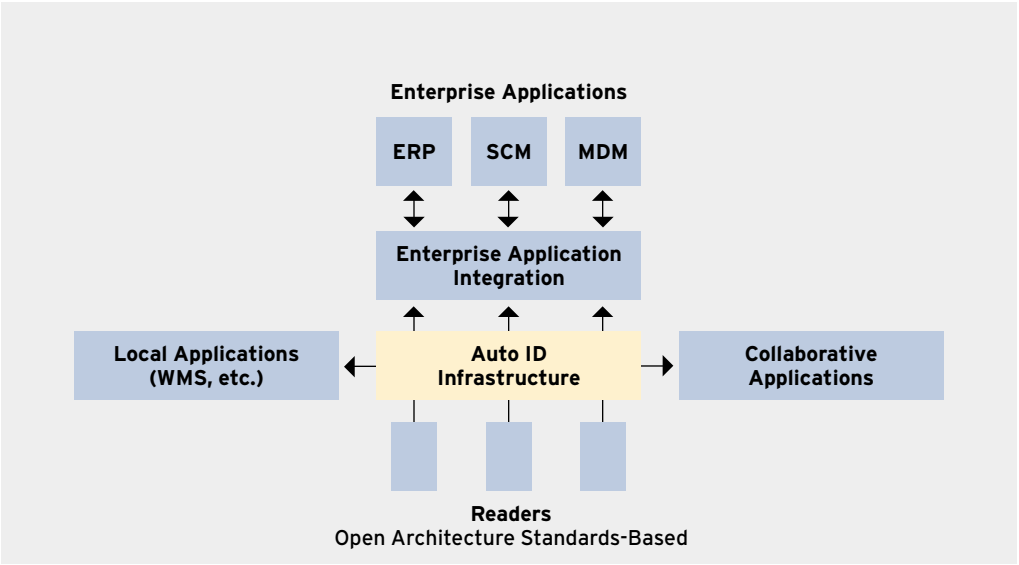


Figure B.3: Process changes and benefits from pallet and case level for the retail store



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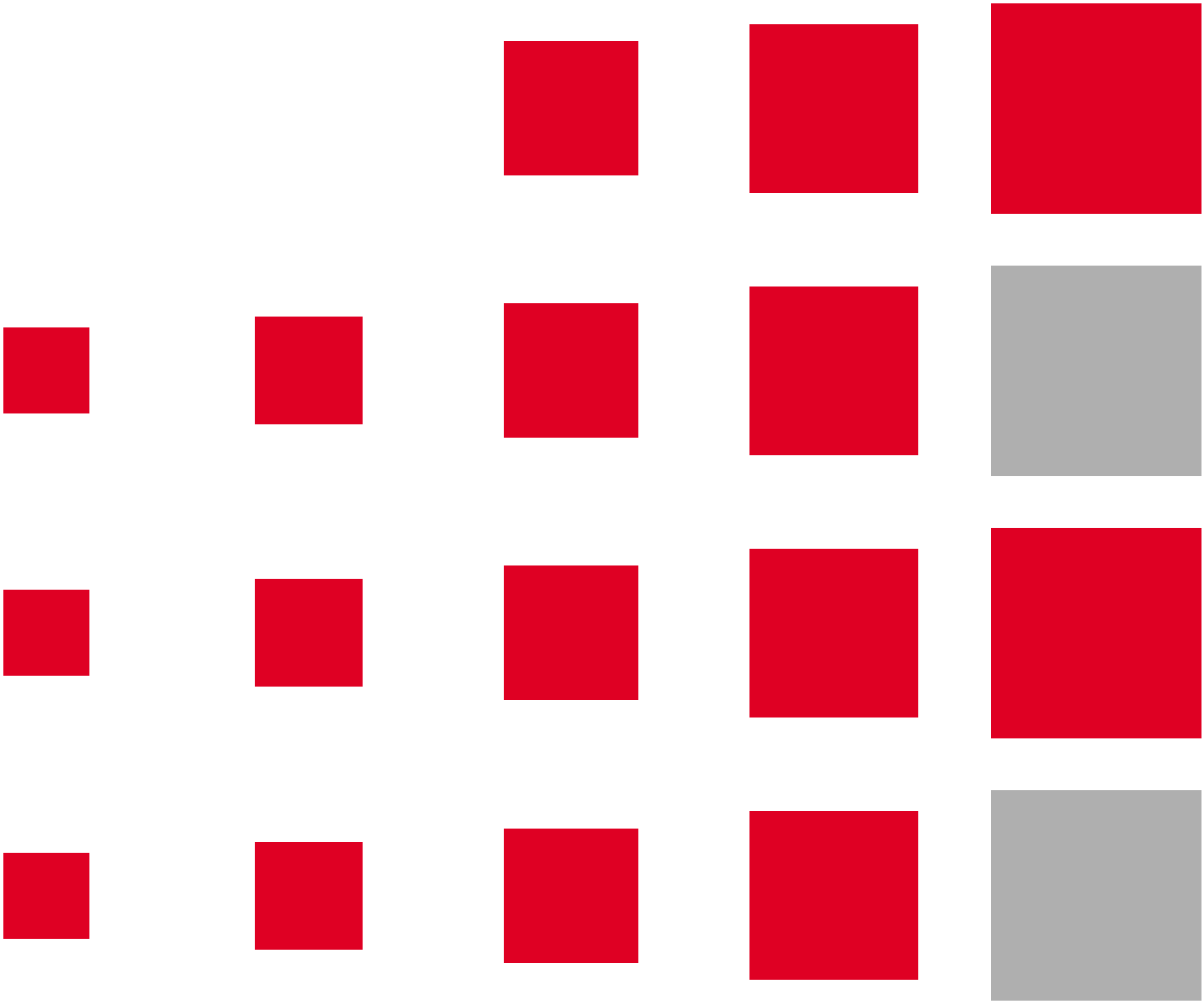
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