University of St.Gallen

AUTO–ID LABS

The impact of Auto-ID technology on process performance – RFID in the FMCG supply chain

DISSERTATION

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Prof. Ernst Mohr, PhD

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Abbreviations

3PL	Third-party logistics provider
ASO	Automatic store ordering
Auto-ID	Automatic identification
CMI	Co-managed inventory
CPFR	Collaborative planning, forecasting and replenishment
CPG	Consumer packaged goods
CRP	Continuous replenishment program
DC	Distribution center
DESADV	Dispatch advice
DSD	Direct store delivery
EAS	Electronic article surveillance
ECR	Efficient consumer response
EDI	Electronic data interchange
EDLC	Every-day-low-cost
EDLP	Every-day-low-price
EPC	Electronic product code
EPC IS	EPC information services
EPS	Earnings per share
ERP	Enterprise resource planning
FIFO	First-in-first-out
FMCG	Fast-moving consumer goods
GDS	Global data synchronization
GDSN	Global data synchronization network
GLN	Global location number
GTIN	Global trade identification number
HF	High frequency
IS	Information systems
IT	Information technology
JIT	Just-in-time
KPI	Key performance indicator
MRP	Material requirements planning
ONS	Object naming service
OOS	Out-of-stock
POS	Point-of-sale
RFID	Radio frequency identification
ROI	Return on investment
SGTIN	Serialized global trade identification number
SKU	Stock keeping unit
SSCC	Serialized shipping container code
UHF	Ultra high frequency
UPC	Uniform product code
VMI	Vendor-managed inventory
WMS	Warehouse management system
XML	Extensible markup language

Abstract

A number of retailers in the fast-moving consumer goods (FMCG) industry have begun to roll out radio frequency identification (RFID) technology. Despite these commitments, the business case for RFID in the FMCG industry is still unproven. This thesis aims at providing a realistic perspective on the potentials of RFID that takes existing processes and practices into account. So far, research in this area is limited. The thesis deals with the question of how RFID technology can improve supply chain performance in the FMCG industry. To answer this question, the thesis first looks in general at the way that Auto-ID technologies such as RFID can improve process performance. A conceptual framework is proposed that distinguishes between three effects (automational, informational, and transformational) of Auto-ID technologies. The framework is used to analyze different benefits of RFID that companies in the FMCG industry intend to realize. The examples are taken from field research conducted with a number of retailers and manufacturers. They provide insights into the complementary and contextual factors that influence the value of RFID. The results from the field research indicate that companies currently focus on the automational and the informational effects of RFID, and that some companies use RFID as a catalyst for change. Examples of transformational effects, i.e. process innovations based on RFID, are still rare. This seems to partly result from difficulties among companies in evaluating the informational and transformational effects that arise from high-quality RFID data. The thesis develops two exemplary analytical models that deal with the potential impact of RFID data on product availability, one of the most frequently mentioned benefits of RFID, via higher inventory accuracy and a redesign of the replenishment-from-the-backroom process. Overall, the results of the research suggest that RFID technology – at least initially – may allow the most efficient players in the FMCG supply chain to extend their lead. It is still too early to determine whether new ways of doing business, enabled by RFID, may ultimately challenge current industry leaders.

I.1 Problem statement

I.1.1 Situation

Today's fast-moving consumer goods (FMCG) supply chain still faces a number of challenges. The introduction of barcodes and other technologies as well as industry initiatives such as Efficient Consumer Response (ECR) have not eliminated a number of issues. These include:

- Out-of-stock: Based on an analysis of 52 studies that examine out-of-stocks (OOS), Gruen et al.[1] calculate an average out-of-stock level of 8.3% for the retail industry. The study does not provide any detailed data for grocery products. The out-of-stock figure varied between 7.9% in the US and 8.6% in Europe. The authors identify a number of root causes for out-of-stock. According to the study, 47% of out-of-stock situations were caused by store ordering and forecasting, 28% by upstream activities, and 25% by inadequate shelf restocking from backroom (i.e. the product was in the store, but not on the shelf). In 2002, GMA[2] conducted an additional study in the US which examined 25 categories of grocery products that are delivered directly to the store. The study found that for promotional items, the out-of-stock level almost doubled.

- Shrinkage: According to a survey by Hollinger and Davis[3] in the US, shrinkage in the retail industry amounted to 1.7% of sales in 2002. The survey is based on responses from 118 retailers. For supermarkets/grocery, the figure is 1.5%. The authors identify four sources of shrinkage: employee theft (48% of all shrinkage), shoplifting (32%), paperwork and administrative errors (15%), and vendor fraud (5%).

- Invoice inaccuracy: In 2001, GMA[4] conducted a study of invoice accuracy with more than 20 grocery manufacturers in the US. The companies involved reported an average deduction level of 9.9% of annual invoiced sales. Even the top 10 companies faced invoice deductions averaging 5.9%. Major causes of deductions were promotion/billback and pricing (65% of total dollars deducted), shortages/damages, coupons and penalties (17%) and unsaleables (4%).

- Unsaleable products: According to Lightburn[5], the cost of unsaleable food and grocery products amounts to 1% of sales in the US. This data is based on a survey which included about 65 manufacturers and retailers. Damage is the biggest cause of unsaleables with 63% of all unsaleables, followed by out-of-code (16%) and discontinued items (12%).

- Inventory inaccuracy: In a case study with an unidentified US retailer, Raman[6] found that inventory was inaccurate for over 70% of stock keeping units (SKUs) in the store. These figures are based on physical inventory counts at six stores in which physical and book inventory were compared. Each store had on average 9,000 SKUs. Physical inventory was below book inventory for 42% of SKUs and above for 29% of SKUs. The total difference was 61,000 units or a mean of 6.8 units per SKU. This compares to an average inventory of 150,000 units per store.

1 *Gruen at al. (2002)*
2 *GMA (2002b)*
3 *Hollinger, Davis (2002)*
4 *GMA (2002a)*
5 *Lightburn (2002)*
6 *Raman (2000)*

RFID and the barcode

Radio Frequency Identification (RFID) and barcode technology are two examples of automatic identification (Auto-ID) technologies. Industry participants hope that RFID technology can help to address some of the root causes of the issues mentioned above.[1]

While the barcode is now ubiquitous in the FMCG industry, the adoption of RFID is still in its infancy. In 1974, the first retail product was sold using a barcode scanner at the check-out.[2] Since then, the barcode has contributed towards major changes in the retail industry.[3] During a 1999 symposium in Washington, D.C. that marked the 25th anniversary of this event, the question of a possible successor to the barcode arose. The participants named RFID as one promising solution. At this event, the UCC and Procter & Gamble announced the foundation of the Auto-ID Center at the Massachusetts Institute of Technology, initially supported by the two institutions.[4]

Vision and status of RFID adoption

This thesis deals with the use of RFID technology in the FMCG supply chain at the case and pallet level, based on open standards as proposed by the Auto-ID Center and EPCglobal.[5] The vision of the Auto-ID Center and EPCglobal is to create an “Internet of Things”[6], consisting of different components, including low-cost, passive RFID tags and RFID readers for identifying objects. The Auto-ID Center also proposed a numbering scheme, the Electronic Product Code (EPC), to uniquely identify objects. Additional components of what has since become the EPCglobal Network are responsible for filtering and integrating the data and making it accessible to industry participants.[7]

While the ultimate goal is still item-level tagging, the actual adoption of RFID started at the case and pallet level and covers the upstream supply chain process from the manufacturer to the retail shelf. Large retailers such as Wal-Mart, Tesco and Metro have started to roll out RFID. This is in contrast to the adoption of barcodes: The initial deployment of the barcode was on the item level and focused largely on streamlining the check-out process (although some industry participants already expected to realize “other, as yet unknown but surely large, benefits”[8] from the technology).[9]

The roll-out of RFID is still at an early stage. According to a survey by Gartner Research[10], only 7% of retailers questioned in the US, Canada, the UK, Germany and France already conduct RFID projects at the case or pallet level, and an additional 23% expect to start projects within the next two years. Even the activities of leading retailers are currently confined to selected suppliers and regions and cover only a subset of products. For example, the roll-out at Wal-Mart, probably the retailer that drives adoption most aggressively, so far is limited to distribution centers (DCs) in Texas and involves only Wal-Mart’s top-100 suppliers plus a number of volunteers. Even those suppliers, however, do not tag all pallets and cases that go to Wal-Mart’s RFID-equipped DCs, but between two and 10 SKUs. This may include just one product that comes in a variety of sizes.[11] Wal-Mart has issued a mandate to its next 200 biggest suppliers to start tagging pallets and cases for selected products in January 2006.[12] By the end of 2006, it expects all its trading partners that supply products to Wal-Mart in the US to be “engaged in RFID in some form or fashion”.[13]

1 *see e.g. IBM (2002a)*
2 *Nelson (1997)*
3 *see e.g. PwC (2001)*
4 *David, Rittenhouse (2001)*
5 *There are also some roll-outs of RFID on reuseable assets. These activities, however, often only cover the internal flow of assets and are frequently not based on EPCglobal standards.*
6 *Brock (2001), p. 5*
7 *EPCglobal (2004f)*
8 *Brown (1997), p. xv*
9 *The UCC, for example, adopted the EAN.UCC-128 barcode symbol for use with serialized shipping containers only in 1989 (www.uc-council.org/timeline,html).*
10 *Gartner Research (2005b)*
11 *Johnson (2005)*
12 *RFID Journal (2003a)*
13 *Simon Langford from Wal-Mart, cited in Johnson (2005), p. 40*

Companies have been conducting several RFID pilots over the last several years. Examples include the Auto-ID Center Field Trial[1] and the RFID activities of the Metro Future Store Initiative[2]. These trials have frequently focused on testing RFID technology, rather than on the commercial viability of adopting RFID.[3] The tests have largely expanded knowledge of the technological potentials and limitations of passive RFID technology as it exists today. So far, however, companies have yet to proceed to a stage where they can measure actual differences in supply chain performance resulting from the use of RFID.

RFID hype?

Given the early stage of adoption, it is not surprising that there is a lot of uncertainty regarding the actual value of RFID. In its latest report on the hype cycle of retail technologies, published in mid-2004, Gartner Research saw RFID at the case and pallet level at the "peak of inflated expectations", with five to 10 years until the technology reaches its full productivity. Before this "plateau of productivity" is reached, however, the technology is likely to go through the "trough of disillusionment" (see Figure I-1). According to this report, RFID at the item level is still an emerging technology. The first RFID applications that will deliver value to companies are expected to use RFID to track reusable assets. One example is Marks & Spencer's food division which has equipped 3.5 million plastic trays with RFID tags.[4]

Doerr et al.[5], referring to the results of an RFID pilot conducted by the Department of Defense (DoD), state: "This high ROI [return on investment] estimated for [the project] seems to follow a common pattern that should be viewed with skepticism given the current enthusiasm for RFID. This technology may be viewed as an operations technology like robotics, flexible manufacturing, materials requirements planning, and enterprise resource planning. Early reports of the value of such technologies often fail to be sufficiently critical. [...] The typical pattern in the literature is unrestrained exuberance, followed by hostile disillusionment, tapering into a balanced analysis just as the fashion dies. [...] RFID is a technology that has undoubtedly yielded some firms substantial benefits. However, we doubt that it can work for all organizations, all the time. And the current exuberance for RFID technology should, we think, give cause for special concern."

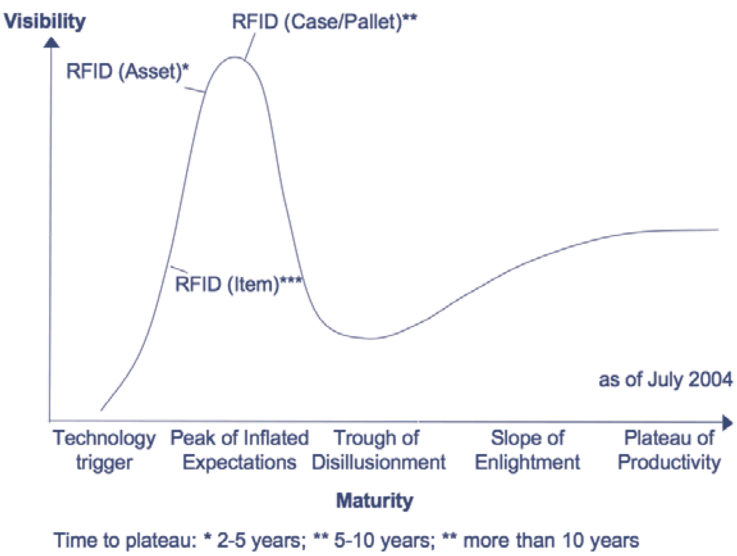

Figure I-1: Gartner Research's Hype Cycle for Retail Technologies 2004[6]

1 *see e.g. Albano (2003)*
2 *see e.g. www.future-store.org*
3 *PA Consulting (2005)*
4 *see e.g. Mahoney (2002) and Stafford (2004)*
5 *Doerr et al. (2004), p. 3*
6 *adapted from Gartner Research (2004a)*

Uncertainty concerning the value of RFID

There is some indication that the initial enthusiasm about RFID has at least partly given way to a more realistic assessment. Some researchers and practitioners have issued concerns regarding its value. These concerns deal with different aspects, including the fundamental value of RFID, the distribution of cost and benefits among the value chain, and company-specific differences:

The fundamental value of RFID. Critics who question the fundamental value of RFID point to the fact that there is little practical experience and research that demonstrates the benefits of RFID compared to existing solutions, especially the barcode. According to Sheffi, for example, RFID technology "is still not out of the fog of innovation: the benefits of the technology are not entirely clear, especially in terms of the advantages over bar code technology."[1] Similarly, McFarlane and Sheffi[2] remark: "[T]he hurdle now is much higher – the system must be demonstratively better than the bar code." Or, as Gartner Research[3] puts it: "Much of the enthusiasm for RFID tagging projects came from a fundamental misunderstanding of the state-of-the-art in data collection technologies." According to Rice[4], there is a need to realistically assess the benefits of RFID "based on true improvement potential rather than blue sky cases."

These general concerns are reflected in some industry studies. A study by ECR Austria[5] on the use of RFID in current logistics processes with several retailers concludes the following: "Den erforderlichen Investitionen stehen zum heutigen Zeitpunkt keine relvanten Einsparungspotenziale gegenüber."

There seems to be an especial uncertainty about the value of higher data quality. One GMA study[6] discusses the value of backroom inventory data from RFID to increase product availability and reduce inventory. It states that whereas some manufacturers regard this information as valuable, "[o]ther manufacturers, especially those with very high fill rates, have questioned the incremental value of this data over existing DC-withdrawal and POS data and current replenishment processes." As Ozer[7] observes: "Industry reports and white papers are now filled with estimates and proclamations of the benefits and quantified values of RFID. Most of such claims are not substantiated and are educated guesses at best." Companies need to figure out how they can actually use RFID data. Cachon[8] believes that "the hope and expectation among many people is that being able to track every unit of inventory in every location of the supply chain will somehow magically make inventory management go to the next level." However, as his research[9] on information sharing in the supply chain shows, increased information does not necessarily provide much value.
These concerns are at least partly shared by the companies that actually roll out RFID. Wal-Mart, for example, has just started an initiative with the University of Arkansas to study the impact of RFID on retail stock-outs.[10]

According to Gartner Research[11], a lot of business cases that try to justify RFID in fact do not require the technology: "One of the most-important problems you face when evaluating business cases that involve radio frequency identification (RFID) is the difficulty in finding benefits that intrinsically flow from RFID tagging. Many of the commercial business cases being promoted have focused on business benefits that are not intrinsic to RFID. Often, the return on investment (ROI) from these business cases flows from data synchronization or systems integration that can be achieved without RFID. In many such cases, RFID is superfluous."

1 *Sheffi (2004), p. 9*
2 *McFarlane, Sheffi (2003), p. 15*
3 *Gartner Research (2004b)*
4 *Rice (2005), p. 8*
5 *Bayer (2004), slide 26*
6 *GMA (2004), p. 15*
7 *Ozer (2005)*
8 *cited in Knowledge@Wharton (2005)*
9 *see e.g. Cachon, Fisher (2000)*
10 *RFID Journal (2005l)*
11 *Gartner Research (2003)*

Womack[1] even raises doubts about the value of Auto-ID technologies in general. He recommends that companies first try to simplify their processes and then ensure that their processes "make every step capable so that you don't have things going wrong all the time" before investing in barcode or RFID technology.

Distribution of cost and benefits. Compared to this fundamental criticism, the second area of concern deals with the distribution of cost and benefits of RFID within the supply chain. These studies do not necessarily question the overall value of RFID for the FMCG industry. Rather, they point to the fact that retailers are the main beneficiaries of RFID, while the majority of the cost is borne by manufacturers.

It is known today that the retailers currently adopting RFID do not intend to compensate the manufacturers for the cost of RFID tags. Furthermore, while a lot of money has been spent on optimizing upstream supply chain activities, there is still a lot of potential to improve process execution at the retail store.[2]

In a report for GMA, A.T. Kearney and IBM evaluated 25 RFID business cases of consumer packaged goods (CPG) manufacturers that, overall, show "unfavourable economics for manufacturers and unequal distribution of cost and benefits".[3] In his assessment, Byrnes concludes that large retailers are likely to achieve a positive net present value from case-level tagging, whereas the net present value for large manufacturers is negative.[4] These findings are also reflected in the experience of individual companies. Udo Scharr[5] from Procter & Gamble, for example, reports that the results of their business case study with Metro indicate that the benefits of RFID at the case and pallet level may outweigh the costs for the entire supply chain but that the technology does not pay off for Procter & Gamble.

Differences between companies. Whereas the second point dealt with an unequal distribution of cost and benefits between retailers and manufacturers, the third one points at differences between companies that are at similar positions in the value chain. As Bill Allen[6] from Texas Instruments, one of the largest makers of RFID chips, states: "RFID is NOT the right solution for every problem; RFID is NOT a cure for bad business practices; RFID is NOT all things to all businesses; RFID does NOT always have an ROI."

For CPG manufacturers, an A.T. Kearney study[7] concludes that for those companies that "have spent the past several years on supply chain efficiency efforts – installing warehouse management systems (WMS), labor scheduling and inventory control systems […], the incremental value of RFID/EPC case tagging is minimal." The GMA study[8] comes to a similar conclusion: "Even optimistic estimates for tag prices are insufficient to generate a positive return for widespread tagging of pallets and cases across all product categories included in this study. Some companies estimate positive returns when tags reach the $0.05 […] range, yet many others do not project a positive return even if tags were free."

Byrnes[9] points to the effect of company size: While the net present value (NPV) for large retailers with annual sales of $10 billion may be positive, the NPV for small retailers with annual sales of $100 million is likely to be negative.

1 *Womack (2005), p. 28*
2 *Raman et al. (2001)*
3 *GMA (2004), p. 7*
4 *Byrnes (2003)*
5 *Scharr (2005)*
6 *Allen (2004), slide 3*
7 *A.T. Kearney (2004), p. 2*
8 *GMA (2004), p. 5*
9 *Byrnes (2003)*

Publications dealing with RFID in the FMCG supply chain

A large number of white papers and reports examine the impact of RFID on supply chain performance. Some of these studies deal with RFID in retailing in general, others focus specifically on RFID at the case and pallet level in the FMCG supply chain. In contrast, the number of academic publications in this area is still limited.

Category	Practical publications	Academic publications
Overview of RFID and potential applications	Accenture 2002a Bearing Point 2003 ECR D-A-CH 2003	Angeles 2004 Fleisch et al. 2005 Jones et al. 2004 Kärkkäinen,Holmström 2002 McFarlane, Sheffi 2003 Penttilä et al. 2004 Prater et al. 2005 Rutner et al. 2004 Strassner,Fleisch 2005
High-level assessment of financial impact	A.T. Kearney 2003 Behrenbeck et al. 2004 Byrnes 2003 CCG 2004 ECR Austria 2004 GMA 2004 McKinsey 2003 PA Consulting 2005 Soreon 2004	
Analysis of specific applications	Accenture 2002b-d, 2003a IBM 2002a-d Lee et al. 2004 Metro 2004a	DeHoratius 2004 Wong,McFarlane 2003, 2004
Case studies	Metro 2004b Metro, KSA 2004 RFID Journal 2005c,j	Gozycki et al. 2004 Kärkkäinen 2003
Guidelines on how to approach RFID	A.T. Kearney 2004 Deloitte 2004a,b Fleisch et al. 2004 GCI 2003a RFID Journal 2005a	-
Mathematical models	-	Atali et al. 2005 Fleisch, Tellkamp 2005 Gaukler et al. 2004, 2005 Kang, Gershwin 2004 Lee, Whang 2003 Lee et al. 2004

Tablel I-1:
Selected publications on RFID in the supply chain

In the context of this research, the publications can broadly be divided into six categories (see Table I-1):

- Publications that provide a broad overview of RFID and potential applications in the supply chain.
- Publications that focus on a high-level assessment of the financial impact of RFID.
- Publications that discuss one or more specific applications of RFID in the FMCG supply chain. A few of these studies also provide quantitative estimates of the financial impact.
- Publications that provide case studies on how individual companies have applied RFID.
- Publications that try to provide guidelines on how companies should approach RFID.
- Publications that study the impact of specific RFID applications by developing formal mathematical models.

Each group of publications has different strengths and shortcomings. The first two groups can provide an introduction for managers and researchers who are interested in RFID. The practical publications are mainly targeted at senior management and give managers a quick and comprehensive overview of RFID and its potential applications in supply chains. However, they lack details of specific processes in the FMCG industry. Companies will not be able to assess the potential impact of RFID on their business solely from these reports. Most of the academic publications fail to provide a theoretical framework that links RFID to existing research and conceptualizes the potential impact of the technology on supply chain performance. An exception is the research by Fleisch and Strassner.

Fleisch[1] develops a number of models in order to explain the business impact of ubiquitous computing technologies. RFID is only one example of a ubiquitous computing technology that improves the integration of the physical and virtual world and provides the data to realize digital management control loops. Technologies such as RFID help to improve different dimensions of data quality, including accuracy, timeliness, and granularity. This allows companies to automate process control as well as to develop smart products and services.

The thesis by Strassner[2] looks at RFID in supply chain management in the context of the automotive industry. The author uses coordination theory as a theoretical basis and describes RFID as a coordination technology that will lead, as suggested by Malone[3], to a substitution of existing coordination mechanisms, increased coordination, and more coordination-intensive structures.[4] These effects result from a number of coordination instruments that RFID offers, namely automation, integration depth, integration range, and decentralization. The thesis also applies a diffusion model for RFID, originally published by Strassner and Fleisch[5]. The model suggests that the adoption of RFID proceeds along the three dimensions, of which two describe the integration depth and one the integration range.

1 *Fleisch et al. (2005)*
2 *Strassner (2005), p. 203 ff.*
3 *Malone (1988)*
4 *In the German-speaking countries, there is one additional Ph.D. thesis that deals with RFID technology. In this thesis, Pflaum (2002) focuses mainly on technology-related aspects. The author describes and evaluates different transponder categories (e.g. memory size, frequency). This thesis might be of interest to companies that are evaluating different technologies, but provides only limited insights into the impact on supply chain performance.*
5 *Strassner, Fleisch (2005)*

The third group of studies goes into much more detail. These reports usually focus on current practices and existing problems in supply chains. On the basis of an analysis of this kind, the studies discuss potential applications of RFID and the resulting impact on supply chain performance. These insights can help companies to direct their evaluation of RFID at those areas where industry analysts expect the highest value. The practical publications mentioned in Table I-1 all discuss RFID in isolation from supply chain practices and concepts such as ECR or initiatives for global data synchronization (GDS).[1] In fact, Gartner Research[2] argues that a lot of the benefits that are often attributed to RFID in these studies are unrelated to RFID, and relate instead to issues such as information sharing or data synchronization.

An example from a report issued by GMA[3] illustrates that RFID data does not necessarily provide any additional value. The report suggests that retailers and manufacturers may use the RFID data on the movement of cases from the store backroom onto the shop floor in order to estimate the actual demand and drive upstream supply processes. The report, however, fails to elaborate why this data should be superior to point-of-sale (POS) data which reflects true demand. If the trading partners currently face problems in receiving timely information on the demand for promoted products, the difficulty may instead arise from delayed information sharing than from the fact that the data itself is not available.[4]

Additionally, reports sometimes do not distinguish between the potential benefits of RFID and the wider benefits that companies might derive from the EPCglobal Network. The report by Lee et al.[5], for example, states that "RFID/EPC can reduce the bullwhip effect by providing manufacturers with timely and accurate information on actual sales level at the retail store." One reason for this is that the EPCglobal Network may reduce the cost of transferring the data and thereby increase the amount of data sharing. As in the previous example, however, the data itself is already available today.

In contrast to the practical publications, the few academic publications that deal with specific applications of RFID in the FMCG supply chain provide an in-depth look at the processes and try to identify specific situations in which RFID can actually make a difference. The papers mentioned in Table I-1 focus on product availability. The research of Wong and McFarlane[6] deals with RFID at the case level to improve the replenishment-from-the-backroom process, whereas DeHoratius[7] discusses applications of RFID in the supply chain to improve inventory accuracy.

The few case studies available on the use of RFID in the FMCG supply chain usually describe how individual companies intend to apply RFID. The case studies published by practitioners that are included in the table deal with RFID at the case and pallet level, whereas the case studies provided by academics deal with trials where RFID tags were attached to reuseable assets, which is not the focus of the thesis. The value of the latter case studies for this thesis is further limited by the fact that both examples have not yet led to specific roll-out plans. One general shortcoming of the case studies available so far is that they do not make a statement regarding the generalizability of results.

The fifth category of publications is geared towards practitioners and provides specific guidance to managers concerning the process of evaluating and implementing RFID. This includes studies that deal with the process of how manufacturers can find out how to comply with retailer mandates. Often, these studies also provide a broad description of the potential benefits, yet do not address whether (or under which circumstances) an investment in RFID may be worthwhile.

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1 *There are a few studies (e.g. EPCglobal 2004e, GCI 2004) that deal with the relationship between the EPCglobal Network and Global Data Synchronization. These studies, however, do not discuss specific applications.*
2 *Gartner Research (2003)*
3 *GMA (2004), p. 30 ff*
4 *RFID can, of course, help to ensure that promotional and other products are replenished from the backroom in time, as discussed in chapter IV.3 and IV.8*
5 *Lee et al. (2004), p. 14*
6 *Wong, McFarlane (2003, 2004)*
7 *DeHoratius (2004)*

Finally, a few researchers have developed mathematical models to study the impact of RFID. This type of research can help to demonstrate the circumstances under which RFID can improve supply chain performance. In other contexts, for example when studying the bullwhip effect, formal models of this kind have been used to show the value of information sharing. Nonetheless, mathematical models often require a high degree of abstraction from reality. They might therefore prove to be of limited use for companies interested in RFID. In addition, the scope of these models is limited to specific applications of RFID. The models therefore do not allow companies to conduct an overall assessment of RFID in their supply chains.

I.1.2 Practical perspective

A lot of companies in the FMCG industry are still in the early stages of defining their RFID strategy. There still seems to be a lack of knowledge among companies on how RFID at the case and pallet level is likely to affect supply chain processes in the FMCG industry. One indicator for this may be the still-growing interest in conferences on RFID. For example, the number of participants at the RFID Journal Live conference in the US reached 1,600 in 2005 and doubled both in 2004 and 2005.[1]

So far, there are only a few case studies on how companies intend to apply RFID. Existing practical publications that describe the benefits and applications of RFID often fail to provide the level of detail that companies require in order to understand how they might be able to supply RFID. Furthermore, these white papers and reports sometimes fail to specify in detail which benefits actually require RFID and under which circumstances RFID is likely to be valuable.

Anecdotal evidence suggests that publications sometimes create expectations of huge benefits among companies, which fail to materialize when analyzed more closely. One example of such a benefit is a reduction in inventory from RFID. IBM[2], for example, estimates that RFID at the case level will allow manufacturers to save 20% of inventory carrying cost at their warehouses due to increased visibility, improved information accuracy, and higher forecasting accuracy. However, both manufacturers involved in the research for this thesis could not establish a causal link between the use of RFID and inventory level. This might not be an isolated example. The same IBM report also states that RFID will also reduce inventory carrying cost at retail DCs. In contrast, neither Metro[3] nor Tesco[4] mention inventory reductions as a potential benefit of RFID, and Wal-Mart[5] talks only about improved internal inventory management, without explicitly mentioning inventory reductions as a benefit.

This thesis seeks to improve the practical understanding of the potential benefits of RFID at the case and pallet level

- by providing a comprehensive discussion of the benefits that RFID can offer, how companies currently intend to apply RFID, and whether RFID will lead to a transformation of the FMCG supply chain; and

- by identifying a number of factors that influence the value of RFID to a company.

1 *RFID Journal (2005k)*
2 *IBM (2002b)*
3 *see Metro (2005a), Ebling, Scharr (2004)*
4 *see Clarke, Palinkas (2003)*
5 *see Langford (2004)*

I.1.3 Theoretical perspective

Even in scientific journals, researchers sometimes make bold claims about the potential of RFID. Penttilä et al.[1] provide an introduction to RFID and describe the differences between RFID and barcode technology. They remark that RFID offers non-line-of-sight identification and enables unique object identification, which can lead to more accurate and timely information in the supply chain. The authors then conclude that "the use of RFID tags within supply chain management applications will lead to a complete re-evaluation and modification of business processes. [...] The possibilities that RFID technology offers for consumers and retailers are enormous, and the applications are limited only by one's imagination."[2] The paper fails, however, to provide any supporting evidence as to what these possibilities may look like.

This thesis postulates that there are research deficits in two areas. First, there is limited academic research that deals with the general impact of data capturing technologies on business process performance. A great deal of existing research in the area of information systems deals with the effects of increased information processing and closer intra- and inter-organizational integration.[3] A few researchers have examined the impact of the barcode. Dunlop and Rivkin[4], for example, describe the development and significance of the barcode for the retail industry and also discuss economic theories that can help to understand the adoption and the impact of the barcode. They specifically look at the role of network externalities, changes in contractual relations between firms, and the evolution of complementary systems. Hwang-Smith and Weil[5] as well as Hwang and Weil[6] conduct empirical analyses on the impact of the barcode and complementary technologies. None of these researchers, however, develops a conceptual model of the barcode's impact (or, more generally, the impact of Auto-ID technologies). This is also true for research on RFID.

The research most closely related to the current works is that of Fleisch and Strassner mentioned above. Compared to their research, however, this thesis uses different theoretical concepts to explain the potential value of RFID. Specifically, the conceptual framework draws on complementarity theory and research on the business value of information technology rather than coordination theory.

Second, there is limited research that tries to quantify the value of RFID data in the FMCG supply chain. Otto[7] mentions the impact of new data collection technologies such as RFID as one area for further research on supply chain event management. According to Hausman[8] of Stanford University, research is needed that examines, for example, how "real-time, near-complete product progress information" will change inventory control policies.

This thesis suggests two models that deal with the value of RFID in increasing product availability. Examples of research in this area include Gaukler et al. and Kang and Gershwin. The models differ in their research approach from previous research: The first model on the replenishment-from-the-backroom process is – to this author's knowledge – the first formal model that examines the cost of delayed shelf replenishment in the context of RFID. The second model deals with the impact of inventory inaccuracy on stock-outs. It applies a different modelling approach compared to Kang and Gershwin, who draw their conclusions from simulation experiments, whereas this thesis develops a formal mathematical model.

1 *Penttilä et al. (2004), p. 149*
2 *ibid, p. 149*
3 *For a model that describes the development of information systems, see Fleisch et al. (2005)*
4 *Dunlop, Rivkin (1997)*
5 *Hwang Smith and Weil (2004)*
6 *Hwang, Weil (1997)*
7 *Otto (2003)*
8 *Hausman (2003)*

To summarize, this thesis tries to contribute towards closing the two identified theoretical gaps

- by suggesting a conceptual model that explains the impact of automatic identification technology on business process performance; and
- by formulating some simple formal models that can help to quantify the impact of improved data quality on product availability.

I.2 Research question

The previous sections have shown (a) that analyzing the potential effect of RFID on FMCG supply chains is of high practical relevance and (b) that so far the topic has not been systematically addressed from a scientific perspective.

This thesis aims to improve the understanding of the value of RFID in the FMCG supply chain by addressing the following research question:

How can RFID technology improve supply chain performance in the FMCG industry?

In order to answer the research question, this thesis specifically considers the following sub-questions:

- How do Auto-ID technologies in general affect process performance?
- Which benefits does RFID offer in the FMCG industry?
- In which areas will RFID transform the FMCG supply chain?
- Which complementary and contextual factors influence the value of RFID in the FMCG supply chain?
- How can the impact of RFID in the FMCG supply chain be quantified?

Figure I-2 shows the relationship between the research question, the theoretical and practical deficits, and the sub-questions.

Research question: How can RFID technology improve supply chain performance in the FMCG industry?		
Perspective	**Research deficits**	**Sub-question**
Practical	Limited understanding of RFID benefits, how companies currently intend to apply RFID, and where RFID will lead to a transformation of the FMCG supply chain No overview of factors that can influence the value of RFID	Which benefits does RFID offer in the FMCG supply chain? In which areas will RFID transform the FMCG supply chain? Which factors influence the value of RFID in the FMCG supply chain?
Theoretical	No conceptual model that explains the impact of Auto-ID technologies on business process performance Lack of formal models that quantify value of RFID data	How do Auto-ID technologies in general affect process performance? How can the impact of RFID in the FMCG supply chain be quantified?

Figure I-2: Research question, theoretical and practical deficits, and sub-questions

I.3 Scope of the thesis

The unit of analysis in this research is the impact of automatic identification technology on business process performance. The level of analysis is the business process. According to Davenport[1], a business process is “the specific ordering of work activities across time and space, with a beginning, an end, and clearly identified inputs and outputs.” RFID is considered from a management perspective rather than a consumer perspective.[2]

This thesis specifically studies the impact of low-cost passive RFID at the case and pallet level on the performance of the FMCG supply chain from the manufacturer warehouse up to the retail shelf. The RFID tags only contain an identifier which is used as a reference to the data on the product. The scope of this thesis is therefore much more focused than, for example, the thesis by Strassner[3] which looks at RFID applications that cover the whole range from low integration depth and range (e.g. internal applications for tracking reuseable assets) to high integration depth and range (e.g. supply-chain-wide applications at the item level).

The focus is on the flow of physical products and the accompanying flow of information in the supply chain, which can be defined as a “network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customer.”[4] As Porter and Millar[5] formulate: “Every value activity has both a physical and an information-processing component. The physical component includes all the physical tasks required to perform the activity. The information-processing component encompasses the steps required to capture, manipulate, and channel the data necessary to perform the activity.” Throughout this thesis the supply chain is treated as one entity with the goal of improving overall performance. This abstracts from the fact that there can be conflicting goals, that cost and benefits may be unevenly distributed, and that the management of cooperation can be difficult.[6]

There are several reasons for choosing the FMCG supply chain as the research object:

- The FMCG industry has a great deal of experience with the barcode. This makes it possible to study the incremental benefit of RFID over the barcode as another means of automatic identification.

- There is a strong focus on supply chain management in the FMCG supply chain.[7] There are a number of initatives that promote standardization, electronic data interchange, and collaboration, and these concepts are used widely in the industry. This allows the examination of the potential impact of RFID starting from current “best practice” in supply chain management.

- The development of low-cost RFID tags began in the FMCG industry in 1999 when the Auto-ID Center was established. A number of large retailers have announced that they intend to roll out RFID at case and pallet level. From a practical perspective, this means that there are at least a number of cases available in which the impact of RFID on supply chain performance can be studied in a real world environment.

- The retail industry is divided into several segments, for example FMCG, apparel, and consumer electronics. Different segments in the retail industry require different supply chain strategies (see chapter II.2). With case studies coming from different segments, it would be difficult to draw any general conclusions.

1 *Davenport (1993), p. 5*
2 *Rudolph and Schweizer (2002), for example, distinguish between these two perspectives when they discuss the use of innovative technologies in retailing*
3 *Strassner (2005), p. 190*
4 *Christopher (1994), p. 11*
5 *Porter, Millar (1985), p. 152*
6 *See e.g. Schmickler and Rudolph (2002) on how companies in the retail industry can initiate, plan and implement cooperation*
7 *see e.g. Stank et al. (1999)*

The examples in this thesis originate from field research with a number of retailers and manufacturers from Western Europe. There are two reasons for this. The first is opportunistic. Due to geographical location, it was easier to gain access to companies located in Western Europe than to companies, for example in the US. (Currently, the US and Western Europe are the main geographical areas in which large FMCG companies have started to adopt RFID at the case and pallet level.) The second reason is related to the fact that the situation and processes in the FMCG industry differ between Western Europe and the US. One aspect is that there is no company in Western Europe with a market share comparable to Wal-Mart in the USA. RFID-specific aspects include differences in regulation regarding frequency and power in the ultra high frequency (UHF) spectrum.

FMCG companies are aware that there are differences between Europe and the US regarding the adoption of RFID. This was one of the main reasons for creating a special working group, the European Adoption Program, within EPCglobal that aims, among others, at fostering adoption of RFID technology in Europe and providing input into the standardization process from a European perspective.[1]

I.4 Theoretical foundation

General perspective on technology choice and organizations

This research assumes a rational approach towards the adoption of a new technology: Companies will only invest in a new technology if the expected benefits exceed the cost, and if the expected value exceeds the value of alternative solutions. This contrasts with other perspectives which view the adoption of technology from a fad or fashion perspective[2]. It also contrasts with the concept of bounded rationality. As March and Simon's[3] show, organizations tend not to optimize, but look for "satisficing" solutions. New technologies can trigger a process that leads to organizational change.[4]

Organizations are interpreted as information processing units.[5] An organization possesses distinct information processing capabilities. Organizational performance improves when there is a fit between information processing needs and information processing capabilities.[6] Companies can increase information processing capabilities by investing in vertical information systems and by creating lateral relations, or reduce information processing needs by creating slack resources, self-contained tasks, or by reducing environmental uncertainty.[7]

The information processing view can be regarded as a helpful general concept for the remainder of this thesis. However, the information processing view is a very general concept that does not offer specific insights or suggestions for coming up with a model on the effect of new technology, specifically new data capturing technologies. This research therefore draws on two additional research streams, research on the business value of information technology (IT) and complementarity theory.

Both research streams raise similar research questions. Complementarity theory asks, among others: How do changes in the environment affect organizational design and performance? Research on the value of IT asks, more specifically: How does information technology affect the performance of organizations? Researchers in both areas are also concerned with the question why some companies are able to increase performance by investing in technology, whereas others fail.

1 *EPCglobal (2004a)*
2 *Abrahamson (1991, 1996)*
3 *March, Simon (1959)*
4 *Barley (1986)*
5 *Galbraith (1977), Brynjolfsson, Hitt (2000)*
6 *Tushman, Nadler (1978)*
7 *Galbraith (1977)*

Complementarity theory

In recent years, researchers from different research streams have used complementarity theory. This includes research on strategy and organizational design (e.g. Andrew M. Pettigrew[1] and John Roberts[2]), the business value of IT (e.g. Erik Brynjolfsson and Lorin M. Hitt[3]), and business engineering.[4] The role of complementarities has also been recognized in the literature on supply chain management[5] and, more specifically, the introduction of retail technologies and the barcode[6].

Questions addressed	Main statements	Key contributions to thesis
How do changes in the environment affect organizational design and performance?	Certain design variables (e.g. technologies / practices) can be complementary (i.e. mutually reinforcing) This leads to coherent patterns of organizational practices Changes in the environment can change the relative profitability of the coherent patterns	Recognizes changes in environment (e.g. falling prices of technology) as a driver for change Helps to explain why some companies are likely to benefit more from adopting new technologies than others Allows to identify different roles and effects of Auto-ID technologies

Figure I-3: Contribution of complementarity theory to thesis

Complementarity theory can help to explain the impact of new data capturing technologies in three ways (see Figure I-3). First, it recognizes changes in the economic, legal, social and technological environment as an important element for adjusting organizational design.[7] One example of changes in the environment is a change in the price of an input.[8] Second, it highlights the role of complementary technologies and practices that need to be present so that a new technology can increase performance. Third, it helps to distinguish more clearly between the different effects and roles of Auto-ID technologies.

Research on the business value of information technology

Complementarity theory does not specifically deal with the impact of IT, although Milgrom and Roberts[9] recognize the role of information technology in the reduction of "the cost of collecting, organizing, and communicating data." Here, research on the business value of IT offers additional insights. Partly as a reaction to the IT productivity paradox, researchers have come up with a number of frameworks that seek to conceptualize the impact of information technology on performance. The frameworks vary in complexity, and not all include all aspects. Melville et al.[10], for example, propose a framework of IT business value, based on a review of the existing evidence on the business value of IT. Their framework (a) draws attention to the importance of measuring the impact at the process level and (b) highlights the role of complementarities and contextual factors. Figure I-4 summarizes some key statements and the contribution of this research to this thesis

1 *Whittington, Pettigrew (2003)*
2 *Roberts (2004). The Economist mentions this book as the best business book of the year 2004 (see www.economist.com/books/displayStory.cfm?story_id=3499624)*
3 *Brynjolfsson, Hitt (2000)*
4 *Barua et al. (1996)*
5 *e.g. Whang (1998)*
6 *e.g. Dunlop, Rivkin (1997), Hwang, Weil (1997)*
7 *Roberts (2004), p. 13 and p. 60 ff*
8 *see e.g. Milgrom, Roberts (1990)*
9 *Milgrom, Roberts (1990), p. 513*
10 *Melville et al. (2004)*

Questions addressed	Main statements	Key contributions to thesis
How does information technology affect the performance of organizations?	The impact of IT on organizational performance is difficult to establish ("productivity paradox") Complementarities as well as contextual factors affect the impact of IT IT has only an indirect impact on firm performance via business processes IT is not only about automation, but also about information and transformation	Helps to justify why focus on process-level performance measures Supports argument for important role of complementarities Allows to derive specific conceptual framework by adjusting existing generic frameworks on the impact of IT

Figure I-4: Contribution of research on the business value of IT to thesis

I.5 Research approach

Scientific context for thesis

This thesis follows Ulrich's[1] understanding regarding the role of research in business administration as applied social science ("angewandte Sozialforschung"). Research in business administration derives its research questions from the actual challenges that companies face. Its goal is to generate normative conclusions and provide guidance to decision makers rather than simply to observe reality or test hypotheses derived from theory. Theoretical concepts are seen as a means rather than an end.

The motivation for this thesis derives from a practical challenge. RFID at the case and pallet level is an emerging technology, and companies in the FMCG industry lack a detailed understanding on how they can apply the technology. An understanding of the potential benefits and limitations of RFID is a necessary step before companies can decide on how to approach the technology.

Additionally, this thesis aims to increase the general knowledge on the impact of Auto-ID technologies by suggesting a theoretical framework and by developing simple formal models that help to quantify the value of RFID data. Although the theoretical contributions do not provide immediate benefit to companies, they are of practical value. Applied researchers may use the framework to get a better understanding of the value of Auto-ID technologies in different contexts and thereby improve the quality of their recommendations to companies. Furthermore, formal models that show the value of RFID can foster adoption of the technology by reducing the uncertainty inherent in new technology, especially when the causal relationship between the technology and performance is difficult to observe.

Research method

Figure I-5 describes the research process. After the identification of the business challenge that provides the motivation for the thesis, the research proceeded to the stage of problem definition. The aim of this stage was to identify a suitable scope for the thesis and to formulate a research question. The research question should not only contribute towards solving the practical challenge, but also to address some theoretical aspects.

1 *Ulrich (1981)*

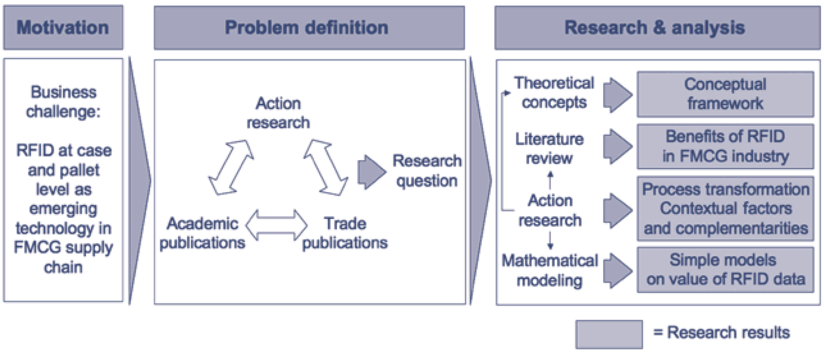

Figure I-5:
Research process

The activities at this stage consisted mainly of work in various research projects as an action researcher. According to Coughlan and Coghlan[1], action research and positivist science differ in a number of respects, among others, the role of the researcher and his relationship to the research setting: "The positivist scientist's relationship to the setting is one of neutrality and detachment, while the action researcher is immersed in the setting. In short, the contrast of roles is between that of a detached observer in positivist science and of an actor and agent of change in action research." Table I-2 gives an overview of projects relevant to this thesis.

The main reason for using action research was that this approach was the only way to obtain exposure to companies at a level of detail required for understanding the potential impact of RFID. Many companies are still in the process of understanding the potential effect of RFID on their operations. They sometimes lack the resources or expertise to conduct an analysis. In order to get results, this author needed to actively support and drive this process.

Research context	**Projects relevant to thesis**	**Timeline**	**Companies involved**
M-Lab	Projects on potential benefits of RFID in the supply chain	12/2001 05/2005	Migros, Novartis, Volkswagen, Infineon, SAP, among others
Auto-ID Center	Development of Auto-ID Calculator	05/2002 07/2003	Chep, CVS, IBM, Kodak, Metro, Unilever, among others
Metro Group Future Store Initiative	Report on potential benefits of RFID in the FMCG supply chain	07/2003 01/2004	Metro Group, SAP, Intel, Retail Forward, two anonymous CPG manufacturers
	Case study on Kaufhof / Gerry Weber pilot	01/2004 07/2004	Kaufhof
EPCglobal European Adoption Program	Participation in EPCglobal working group	04/2003 07/2005	Carrefour, Metro, Tesco, Nestlé Unilever, among others
Bilateral projects	Project on potential benefits of RFID in the supply chain	12/2003 04/2004	Anonymous retailer A
	Project on potential benefits of RFID in retail stores and in the supply chain	03/2004 11/2004	Anonymous retailer B

Figure I-2:
Project environment for this thesis

[1] *Coughlan, Coghlan (2002), p. 224*

There were two additional sources of input at this stage. Trade publications and other material (white papers, reports, articles in trade journals, presentations at industry meetings, among others) provided an overview of RFID applications. Additionally, a review of academic publications from a number of fields, including articles on adoption theory, technology evaluation and the impact of electronic data interchange (EDI), identified potentially relevant theoretical concepts. The final formulation of the research question resulted from this iterative learning process between theory (review of academic publications) and empiricism (conduct of action research and study of trade publications).[1] The research question was broken down into a number of sub-questions which are answered using different research methods. As in the previous research phase, insights from action research played an important role. Some results derive directly from work as action researcher, whereas others are only influenced by it. For example, the final impetus to develop mathematical models specifically for inventory accuracy and the replenishment-from-the-backroom process came from the insight gained during projects that retailers found it hard to estimate the value of RFID in these areas. Also, there are strong relationships between some of the other results and the action research. For example, the conceptual framework helped to structure the analysis of the case examples, and the prioritized list of potential benefits from RFID, based on a review of trade publications, ensured that the action research covers the most-frequently mentioned benefits.

Limitations of research approach

Conducting research at this point in time is not without risk. Conclusions are drawn before the actual applications have been implemented and before evidence to suggest whether or not the results are as expected is actually available. This means that the results of this thesis are preliminary and need to be examined more thoroughly once RFID has been rolled out in a number of companies. The main argument for exploring this research question at this point in time is the high practical relevance of the topic.

There are three aspects that limit the risk of drawing false conclusions:

- Research method and data collection: Action research allowed the author to actively engage in projects to study the impact of RFID. The field research results are based on multiple sources of evidence, mainly open-ended and focused interviews, internal data (e.g. on processes), observations (e.g. during site visits), presentations and other documents (e.g. project documentations). The descriptions only include those RFID applications for which the project team could establish a causal link between RFID and supply chain performance.

- Relationship to theories and concepts: The framework is derived from existing theories and concepts. Consequently, a link is established between the findings of this research and previous research. This not only enhances confidence in the findings, but also offers opportunities for further work.

- Methodical triangulation[2] using mathematical models: Triangulation can be defined as the “combination of methodologies in the study of the same phenomenon.”[3] Triangulation allows the researcher to check whether two or more distinct research methods lead to comparable results[4]. In addition to qualitative findings from case studies, mathematical models can provide an additional source of evidence. These models explicitly capture the interrelationships between various parameters and help to determine how changes in any of the inputs affect the output.

1 *see Gassmann (1999)*
2 *Yin (1994)*
3 *Denzin (1978), p. 291*
4 *Jick (1979)*

The value of using both empirical research as well as mathematical models to study a phenomenon can be illustrated with the example of Campbell Soup's continuous replenishment program (CRP). Clark and Stoddard[1] examine the impact of EDI and CRP on stock-outs and inventory turns. They use case studies, survey data as well as data regression analysis as their research method and conclude that EDI in combination with CRP leads to increased performance, whereas the adoption of EDI alone does not lead to significant effects. As Cachon and Fisher state, this is contrary to their findings from mathematically modeling the effect of CRP for the same company. According to their model, Campbell Soup could have achieved the same results without the transfer of decision rights on order quantities. It would have been sufficient if the retailers had electronically transmitted their orders on a daily basis.[2] The diverging results from Cachon and Fisher indicate that there is a need for additional empirical studies.

I.6 Target group

There are two target groups for this thesis. The first target group consists of practitioners who work on supply chain-related topics in the FMCG industry. More specifically, this thesis might be of interest to people involved in planning and improving the physical flow of products and related information. These people are often involved in current initiatives in the area of electronic data exchange or data synchronization. Some of the examples concern the downstream part of the supply chain. These examples might be relevant for managers dealing with store operations. Practitioners might find chapter II on RFID and the FMCG supply chain, chapter IV which presents examples from field research, and the managerial implications in chapter VI.4 particularly relevant. It is hoped that they will gain some insights into how RFID can help them to improve the performance of their supply chains.

The second target group involves researchers in the area of supply chain management. There are several survey-based studies that examine the impact of different supply chain concepts such as quick response or inter-organizational systems such as EDI. In a number of years, provided that RFID has been widely adopted in the FMCG industry, this thesis might provide some insights from which empirical-quantitative researchers can derive testable hypotheses. For these researchers, chapter III which presents the conceptual framework might be of relevance. This chapter might also interest applied researchers who work with companies on how to apply Auto-ID technologies in different contexts. Chapter V might provide a starting point for researchers who seek to develop formal mathematical models on the value of RFID data.

I.7 Structure of the thesis

This thesis is organized as follows: Each of the following chapters addresses one or two sub-questions formulated in chapter I.2. Chapter II starts with an overview of supply chain management in the FMCG industry. Additionally, it contains an introduction to RFID, the EPCglobal Network and the EAN.UCC system. This provides the context for the remainder of the thesis. It then identifies frequently-mentioned benefits of RFID at the case and pallet level in the FMCG supply chain.

Chapter III presents an introduction to complementarity theory and research on the business value of IT and describes the theoretical framework. Examples of benefits of RFID from chapter II are used to illustrate the framework. Finally, this chapter contains a brief analysis of the impact of the barcode in the retail supply chain.

The theoretical framework is used to structure the analysis of the empirical results in chapter IV. The chapter describes, based on the prioritized list of RFID benefits (see chapter II), how the companies that took part in the various research projects for this thesis intend to apply RFID. It then identifies a number of contextual factors and complementarities that influence the value of RFID.

1 *Clark, Stoddard (1997)*

2 *Cachon, Fisher (1997)*

Chapter V deals with the question of how companies can assess the impact of RFID. The experience from the action research projects again demonstrated the need for models that try to quantify the value of RFID data. Specifically, this chapter presents two quantitative models: one that illustrates the value of increased inventory accuracy, and one that deals with the impact of delays in the replenishment from the backroom process.

The thesis concludes with chapter VI, which contains a summary of the main findings, presents the managerial and theoretical implications, and introduces some future prospects. Figure I-6 illustrates the structure of the thesis.

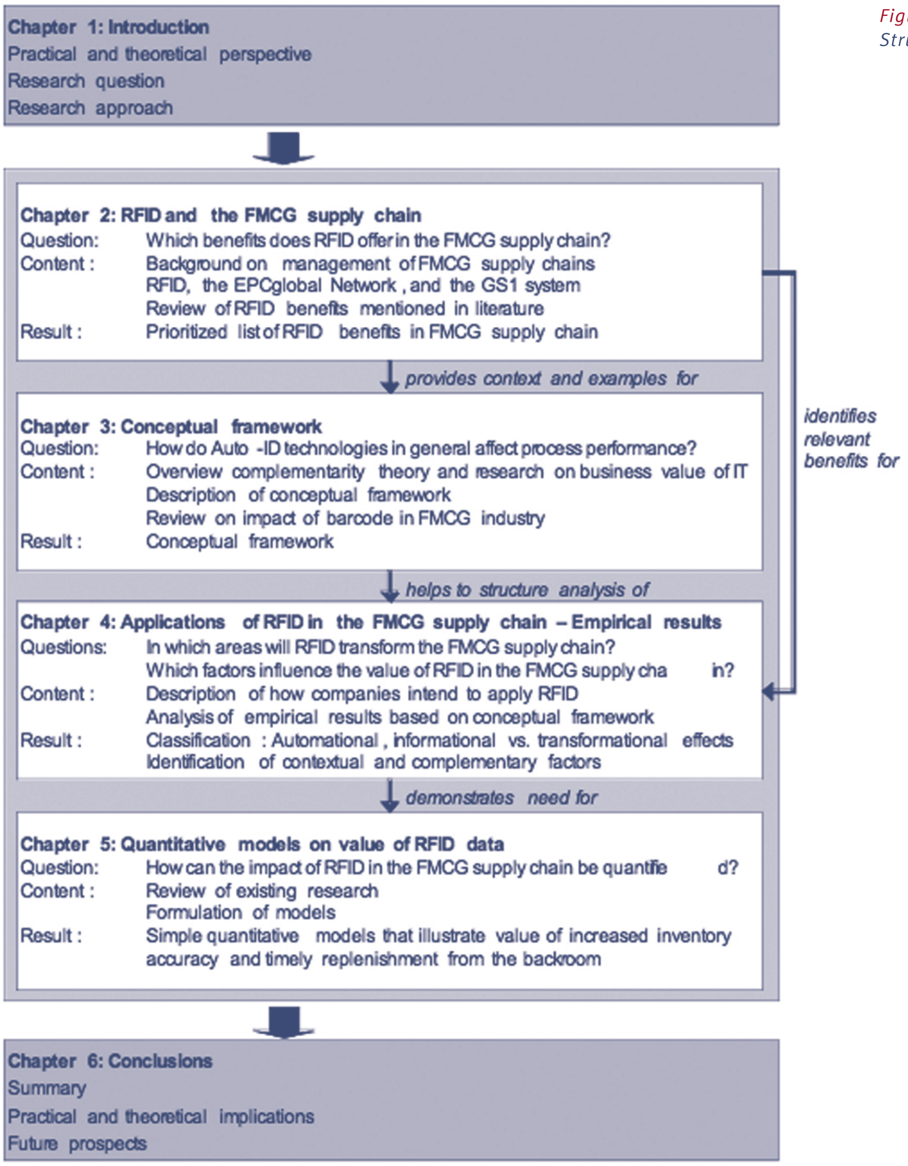

Figure I-6:
Structure of the thesis

This chapter starts with an overview of the FMCG industry and an introduction on how companies in the FMCG industry manage their supply chains. It then offers a brief introduction to RFID technology, shows how RFID relates to the EPCglobal Network and the EAN.UCC system and describes the current status of RFID adoption. Finally, the chapter analyzes existing industry reports, company information and survey results in order to derive a list of the most-frequently mentioned benefits of RFID.

II.1 Overview of the FMCG industry

According to Beck[1], the fast-moving consumer goods (FMCG) industry includes "those retailers and their suppliers who provide a range of goods sold primarily through supermarkets and hypermarkets. The core of their business is providing 'essentials' such as various fresh and processed foodstuffs, but they also stock a wide selection of other goods as well including health and beauty products, tobacco, alcohol, clothing, some electrical items, baby products and more general household items." Examples of FMCG retailers and manufacturers are Carrefour, Tesco and Wal-Mart, and Gillette, Johnson & Johnson, Procter & Gamble and Unilever, respectively. In the USA, this sector is also referred to as the Consumer Packaged Goods sector. EPCglobal also uses the term FMCG to label the business action group that defines end-user requirements and drives adoption of the EPCglobal Network in the retail industry. Cooper et al.[2] define fast-moving consumer goods as: "[p]roducts sold for everyday use in large quantities; applied to items such as processed foods, snacks, detergents, toothpaste, and so on. The products will typically be branded."

Companies such as Carrefour, Tesco, and Wal-Mart are often referred to as grocery retailers.[3] Guptill and Wilkens1[4] describe a grocery store as a retail store with at least 1,500 different food items and/or $2 million in annual sales that sells dry grocery, canned goods, and non-food items plus some perishable items. According to the Oxford English Dictionary, a grocer is a "trader who deals in spices, dried fruits, sugar, and, in general, all articles of domestic consumption except those that are considered the distinctive wares of some other class of tradesmen"[5].

The grocery industry is a very competitive, low margin and high volume industry dominated by chains that employ advanced technology.[6] As Cachon[7] states: "Retailers must constantly strive for excellence in operations; extremely narrow profit margins leave little room for waste and inefficiency." Retailers are now among the largest employers in the world.[8] Both in the USA and Europe, consumer characteristics and shopping behavior have changed over the last decades.[9] Grocery retailers have reacted to these developments by employing technological innovations, developing new product and service offerings, and corporate restructuring as well as mergers and acquisitions. These changes have had implications for their marketing mix, productivity, and the relationship between retailers and manufacturers.[10] Bell et al.[11] see five challenges for food retailers: ensuring further growth, increasing added value, providing competitive prices and value, engineering an efficient supply chain, and enhancing relationships in the supply chain to move from "push" to "pull" strategies.

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1 *Beck (2002), p. 12*
2 *Cooper et al. (1994), p. 322*
3 *see e.g. Fernie, Staines (2001)*
4 *Guptill, Wilkens (2002)*
5 *www.oed.com*
6 *Keh, Park (1996)*
7 *Cachon (2001), p. 211*
8 *Bell et al. (1996)*
9 *Bell et al. (1996), Keh, Park (1996)*
10 *Keh, Park (1996)*
11 *Bell et al. (1996)*

Over the last years, the power balance has shifted away from manufacturers towards large retailers.[1] In fact, it has been suggested that one of the reasons for the recent Procter & Gamble (P&G) / Gillette merger is that it gives the combined company a better position in dealing with large retailers such as Wal-Mart, although some analysts predict that the power will stay with Wal-Mart[2]. In 2003, Wal-Mart accounted for 17% of P&G's sales but P&G's share of Wal-Mart's revenue was less then 3%.[3]

There are different types of retailers and manufacturers. On the customer side, Schmickler and Rudolph[4] distinguish between content retailers such as Migros with a strong emphasis on private labels, channel retailers such as Wal-Mart with a large number of branded products, and global discounters such as Aldi which sell only a very limited number of SKUs. On the supplier side, there are brand manufacturers which focus on the value-added of their products for customers, channel manufacturers which focus on both consumers and retailers and follow a pragmatic approach to private labels, and private label suppliers which are almost entirely dependent on their retail customers. Retailers may also be classified as "traditional format" retailers (e.g. supermarket chains such as Kroger and Safeway in the US), and "alternative format" retailers (e.g. warehouse clubs and mass merchandisers such as Wal-Mart). This classification does not take into account discounters. In contrast to mass merchandisers which offer up to several tens of thousands of SKUs, the product range of discounters is much more limited. Limited-range supermarkets (e.g. Kwik Save in the UK) may still offer 3,000–7,000 SKUs. This figure can drop as low as 3,000 for soft discounters such as Penny or Plus and to less then 1,200 SKUs for hard discounters (e.g. Aldi, Lidl) with a focus on private-label brands and no-frills presentation of products which are often stacked on pallets in-store.[5]

II.2 Supply chain strategy and FMCG supply chains

Focus on cost efficiency

One of the areas that the retail industry has focused on over the last decade is increasing the efficiency of the supply chain. As Peter Drucker[6] said about ten years ago: "More is occurring in retailing than is occurring in manufacturing or finance. It is retailing distribution which in the next few years is going to be the area of the greatest innovations and greatest changes."

Fisher[7] states that in order to derive a supply chain strategy, a company should first examine the nature of the demand for its products. He uses the concept of demand uncertainty to distinguish between two generic strategies, suitable in situations of high and low demand uncertainty. A focus on a physically efficient process is advisable for companies such as Campbell Soup that face low demand uncertainty and need to satisfy a predictable demand at low cost. Lee[8] extends Fisher's framework by looking at supply uncertainty as well (see Figure II-1). He mentions the grocery industry as an example of a supply chain that faces both low demand and supply uncertainty. Similarly to Fisher, he states that the right strategy in these circumstances is to focus on cost efficiency. This means that companies should eliminate non-value-added activities, pursue scale economies, deploy optimization techniques for determining production and distribution schedules, and establish information linkages to ensure the most efficient, accurate, and cost-effective transmission of information across the supply chain.

1 *Stern, Weitz (1997)*
2 *Financial Times (2005)*
3 *Ghemawat et al. (2004)*
4 *Schmickler, Rudolph (2002), p. 32 ff*
5 *IGD (2004)*
6 *Drucker (1993), p. 1*
7 *Fisher (1997)*
8 *Lee (2002)*

Supply uncertainty		Demand uncertainty: Low (Functional Products)	Demand uncertainty: High (Innovative Products)
	Low (Stable Process)	Grocery, basic apparel, food, oil and gas: **Efficient supply chains**	Fashion apparel, computers, pop music: **Responsive supply chains**
	High (Evolving Process)	Hydro-electric power, some food produce: **Risk-hedging supply chains**	Telecom, high-end computers, semiconductor: **Agile supply chains**

Figure II-1: Uncertainty framework and matched strategies[1]

Recent survey results confirm these theoretical findings. In a survey of manufacturers and retailers in the German-speaking countries, 100% of retailers and 96% of manufacturers gave cost reduction in the supply chain a high or very high priority.[2] In a survey on logistics performance in the US food, grocery and consumer products industry, 83% of respondents mentioned reduced logistics cost as one of the top three strategic objectives, making it the most-frequently mentioned objective.[3]

Supply chain management

In recent years, the concept of supply chain management has gained increasing popularity. Simchi-Levi et al.[4] define supply chain management as "a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system-wide costs while satisfying service level requirements." The emphasis on minimizing the overall system cost calls for global optimization versus local optimization. As the individual activities and stages in the supply chain are connected, there is a need for mechanisms that lead to coordinated decisions.[5] Malone and Crowston[6] define coordination as "managing interdependencies between activities".

As Stern and Weitz[7] point out: "Now, the focus of the logistics decision has shifted to a broader level concerned with costs throughout the whole value chain. Programs such as 'continuous replenishment,' 'just-in-time,' 'quick response,' and 'efficient consumer response' emphasize the need to coordinate inventory levels, delivery patterns, transportation methods, and storage functions throughout an entire distribution system."

Clemons and Row[8] identify two distinct coordination problems: Objective-based coordination problems results from companies that attempt to maximize their individual objectives which are not compatible with total systems objectives, whereas uncertainty-based coordination problems arise from differences in the information available and the information required for a decision.

1 *based on Lee 2002, p. 108 and p. 114*
2 *CCG (2003a)*
3 *IBM (2005)*
4 *Simchi-Levi et al. (2000), p. 1*
5 *Simchi-Levi et al. (2000), p. 100*
6 *Malone, Crowston (1994), p. 90*
7 *Stern, Weitz (1997), p. 824*
8 *Clemons, Row (1993)*

In order to ensure global optimization of the supply chain, it needs to be decided (a) who initiates and implements a decision, and (b) how to divide the savings from coordination among the actors in the supply chain.[1] There is not necessarily the need for global decision-making for coordinating supply chains. Objective-based coordination problems can, for example, be addressed by installing appropriate incentive systems to ensure that the outcome of local optimization is close to the global optimum.[2] In several instances, however, trade-offs need to be made and information from different parts of the supply chain needs to be available in order to ensure coordination.[3] One well-known example in which channel coordination can be improved by supply chain coordination via information sharing, channel alignment and operational efficiency is the bullwhip effect.[4] Global availability of data (e.g. POS data) can already improve supply chain performance measures (e.g. product availability), even when the individual companies in the supply chain use decentralized control mechanisms (e.g. retailer and manufacturer independently decide on inventory levels). A shift to centralized control (e.g. vendor-managed inventory (VMI) systems) may further improve performance. The most significant improvements, however, may be achievable not by optimizing production and inventory decision rules, but by "changing the givens" (e.g. reducing lead times).[5]

Companies may differ in their attitude towards the adoption of new practices and technologies. Power and Simon[6] examine the adoption of supply chain enabling technologies in various industries. Depending on the degree of adoption, they classify companies into three categories, labeled 'strategic', 'tactical' and 'reactive'. They find that 'strategic' implementers are more likely to be larger organisations in the retail or wholesale distribution sectors. Organisations implementing more extensively are more proactive in their planning, more focused on the need to change and realign processes, and more likely to be investing in supporting infrastructure rather than just technology."[7] Furthermore, "[t]he results clearly indicate that the 'tactical' and 'strategic' groups derive significantly greater business benefit from the use of the EAN system, are more knowledgeable of the techniques and implications of use, and perceive implementation to deliver significantly greater benefits over time relative to the cost of implementation. Between the 'strategic' and 'tactical' groups, there is also a clear indication that the 'strategic' group perceive all of these outcomes to be central to the effective operations of their organizations."[8]

Retailer-supplier partnerships

A focus on the performance of the entire value chain versus an intra-company focus has lead to the strengthening of retailer-supplier partnerships. Retailer-supplier or channel partnerships can be defined as "an ongoing relationship between a retailer and an independent supplier in which the parties agree on objectives, policies, and procedures for ordering and physical distribution of the supplier's products."[9]

Cooperation and collaboration between retailers and suppliers can be a way to improve the performance of the entire supply chain.[10] However, companies are unlikely to treat all trading partners equally and devote the same managerial attention to them. Two companies are more likely to collaborate when the expected gains are high and both partners perceive that power between them is balanced and that there is a high degree of interest commonality. One factor that can affect the value of a partnership is the exchange volume. For example, customers that buy large quantities from a company are, in general, more valuable.[11]

1 *Simchi-Levi et al. (2000), p. 101*
2 *Whang (1995)*
3 *Simchi-Levi et al. (2000), p. 100 ff*
4 *Lee et al. (1997)*
5 *Silver et al. (1998), p. 488 ff. and p. 710 ff*
6 *Power, Simon (2004)*
7 *ibid, p. 566*
8 *ibid, p. 583*
9 *Buzzell, Ortmeyer (1995), p. 86*
10 *In the literature, terms like cooperation, collaboration, and coordination are often used interchangeably*
11 *Krapfel et al. (1991)*

Not all retailers and suppliers are equally likely to collaborate. Due to their focus on private brands, global discounters are likely to collaborate primarily with private label suppliers, whereas content and channel retailers may collaborate with all types of manufacturers, although to a different degree. The best fit for the content retail may still be the private label supplier, and channel retailers may prefer channel manufacturers.[1]

In the retail industry, especially large manufacturers take on a leadership role in a large number of initiatives with retailers in order to secure a preferred relationship with them in the long term. The number of preferred relationships is likely to be limited to five to ten companies, and smaller suppliers might not be in a position to achieve such a relationship. They therefore have to be more selective when deciding on their participation in supply chain initiatives.[2]

Taking part in an initiative with trading partners can be seen as an element of strategic relationship management.[3] Large suppliers, for example, may take part in order to reinforce the current relationship, whereas smaller suppliers signal that they want to increase collaboration. However, even when suppliers want to increase collaboration, they might not be in a position to do so. Biel[4] describes the experience of Tesco when the company introduced category management. Differences between manufacturers regarding individual strengths and weaknesses in each category, development potentials, and organizational preconditions effectively limited the number of suppliers with which Tesco started to collaborate.

Bloom and Perry[5] find that large-scale suppliers perform better than their competitors if Wal-Mart is a key customer, whereas small-scale suppliers perform worse. With small suppliers, the authors suggest, Wal-Mart uses its bargaining power to squeeze their profits. In contrast, larger suppliers can benefit from the collaborative relationship that Wal-Mart offers. One example of such a long-term benefit is the close partnership between Procter & Gamble and Wal-Mart[6]. As one Procter & Gamble executive is quoted as saying: "By eliminating non-value-added processes, we will ultimately win the market by providing the best product to the consumer at the lowest cost through the channel."[7]

The role of information in supply chain management

Information plays a critical role in today's FMCG supply chain. Data generated, for example, by barcode scanners is not only used internally (e.g. in automatic store ordering systems), but also applied throughout the entire supply chain. Information technology allows companies (a) to collect information on products as they move through the supply chain and make this information available for all supply chain parties, (b) to provide a consolidated, single system to access the data, and (c) to analyze, plan and make trade-offs based on information for the entire supply chain.[8]

1 *Schmickler, Rudolph (2002), p. 32 ff*
2 *Thonemann et al. (2003), p. 43 ff*
3 *see e.g. Krapfel et al. (1991)*
4 *Lebensmittel Zeitung (1998)*
5 *Bloom, Perry (2001)*
6 *see e.g. Clark, McKenney (1995) and Parry, Sato (1996)*
7 *Clark, McKenney (1995), p. 12*
8 *Simchi-Levi et al. (2000), p. 223*

Retailer-supplier partnerships differ in the way they apply information. Simchi-Levi et al.[1] use the example of ordering to illustrate different types of partnerships which they place on a continuum: On one end is simply the sharing of POS data between retailer and manufacturer (basic quick response strategy[2]). The manufacturer can use this data to better plan production and inventory levels at its warehouses. Then, there are arrangements such as continuous replenishment systems in which the manufacturer uses the data to determine delivery quantities in predefined intervals. VMI systems constitute the next level. In these systems, the manufacturer has the authority to select the appropriate inventory policy (e.g. delivery intervals, inventory levels) within certain boundaries (e.g. previously agreed service levels). This allows the manufacturer to select the policy that best fits its circumstances. Ultimately, the manufacturer may also assume the ownership of the products within the retail DC and store (consignment) until the retailer briefly becomes the owner when the product is scanned at the check-out.

Industry initiatives and standards

There are a number of industry organizations that promote collaboration and common standards in the FMCG industry. Some of these organizations focus to a large extent on supply chain management and collaboration issues (e.g. GS1, ECR Europe, GCI, VICS), whereas others have a more general aim (e.g. FMI, GMA). Although not all of these initiatives exclusively target the FMCG industry, they at least have their roots in this industry (e.g. ECR) or a large proportion of their member organizations come from this industry (e.g. GCI).

The initiatives aim at promoting practices and standards that improve the overall performance of the value chain. ECR Europe, for example, intends "to make the grocery sector as a whole more responsive to consumer demand and promote the removal of unnecessary costs from the supply chain."[3] GS1's mission states that the organization creates open standards and drives their implementation in order to improve supply and demand chain management.[4]

Some of these initiatives have their origins in projects between a few early adopters of new practices and technologies in the retail industry. Wal-Mart is often mentioned as one of the leaders in supply chain management and the use of information technology in retailing, initiatives such as ECR, and practices such collaborative planning, forecasting and replenishment (CPFR) originate from activities that started at Wal-Mart.[5]

Companies can benefit from commonly agreed practices and industry standards due to positive network externalities.[6] Technological standards can also allow technology providers to achieve economies of scale and thereby drive down the cost of technology. Furthermore, standards and common practices increase interchangeability and thereby reduce the need for relationship-specific investments. Standardization, however, is not without its downsides as it reduces the chances that companies can gain a competitive advantage from a technology or practice. As Nicol[7] points out: "The value that accrued from the U.P.C. [uniform product code] really ended up in the hands of the consumer, and that's the hallmark of a good standard."

1 *Simchi-Levi et al. (2000), p. 132 ff.*
2 *There is no unique definition for quick response. The term might also be used to describe what is here called a vendor managed inventory system.*
3 *www.ecrnet.org/01-about/01-about2-0.html*
4 *www.gs1.org/mission.html*
5 *Kinsey, Ashman (2000)*
6 *see e.g. Dunlop, Rivkin (1997)*
7 *Nicol (2001), p. 61*

Companies therefore need to go beyond simply adopting industry standards and practices. Technologies such as EDI and barcoding are necessary preconditions for effective partnerships, but not sufficient.[1] A supplier that adopts its processes (e.g. delivery schemes) in order to serve a retailer better makes an investment in relationship-specific assets and might thereby be able to execute processes more efficiently. The company might also use data that the retailer provides in order to improve its own internal processes. Furthermore, through increased interaction it can derive a better understanding of its customer's business. The latter may lead to strategic benefits for the supplier in the form of developing new products and services and faster response to changing customer demands.[2] If the relationship-specific assets are hard for competitors to imitate (e.g. because supplier and customer both adjust their processes and systems over time, i.e. their resources and capabilities co-evolve), the trading partners are likely to improve their performance versus competitors.[3]

II.3 Managing FMCG supply chains

The previous chapter has looked at supply chain management from a strategic and rather theoretical perspective. This chapter looks at more operational aspects and shows the changes that companies in the FMCG industry have made to their distribution activities. It also provides some evidence on the level of implementation and highlights some empirical results regarding whether supply chain management has increased company performance.

Changes in the way the FMCG supply chain operates are not limited to activities between retailers and suppliers. The changes also involve internal operations, both within individual stages of the supply chain and between stages (e.g. store and retail DC).

Restructuring of the distribution system

McKinnon[4] describes a number of mutually reinforcing trends that have lead to dramatic changes in retail logistics. These include:

- Increased retailer control over secondary distribution from DC to the store;
- Restructuring of retail logistic systems, including regional distribution centers;
- Adoption of quick response practices and implementation of cross docking and sales-based ordering systems which lead to lower inventory levels due to shorter lead times, lower order quantities and higher delivery frequencies.

Increased control of secondary distribution and regional distribution centers have, for example, enabled retailers to increase delivery frequencies as it is now possible to consolidate shipments so that a truck load contains a large variety of products.[5]

Subsequently, retailers such as Wal-Mart have reduced the amount of direct store deliveries (DSD) in favor of cross docking.[6] The experience of Debenhams, a UK retailer, shows that cross docking benefits both the suppliers and the retailers. Suppliers have to make fewer deliveries which can reduce transportation cost, while the retailer reduces the handling cost. However, direct store deliveries are cumbersome to check, and can cause delays and congestion due to limited loading and storage areas.[7]

1 *Buzzell, Ortmeyer (1995)*
2 *Subramani (2004)*
3 *Dyer, Singh (1998)*
4 *McKinnon (1996)*
5 *Holmes (2001)*
6 *Ghemawat et al. (2004)*
7 *EAN (2004)*

These changes at least partly result from technological innovations (see also chapter III.8) and have resulted in a cost advantage for operators of superstores that realize economies of scale in distribution.[1] Independent supermarket retailers often have limited resources and technical knowledge and cannot compete with companies such as Wal-Mart on cost. They therefore try to differentiate themselves on quality and service.[2]

An FMI report[3] estimates distribution cost for self-distributing chains at 2.7% of sales versus 3.6% for traditional food distributors. While traditional grocery retailers may have much higher gross margins than operators of warehouse clubs, for example, they may have comparable operating margins, due to much higher operating expenses. As they furthermore have higher levels of working capital and fixed assets as percentage of sales, their return on invested capital is likely to be much lower.[4]

Retailers with better execution capabilities than competitors enjoy a productivity loop. Superior execution leads to lower cost and lower prices, which drives sales and, due to economies of scale, leads to a further reduction in cost.[5] A statement by Jay Fitzsimmons, Wal-Mart's Senior Vice-President for Finance highlights the importance of supply chain efficiency. He said during a presentation that it is a misconception that Wal-Mart is in the retail business. The company is actually in the distribution business. According to him, one of the company's main concerns is to sell products to customers within 72 hours of leaving the dock door at Procter & Gamble.[6]

Changes in the relationship between retailers and manufacturers

Retailers and manufacturers have introduced supply chain management and ECR practices in order to improve collaboration. One of the primary goals of retailer-supplier partnerships is to reengineer processes. This includes

- the use of information technology (including barcoding) to automate manual activities;
- the elimination of redundancies;
- the reassignment of tasks; and
- the reduction or elimination of control steps.[7]

Frequently mentioned examples of fundamental changes in the relationship between retailers and suppliers in distribution include VMI systems in which the manufacturer becomes responsible for determining ordering quantities and every-day-low-cost/-price policies (EDLC/EDLP) in which manufacturers and retailers, respectively, start to charge stable prices for their products instead of relying on frequent trade promotions.[8] VMI systems can improve product availability and reduce costs as manufacturers may be in a better position to analyze sales data and manage the product flow and as VMI emphasizes optimization of the entire supply chain.[9] EDLC and EDLP policies can not only lower cost, but also decrease complexity and reduce demand variability. Furthermore, promotions can be bad for brand image.[10] According to a Business Week article[11], Procter & Gamble estimated that "only 30% of trade promotion money actually reaches the consumer in the form of lower prices, while 35% is lost in inefficiencies and another 35% winds up in retailers' pockets".

1 *Holmes (2001)*
2 *Progressive Grocer (2005a)*
3 *FMI (2005)*
4 *FMI (1992)*
5 *Mandel (1991)*
6 *DSN (2003)*
7 *Buzzell, Ortmeyer (1995)*
8 *Schwarz (2005)*
9 *Koch (2002)*
10 *Thonemann et al. (2003), p. 97*
11 *Business Week (1992)*

Many practices aim at replacing the traditional push system with a pull system in which actual end-customer demand "pulls" products through the supply chain. By contrast, in a push system, manufacturers base their production decisions on long-term forecasts[1]. Retailers and suppliers have, for example, streamlined primary distribution activities from factory warehouse to retail DC, including closer integration of secondary and primary distribution systems. Furthermore, manufacturers have shortened delivery lead times, reduced order quantities and increased delivery frequencies.[2]

Complete pull systems, however, are difficult to implement. Whereas cross docking can effectively realize a push system for product distribution[3], long lead times, economies of scale in production, and inflexible manufacturing capacities often hinder the implementation of pull systems throughout the entire supply chain[4]. In recent years, manufacturers have increasingly invested in more flexible production equipment. However, trade-offs between manufacturing and inventory cost can make it uneconomical to fully extend the pull system to the production process.[5]

Status-quo: Significant differences in performance and level of adoption

There is mixed evidence regarding the success of the supply chain concepts described above. According to Frankel et al.[6], ECR did not fulfill expectations. They mention two main reasons. First, companies had inflated expectations. Second, companies underestimated the need to change processes and the complexity of these changes. However, despite this general conclusion, several companies have been very successful in implementing ECR. The authors describe a number of case studies in which companies have achieved significant performance improvements by employing ECR concepts. In contrast to the findings of Frankel et al., Schmickler[7] finds in a survey of companies in Germany, Austria and Switzerland that over 85% of retailers and over 80% of manufacturers were satisfied with the results of ECR projects.

A recent survey by Thonemann et al.[8] shows significant differences in logistics performance between what they term "champions" and "laggards". The authors examined supply chain management at 40 consumer goods manufacturers and 18 retailers in Germany. Companies were classified as champions and laggards based on performance indicators such as service and inventory levels, delivery lead times, and logistics costs. Champions were those companies which excelled on both the service and the cost dimension[9]. Supply chain champions among both retailers and manufacturers reach higher service levels with lower levels of inventory than their competitors.[10] Manufacturers classified as champions also had more flexible production capabilities compared to laggards.[11] While champions and laggards mentioned similar levels of trust towards their trading partners, there were big differences in aspects such as operational contacts and joint capacity planning (for manufacturers) and exchange of performance indicators and joint capacity planning (for retailers) between the two groups.[12]

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1 *Simchi-Levi et al. (2000), p. 117 ff*
2 *Whiteoak (1999)*
3 *Stalk et al. (1992)*
4 *see e.g. Simchi-Levi et al. (2000), p. 185 ff. There are different strategies to shift the push-pull boundary. One strategy often mentioned is postponement.*
5 *Whiteoak (1999)*
6 *Frankel et al. (2003)*
7 *Schmickler (2001)*
8 *Thonemann et al. (2003)*
9 *ibid, p. 22 and 28*
10 *ibid, p. 22 and 28*
11 *ibid, p. 58*
12 *ibid, p. 35 and 49*

The degree to which companies have adopted industry standards and practices varies. According to the 5th ECR D-A-CH Monitor which surveys companies in the German-speaking countries, 46% of retailers and 37% of manufacturers, for example, state that they use VMI; 46% of retailers and 45% of branded consumer products manufacturers exchange or receive POS data; and 57% of both retailers and manufacturers use dispatch advices (DESADV).

While companies often have a fairly accurate picture on the internal status of deliveries, they often miss information on the status of deliveries at trading partners. Simon Langford[1] from Wal-Mart, for example, states that "[i]f we take a snapshot of the supply chain end to end, currently we have information when we receive a product, when we ship products, but that's fairly limited. [...] We don't see when they ship a product to us."

Even if information is exchanged between trading partners, this does not necessarily make a difference. A report by FDI, FMI and GMA[2] states that manufacturers would need to convert 40-50% of volume to VMI / CRP / co-managed inventory (CMI) programs before they would see a change in their manufacturing processes. The simple sharing of demand information is not sufficient. The manufacturer needs the discretion to select e.g. when to deliver products.

There seem to exist differences between countries regarding the use of certain practices. A survey in the US[3], for example, shows that a much higher percentage (83% vs. 37%) of manufacturers in the US than in the German-speaking countries offer VMI services. The same survey also shows that the number of trading partners and the volume of sales for which these services are provided is limited. The companies report, for example, that 35% of the sales volume is sold under VMI programs. The figure for dispatch advices is 27% and 16% for EAN.UCC-128 barcodes.

II.4 RFID technology, the EPCglobal Network, and the EAN.UCC system

II.4.1 Enabling technologies

This thesis deals with the impact of RFID technology on the performance of the FMCG supply chain. An identification technology such as the barcode or RFID is only a means, and it is the application of the technology that determines its value. The practical literature on supply chain management therefore distinguishes between what may be called enablers (which are technology-related) and concepts (which deal with specific practices or methods).

ECR Europe[4] recognizes common identification standards (including numbering systems as well as barcode symbols) as one of the enablers for efficient consumer response; the other enablers are electronic message standards and global data synchronization. The other focus areas are demand management, supply management, and integrators. Supply management is seen as an integrated set of four concepts: supply strategies & capabilities; responsive supply; integrated demand driven supply; and operational excellence. Each of these concepts contains a number of practices and methods, such as continuous replenishment, automatic store ordering, product flow techniques, operational reliability, sharing of demand data, and a partnership approach.

Keh[5] makes a similar distinction between enablers and concepts, but uses a different terminology. He distinguishes between operating technology and information technology. Barcoding, EDI etc. are seen as information technology innovations, whereas ECR practices such as continuous replenishment, direct store deliveries, category management, activity-based costing, or cross docking are seen as innovations in operating technology.

1 *cited in FTC (2004), p. 62*
2 *FDI et al. (2002)*
3 *GMA (2003)*
4 *www.globalscorecard.net/guide_to_ecr/d_guide.asp*
5 *Keh (1998)*

II.4.2 Introduction to RFID technology

RFID tags and readers

RFID technology uses electromagnetic waves to gather data from a small device called an RFID tag.[1] In order to read the information on the tag, the tags need to be near the antenna of an RFID reader. There is a large variety of RFID tags that differ, among others, by mode of coupling, communication, and power source.[2] Active tags, for example, contain a battery, whereas passive tags receive their energy from the reader field.

An RFID tag is a microchip attached to an antenna that is packaged so that it can be applied to an object. RFID tags can come in many form factors, including RFID labels .[3] They can also be mounted inside a carton or other forms of packaging or be embedded in plastic.[4]

RFID is not a new technology. One of the earliest papers on RFID was published in 1948, and the first commercial applications were realized in the 1960s. In the 1970, companies began to use RFID for animal tracking, road toll collection, and factory automation.[5] In the past few years, driven by the Auto-ID Center, a large number of potential end users and technology providers shifted attention towards low-cost RFID technology.[6]

Much of the discussion on cost has focused on the cost of RFID tags. These costs are especially significant when tags are not reused. The Auto-ID Center has formulated the target of the $0.05 RFID tag,[7] and there is a great deal of energy going into getting the price of the tags down. One factor that will drive down prices is the production volume.[8] Additionally, RFID tag manufacturers may have to develop new production processes. As a representative from Texas Instruments believes, the costs of creating the inlay and converting it into a label are too high to create a $0.05 tag. An alternative is to print an RFID antenna, using conductive ink, directly onto the back side of a label and then use conductive glue to connect the microchip and the antenna.[9]

Frequencies

The research and standardization efforts of the Auto-ID Center and now EPCglobal have concentrated on two frequencies, UHF (~900 MHz) and high frequency (HF – 13.56 MHz). At present, most of the effort goes into UHF technology as Wal-Mart, Tesco and Metro all use UHF tags for their roll-outs at the case and pallet level. One advantage of UHF technology is that RFID readers can read tags from up to several meters compared to less than one meter for HF technology.[10] A disadvantage is that UHF tags are usually bigger and more susceptible to disruption by metal and water than HF tags.[11]

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1 *Das (2004)*
2 *Schuster et al. (2004)*
3 *An RFID label consists of an RFID inlay that is placed between a paper label and an adhesive layer. An RFID inlay is a microchip attached to an antenna and mounted on a substrate. Semiconductor companies such as Texas Instruments often sell inlays to so-called label converters which produce the final RFID label (RFID Journal (2004e).*
4 *RFID Journal (2002)*
5 *Landt (2001)*
6 *Das (2004)*
7 *Sarma (2001)*
8 *see e.g. Philips (2004), slide 12*
9 *RFID Journal (2004e)*
10 *Lampe et al. (2005)*
11 *Smart Labels Analyst (2004)*

It is unclear what frequency will ultimately be used at the item level: "Most item-level tagging has used 13.56 MHz so far. EPC can use any frequency, but Wal- Mart, the US Military and others have chosen UHF for cases and pallets and will need convincing if they are to abandon it for item level."[1] Whereas Metro uses HF technology in its item level tests at the Metro Future Store and in the project with Gerry Weber,[2] Tesco and Wal-Mart use UHF technology for tagging CDs and DVDs[3] and pharmaceuticals,[4] respectively. Marks & Spencer also uses HF technology in its apparel tagging trials.[5] Some technology vendors also advocate the use of HF technology for item-level tagging. In a white paper, Philips, Tagsys and Texas Instruments[6] argue that "[d]ue to a number of technical and deployment characteristics including read range, form factor, maturity, global standards and worldwide availability, HF technology provides the most effective path with the lowest technical and business risk to achieving item-level identification and pedigree tracking for pharmaceutical and healthcare applications."

Read rates

The laws of physics can prevent RFID tags being read in certain situations. Some press reports state that current read rates are disappointing, but this may be attributed to the early stage of adoption.[7] It is difficult to say where the ultimate boundaries may actually lie.[8] However, it might never be possible to read, for example, all items on a pallet in every situation.

This implies that item-level tagging may never eliminate the need for RFID at the case level. The same is true for the pallet level. Identifying all cases on a pallet may not be achievable with today's technology. The EPCglobal end-user requirements for the Generation 2 UHF reader interface protocol therefore state that the technology should achieve a read rate of 100% on single cases transported on a conveyor at high speed, but demand only as many reads at the case level as possible when the cases are stacked on a pallet.[9] This is one of the reasons why Wal-Mart and Metro intend to use RFID also at the pallet level, despite efforts to introduce case-level tagging.[10] Companies use the unique identifier at the pallet level as the reference to the content of the pallet and other delivery data.

An alternative approach is to read a number of case-level RFID tags on a pallet and conclude from this on the presence of the remaining cases. This is called inferred reads.[11] So far, however, Metro, Tesco and Wal-Mart do not demand that their suppliers provide the serial numbers of the RFID tags applied at the case level. This means that the retailers are not able to associate a case with a specific pallet or delivery.

With RFID, there is not only a risk of so-called false negative reads (i.e. instances in which an RFID reader does not read an RFID tag although it is supposed to record its presence), but also of false positive reads in which an RFID reader accidentally reads an RFID tag. This can become a problem in certain applications, e.g. in order picking when the reader should only detect those tags that the picker puts on the pallet, but not those cases still on the pallet in the rack.

1 *ibid (2004), p. 5*
2 *see www.future-store.org*
3 *RFID Journal (2005e)*
4 *RFID Journal (2004f)*
5 *RFID Journal (2005i)*
6 *Philips et al. (2004), p. 22*
7 *see e.g. RFID Journal (2005d)*
8 *AIM (2005)*
9 *EPCglobal (2004g)*
10 *This statement is not exactly true as Tesco only aims for case-level tagging (see www.tesco.com/radiobarcodes)*
11 *Schuster et al. (2004)*

Demands on read rates may vary, depending on the application. One aspect that needs to be taken into account is whether false positive or negative reads are easily detectable and correctable. It is also important to consider that errors multiply: A read rate of, say, 99.5% at the case level can already significantly reduce the value of RFID when the technology is used, for example, to check the accuracy of incoming deliveries. Assuming 60 cases per pallet, the chance that all cases on a pallet are read is below 75%. This means that the company may still have to check more than 25% of incoming pallets for accuracy which reduces the potential benefits of adopting RFID.

Availability of standards and technology

Up to now, UHF technology has been in short supply, not least because of uncertainty regarding the final standard. An important milestone was achieved when EPCglobal ratified the Generation 2 reader interface protocol for UHF technology at the end of 2004.[1] RFID tags and readers based on this standard are likely to become commercially available in mid-2005.[2] Another major step for the adoption of RFID technology in Europe was when the European Telecommunications Standards Institute (ETSI) approved a new standard for UHF technology in late 2004[3] which, among others, allows users to deploy RFID readers that operate at a higher power, giving longer read ranges.

In contrast to UHF technology, there is an established ISO standard (ISO 15693). EPCglobal has proposed a HF standard in 2003, but has halted any further work on HF protocols due to lack of end-user requirements.[4] For the ISO 15693 standard, tags and readers are commercially available from a number of vendors.

RFID middleware

For RFID readers to deliver data that companies can use in their business applications, there is a need to apply at least some simple filtering to the data. The software component that provides this filtering functionality may be much simpler than the EPC middleware[5] (formerly called Savant) envisioned by proponents of the EPCglobal Network. Specifically, the software does not necessarily need to contain any business logic, and there might not be any hierarchical structure.

An RFID reader is likely to read an RFID tag several times, but this information is irrelevant at the application level. The only information required at the application level is that a specific tag has been read at a specific moment by a specific reader (in case of event-based reads) and, additionally, that a specific tag has disappeared at a specific moment from the area that a specific reader covers (in case of status-based reads).

Privacy

There has been much discussion on RFID and privacy.[6] However, at the case and pallet level, consumers, in general, do not come into contact with RFID tags. Wal-Mart has announced that it does not intend to place RFID readers on the shop floor for the foreseeable future, but admits that products sold in "cases of one" (e.g. HP printers) will contain an RFID tag. On these cases, the company intends to apply an EPC-logo to inform consumers. [7]

1 *EPCglobal (2004b)*
2 *RFID Journal (2004g)*
3 *www.etsi.org/pressroom/previous/2004/2004_10_rfid.htm*
4 *EPCglobal (2004d)*
5 *Oat Systems, MIT Auto-ID Center (2002)*
6 *see e.g. Thiesse (2005)*
7 *RFID Journal (2004b)*

II.4.3 RFID and the EPCglobal Network

The ultimate vision of the founders of the Auto-ID Center was to create an "Internet of Things"[1]. This vision included much more than a numbering system to uniquely identify products at the item level and RFID technology to capture the data. It also included a network that allowed trading partners to manage and access the associated data. The network was named the EPCglobal Network when the Auto-ID Center transferred the technology to EPCglobal at the end of 2003.

In the discussion on RFID, there is often no clear distinction between the benefits from RFID and the benefits that companies may be able derive from the entire EPCglobal Network.[2] According to EPCglobal[3], "the EPCglobal Network is a method for using RFID technology in the global supply chain by using inexpensive RFID tags and readers to pass Electronic Product Code numbers, and then leveraging the Internet to access large amounts of associated information that can be shared among authorized users." The EPCglobal Network consists of a number of components that are described in Table II 1. RFID technology constitutes the so-called ID systems.

The complete EPCglobal Network specification is not yet available. So far, standards are available for the EPC and the ID system (i.e. RFID tags and readers). There is still significant effort required to analyze and develop the standards and specifications to implement the remaining components.[4] This is one of the reasons why companies such as Wal-Mart, Metro and Tesco initially only use the EPC and the ID System (i.e. RFID technology) and integrate these components into their existing IT systems.

Component	Description
Electronic Product Code (EPC)	Unique number that identifies a specific object in motion in the supply chain
ID System	The ID System consists of EPC tags and EPC readers. [...] The EPC is stored on this tag, which is applied to cases, pallets, and/or items. EPC tags communicate their EPCs to EPC readers using RFID. EPC readers communicate with EPC Tags via radio waves and deliver information to local business information systems using EPC Middleware
EPC Middleware	EPC Middleware manages real-time read events and information, provides alerts, and manages the basic read information for communication to EPC Information Services (EPC IS) and a company's other existing information systems. [...]
Discovery Services	A suite of services that enable users to find data related to a specific EPC and to request access to that data. Object Naming Service (ONS) is one component of Discovery Services.
EPC Information Services (EPC IS)	Enables users to exchange EPC-related data with trading partners through the EPCglobal Network.

Table II-1: The components of the EPCglobal Network[5]

1 *Brock (2001), p. 5*
2 *see e.g. the Auto-ID Center reports by Accenture (2002a-d, 2003a) and IBM (2002a-d)*
3 *EPCglobal (2004f), p. 5*
4 *EPCglobal (2005), p. 9 ff*
5 *adapted from EPCglobal (2004f), p. 5*

Once implemented, the EPCglobal Network provides the infrastructure that could improve product authentication or allow manufacturers to request information on the location of inventory in retail stores. The central discovery service, which includes the object naming service (ONS), only enables users to find data related to a specific EPC and request access. The actual access to and exchange of the data is handled locally via the EPC Information Services (EPC IS) of the involved companies. In order to provide the data and act on it, companies need not only to capture and store the data and integrate their EPC IS into their information systems, but also to define the related business processes, including rules for automatic decision making.

II.4.4 The EPCglobal Network and the EAN.UCC System

With the transition to EPCglobal, a subsidiary of GS1, the EPCglobal Network became part of the EAN.UCC System. GS1, formerly UCC in the US and EAN International in the rest of the world, is a voluntary standards organization that develops and manages the EAN.UCC system.[1] The EAN.UCC system includes a numbering system for identification (e.g. Global trade identification number (GTIN), Serialized shipping container code (SSCC), Global location number (GLN)), barcode symbols for representing the numbers (e.g. EAN.UCC-13, EAN.UCC-128), EDI messages and Extensible markup language (XML) schemas for data exchange, and information networks such as the Global Data Synchronization Network (GDSN) and the EPCglobal Network.[2]

The Electronic Product Code and the ID system of the EPCglobal Network supplement already existing elements of the EAN.UCC system. The EPC is related to the existing numbering systems, and the specification of the EPC permits the direct transfer of GTIN, SSCC and GLN numbers into EPCs. (As the GTIN is the same for all objects of the same SKU, a serial number is attached to the GTIN in order to facilitate unique identification. Thereby, the GTIN becomes the Serialized global trade identification number (SGTIN). In contrast to GTINs, SSCCs and GLNs are already unique for each object.) The ID System (i.e. RFID technology) supports the same function as the current standards for barcode symbols. It provides input for information systems by identifying physical objects. The other components of the EPCglobal Network have no equivalent in previous elements of the EAN.UCC System.

Realizing the GDS Network is another major GS1 infrastructure initiative besides the EPCglobal Network. The two networks serve related, but distinct purposes. According to Sarma, the EPCglobal Network is the next step from the GDS Network, with both systems built around data exchange.[3] The GDS Network intends to facilitate the exchange of master data on products and locations. Companies can find the data pools that contain the data via the GS1 Global Registry.[4] Master data describes the specifications and structure of products and locations and can be divided into neutral data (which includes core product data that applies to all instances of any product, category-specific data that only applies to specific product categories, and target market data) and relationship-dependent data (e.g. marketing conditions, price information, logistics agreements).[5] This data is static, whereas the EPCglobal Network provides dynamic data (see Figure II 2) about the history of an individual product (e.g. track & trace information) and instance data (e.g. batch number).

1 *Despite the renaming of EAN International (including its member organizations) and the UCC into GS1, the system of standards is still referred to as the EAN.UCC System (see www.gs1.org)*
2 *www.gs1.org*
3 *Sarma (2004)*
4 *EPCglobal (2004e)*
5 *GCI (2004)*

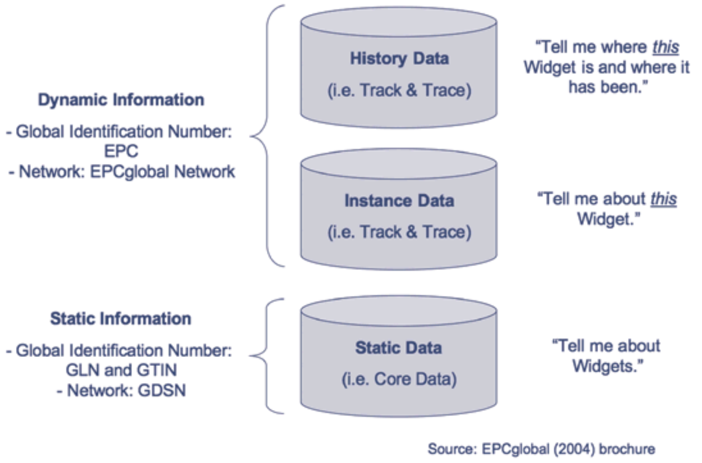

Figure II-2: Information in the EPCglobal Network and the Global Data Synchronization Network (GDSN)[1]

Figure II 3 schematically shows how, in the future, companies may acquire data about products and exchange information: RFID readers capture information about the physical location and movement of products in the supply chain by reading the EPCs stored on RFID tags. This history data is used internally, but also made available to trading partners. In order to ensure that trading partners can find and request access to this history data as well as instance data, there is a need to let the Discovery Service know where information on a specific EPC is available. Manufacturers also provide information on where trading partners can find product master data. The references to these data pools are stored in the GS1 Global Registry.[2] The actual access and exchange of both static and dynamic data is handled independently of the central services. Furthermore, there is additional information exchange between companies that is unaffected by the GDS Network and the EPCglobal Network. This includes EDI messages on orders and invoices. To some extent, the EPCglobal Network may, however, change the way information is exchanged. For example, in case of VMI systems at the DC level, the retailer may stop "pushing" information on inventory levels via EDI. Instead, the manufacturer may "pull" the information from the retailer's warehouse management system via the EPCglobal Network.[3]

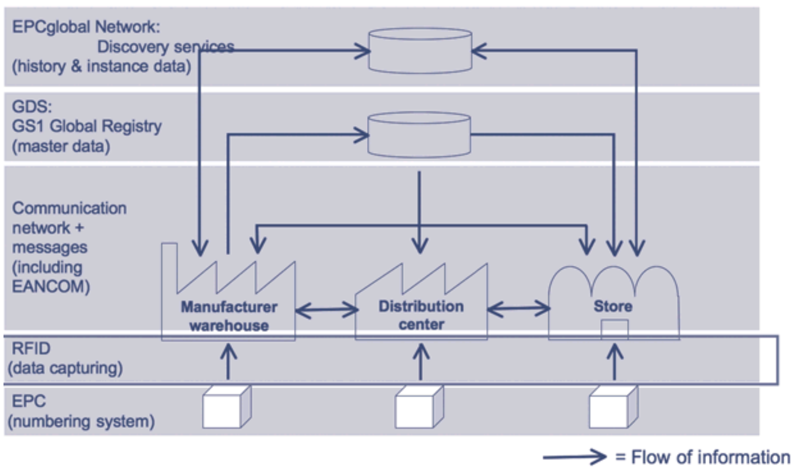

Figure II-3: RFID, the EPCglobal Network, and the EAN.UCC System

1 *EPCglobal (2004e), p. 5*

2 *External data pools that are, for example, provided by UCCnet have been omitted in the picture*

3 *For the EPCglobal US Conference 2004 in Baltimore, Procter & Gamble and Wal-Mart, together with Tibco, IBM and VeriSign realized a live demonstration in which Procter & Gamble uses the EPCglobal Network to check inventory levels at Wal-Mart stores.*

When talking about the barcode, there is usually no clear distinction made between the numbering system and its representation. There are different numbering schemes: the GTIN is used to identify trade items (e.g. SKUs or cases with several items of one SKU), and the SSCC to identify logistic units (e.g. pallets with several cases or cases containing different SKUs)[1]. Furthermore, there exist GLNs which uniquely identify locations. Each number can be represented in a barcode symbol. GTINs are usually represented as EAN.UCC-13 barcodes, whereas SSCCs are often represented as EAN.UCC-128 barcodes. For the remainder of this chapter, the term barcode refers to the use of EAN.UCC-13 and EAN.UCC-128 barcode symbols for unit identification.[2]

II.5 Adoption of RFID in the FMCG supply chain

II.5.1 Status-quo of RFID adoption in the FMCG industry

So far, a few large retailers, including Wal-Mart, Metro and Tesco, have announced their intention to deploy RFID at the case and pallet level. Figure II 4 provides an overview of major milestones in the adoption of RFID technology for Wal-Mart, Metro and Tesco. While item-level tagging may be the ultimate goal and Metro and Tesco still conduct tests, none of the three retailers has yet committed to adopting RFID at this level. The timelines and approaches of the companies regarding case and pallet level tagging differ somewhat:

Metro was the first to start its roll-out, in November 2004. The company began with 20 partners only at the pallet level. By the end of 2005, the company expects to have 100 participating and to extend the roll-out to the case level. In 2006, Metro expects to receive RFID-tagged shipments from 300 suppliers, covering 60% to 80% of sales.[3] The roll-out simultaneously covers several of Metro's distribution lines in Germany.

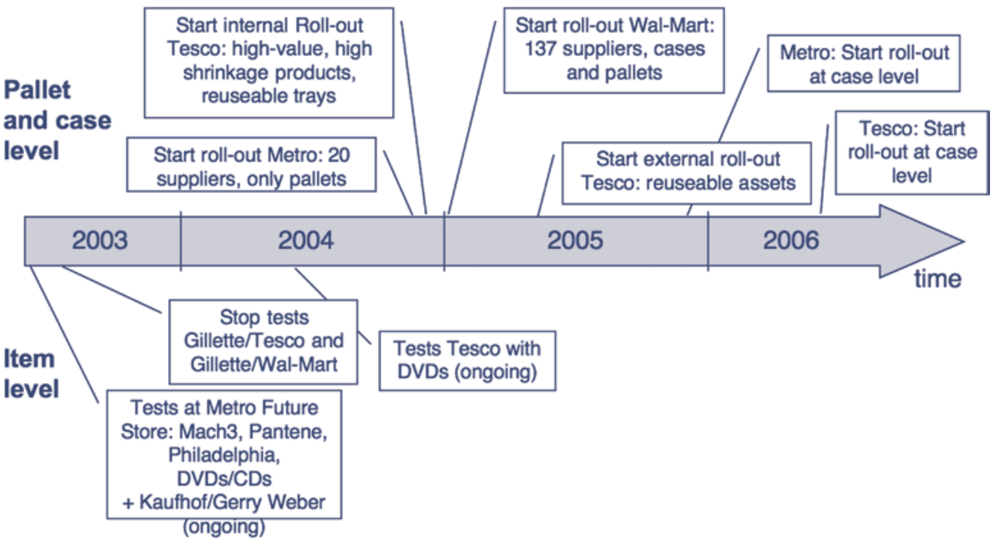

Figure II-4: Major milestones in the adoption of RFID in the FMCG industry[4]

1 *www.ean-int.org/numbering.html*
2 *EAN.UCC-128 barcodes are not only used to identify units, but also to encode other data such as expiry dates*
3 *RFID Journal (2005g)*
4 *The information was gathered from www.future-store.org, www.rfidjournal.com, www.tesco.com/radiobarcodes, and Metro (2005a)*

In January 2005, Wal-Mart's roll-out started, including the company's top-100 suppliers plus an additional 37 voluntary adopters. Wal-Mart simultaneously adopted RFID at the case and pallet level. Wal-Mart followed a regional roll-out approach, beginning in Texas. The company plans to have installed RFID technology at 600 Wal-Mart and Sam's Club stores and 12 DCs by the end of 2005. In January 2006, the next 200 suppliers are expected to start shipping RFID-tagged cases and pallets to Wal-Mart. Initial process changes that Wal-Mart intends to realize include the automatic generation of prioritized picking lists for store employees for those products available in the backroom.[1] This process change becomes possible with the separation of backroom and shop floor inventories enabled by RFID (see also chapters IV.3 and V.4).

Tesco has started to roll out RFID internally on reuseable trays for high-value, high-shrinkage products as part of its Secure Supply Chain initiative. The company modified its original case-level supplier roll-out plans in November 2004. It will now start in the second quarter of 2005 with products that are delivered in reuseable containers and extend it to products that are delivered in one-way packages over time.

A number of manufacturers are working closely with retailers on RFID. Examples include Gillette and Procter & Gamble. Both companies are looking closely at how they can use the technology in internal and customer-facing processes. Procter & Gamble, for example, has conducted a project with Metro in this area.[2] A large number of companies may initially use a "slap & ship" approach that involves placing RFID tags on cases and pallets in a DC only on the products that are shipped to a retailer that has rolled-out RFID. Slap & ship could involve manually breaking down pallets that are ready for shipment just to attach RFID tags to cases.[3] Campbell Soup, for example, applies RFID tags to cases and pallets at a third party facility.[4] Initially, this approach may cover only a few products for designated distribution centers or stores.[5]

Slap & ship has some advantages. It ensures that a manufacturer can fulfill RFID mandates in time and does not risk losing the customer; it provides the opportunity for learning (both on the technology and business side); and it can lower the cost of final deployment as technology and implementation costs are likely to decline in coming years. However, slap & ship only increases operational costs as a company does not derive any benefits from RFID in its internal operations. At some point (which Deloitte[6] calls the "tipping point"), it may become beneficial to take incremental steps towards a full-scale implementation, including source tagging of cases and pallets, deploying readers in the internal supply chain and adjusting processes and information systems. The benefits can allow a manufacturer to recover at least part of the cost of RFID tags through internal process improvements. The tipping point is company-specific and depends on a number of factors, including cost drivers such as the number of retailers rolling-out RFID, the case volume to those retailers, the RFID tag price and value drivers such as the product portfolio, the sophistication of the distribution system, and technology maturity and reliability.[7]

1 *Computerworld (2005), RFID Journal (2005h)*
2 *see Ebling, Scharr (2004)*
3 *Deloitte (2004a)*
4 *Engle (2004), slide 15. The company calls its approach "tag at ship", rather than "slap & ship"*
5 *see e.g. Johnson (2005)*
6 *Deloitte (2004a)*
7 *Deloitte (2004a)*

II.5.2 RFID on reuseable assets, at the item level, and in the supply chains of other industries

RFID on reuseable assets

In the FMCG industry, there are a few roll-outs and pilots that involve reuseable assets. Examples include Tesco's Secure Supply Chain initiative, tracking of food transported in reuseable assets at Marks & Spencer's food division,[1] and the management of the returns process for reuseable assets at Spar Austria[2]. Another company that has conducted extensive tests, including a trial involving 250 000 pallets in Forida, is Chep, a provider of reuseable asset pools.[3]

The example from Spar Austria is illustrative in that it shows how specific circumstances influence the requirements and potential benefits of an RFID-based solution. Spar is organized as a cooperative with commercially independent retail stores. The company ships part of its assortment in reuseable trays from the DC to the independent retail stores. After the retailer has replenished the products, a store employee puts the trays on a roll cage and attaches a label that contains an SSCC, encoded as a barcode, before the roll cage is returned to the DC. The label is scanned at the DC in order to identify the roll cage and hence the trays the retail store has returned. The trays themselves are identified automatically. Employees put the trays on an automatic sorter which uses a sophisticated optical system to identify the pallets based on a number of parameters, including size and color. The retail store is billed for any missing trays. The need for allocating the trays to a store comes partly from the fact that the retail stores are independent. With passive UHF tags attached to roll cages, Spar Austria expects to reduce the handling effort for identifying roll cages, eliminate the need for labels, and lower the cost of dispute resolution between DC and the retail stores (labels sometimes get lost). So far, Spar Austria has conducted a pilot project that involved 15,000 roll cages.

In applications that reuse RFID tags, two capabilities that distinguish RFID from the barcode can become relevant that do not play a role in applications of "one-way" low-cost passive RFID technology in the FMCG supply chain as described in this thesis. First, RFID offers the opportunity to re-write the tag and thus change the identification number on an object. This eliminates the need to replace a label or to administer references in a database.[4] Second, RFID allows the decentralized storage of data on the object. In a trial of RFID on reuseable trays, Sainsbury's, for example, has saved the description, quantity and expiry dates of the products in the crate on the tag, in addition to the crate's unique identifier.[5]

RFID at the item level

A few companies in the FMCG industry are conducting tests with RFID at the item level. This includes retailers such as Metro and Tesco and manufacturers such as Gillette. In its Extra Future Store, Metro tests RFID at the item level on Gillette Mach3 razor blades, Procter & Gamble Pantene shampoo, Kraft Philadelphia cream cheese, as well as on DVDs and CDs.[6] Tesco conducts trials with DVDs at the store level.[7] Gillette is interested in RFID not least because the company's products are of relatively high value compared to the average product sold in a supermarket and are frequently stolen (see also chapter IV.6).

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1 *Mahoney (2002)*
2 *Gleiss (2004)*
3 *RFID Journal (2004a)*
4 *see e.g. Mahoney (2002)*
5 *Kärkkäinen (2003)*
6 *www.future-store.org*
7 *RFID Journal (2005e)*

In the apparel supply chain, a number of companies are conducting tests with RFID at the item level. This includes Kaufhof / Gerry Weber and Marks & Spencer. In the Kaufhof [1]/ Gerry Weber project, RFID is primarily used to eliminate manual quantity checks in the supply chain, to conduct cycle counts at the store in order to ensure accurate inventory information, and to speed up the check-out process. Gerry Weber is a German-based fashion and lifestyle company that sells its products via own stores and shops-in-shops. The project partners are also experimenting with RFID applications to increase customer service. Gerry Weber and Kaufhof currently use HF tags that are integrated into reuseable labels which also contain an electronic article surveillance (EAS) tag, operating at 8.2 MHz, because current read rates for the HF tags are not yet sufficient.[2]

Marks & Spencer has been testing RFID since 2003. The company announced that it will extend its trials to 53 stores and six clothing departments in spring 2006. By using a mobile reader in the store, the company intends to keep inventory records accurate and reduce the time for cycle counts. Accurate inventory data helps Marks & Spencer to increase product availability, especially for high-value and size-complex products such as bras which, according to the company, come in 48 different sizes. In contrast to Gerry Weber, Marks & Spencer uses tags that operate at 868 MHz.[3]

Otto, a large mail order company, has tested RFID technology in its downstream supply chain from its DC to the consumer. The company has calculated that the potential savings (fewer picking errors, reduced theft, and improved handling of returns) does not warrant the tagging of all products, partly due to the high degree of automation at its DCs. The test therefore concentrated on high-value articles, including consumer electronics.[4]

RFID in the supply chain of other industries

The first industrial applications of RFID date back to the 1970s and include applications for factory automation and asset tracking.[5] In these applications, the RFID tags are generally used several times which decreases the effect of high tag costs, and the use of active tags is not uncommon. Strassner[6] describes a number of applications that involve reusable tags in the automotive supply chain. At current prices, he concludes that the tag costs are too high to warrant the use of “one way” RFID tags in logistics applications.[7] With an expected fall in tag price, however, this may change in coming years, and not only in the FMCG industry.

The US Department of Defense (DoD) started to roll out passive RFID technology in January 2005. The mandate covers cases and pallets, but also items that currently require a unique identification number.[8] The DoD has been using active RFID for a number of years already[9], including Operation Iraqi Freedom[10]. In conjunction with the RFID mandate, the DoD demands that suppliers send dispatch advices.[11] One of the major reasons for the deployment of RFID is that it is difficult to keep track of inventory and to ensure supply in situations with rapidly changing demand and customer requirements as well as frequent changes in the location of troops.[12] The DoD expects that RFID technology will enable “[b]etter inventory control in deployed environments and support for agile combat in an austere environment.”[13]

1 *Kaufhof is part of Metro Group, and the project is part of Metro’s Future Store Initiative*
2 *see Metro (2004b) and Tellkamp, Quiede (2005)*
3 *RFID Journal (2005i)*
4 *Nickerl (2004)*
5 *Landt (2001). See also Finkenzeller (2002) for additional examples*
6 *Strassner (2005), p. 157 ff*
7 *ibid, p. 203*
8 *RFID Journal (2004d)*
9 *RFID Journal (2003b)*
10 *Morales, Geary (2003)*
11 *Smiths (2005)*
12 *Morales, Geary (2003)*
13 *Smiths (2005), slide 14*

There are a number of logistics service providers that are pursuing RFID projects at the level of the logistics unit, including DHL[1] and Kühne & Nagel[2]. These activities go beyond simply reacting to the demands of retailers or manufacturers. In contrast, many other third-party logistics providers (3PLs) in Europe, especially smaller players, seem rather slow to embrace RFID.[3]

In the pharma supply chain, RFID may be used for tracking & tracing pharmaceuticals.[4] The Food and Drug Adminstration (FDA) in the US supports the use of RFID at the item level to fight drug counterfeiting.[5] Purdue, a privately held pharmaceutical company, has already started to apply tags at the item level to fulfill Wal-Mart's mandate concerning Schedule II narcotics.[6]

Diffusion of RFID technology

Strassner and Fleisch[7] suggest a diffusion path for RFID applications along three dimensions, (1) from local and closed systems to global and open systems; (2) from reuseable assets to pallets and cases and, finally, items; and (3) from A resources (characterized, for example, by high security relevance, high recovery cost, high levels of shrinkage, and short product life cycles or storage life) to C resources.

Tesco is an example of a company whose RFID activities can be described using this model: Tesco's Secure Supply Chain initiative constitutes an example of a local and closed system involving reuseable assets in order to track high value goods. The company intends later to move to a collaborative closed system covering products that its suppliers ship in reuseable assets. Over time, Tesco expects to extend the use of RFID to non-reuseable cases in a global and open system. This means that, once fully rolled out, RFID ranks high on the first dimension, medium on the second, and covers the whole range for the third dimension, as the retailers expect all their suppliers, regardless of whether they provide A or C products, to apply RFID.

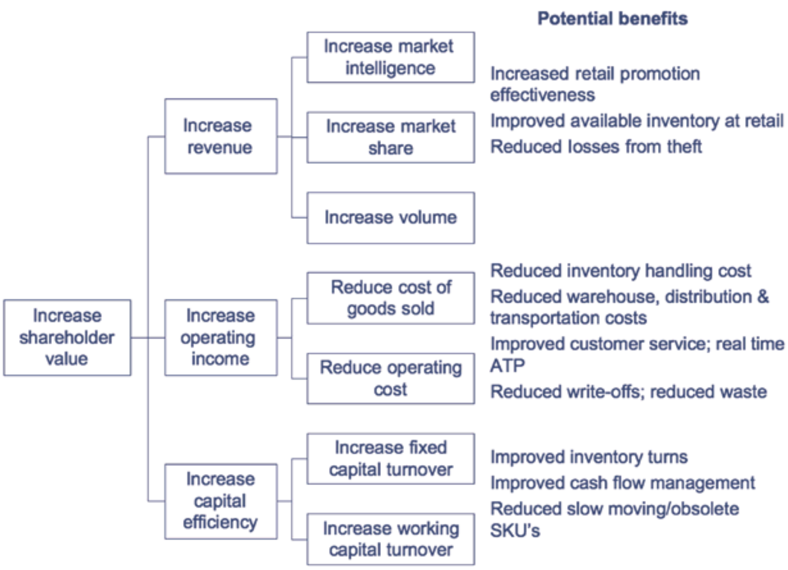

Figure II-5: Impact of RFID and EPCglobal Network on shareholder value[8]

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1 *DHL (2004)*
2 *Unruh (2005)*
3 *RFID Journal (2005f)*
4 *Koh et al. (2003a)*
5 *FDA (2004a)*
6 *RFID Journal (2004f)*
7 *Strassner, Fleisch (2005)*
8 *IBM (2002a), p. 8*

II.6 Benefits of RFID in the FMCG supply chain

Previous studies

Practitioners and – to a limited extent – researchers have discussed several applications and the resulting benefits of RFID in retail and, more specifically, FMCG supply chains. As described in the introduction, the focus of this thesis is on applications that involve low-cost, standardized passive RFID tags on items, cases and pallets and excludes, e.g. applications on reusable assets. Various consulting reports discuss the applications and benefits of RFID in retail supply chains in general. IBM[1] and Accentur[2] were among the first to publish reports as part of their work for the Auto-ID Center. Figure II 5 shows several potential benefits of RFID and the EPCglobal Network and their impact on shareholder value. These studies usually distinguish between the use of RFID tags on pallets, cases and items. Furthermore, they generally discriminate between the benefits for the retailer and those for the manufacturer. In order to account for differences between segments in the retail industries, later studies often examine different product categories separately, e.g. grocery products, apparel and consumer electronics (e.g. IBM[3]). There are also a few articles that look at the influence of company size on the impact of RFID (e.g. Byrnes[4]). Some studies only discuss selected applications of RFID in the warehouse, the distribution center, or the store. In Figure II 6, three of the above mentioned dimensions (product category, supply chain position, level of tagging) have been selected to illustrate how previous studies have looked at RFID.

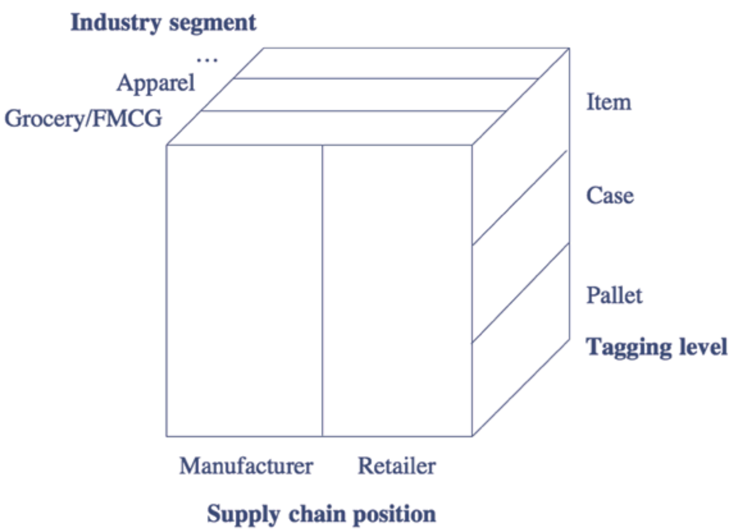

Figure II-6: Dimensions in which previous studies have looked at RFID

RFID and logistics service providers

This research does not specifically consider the role of third-party logistics providers, in particular freight forwarders. This is consistent with most other studies on RFID in retail supply chains, the report by Accenture[5] being one exception. In general, logistics service providers seem to take a rather passive stance towards RFID and are waiting for customer requirements to arise.[6] Only a few logistics companies were actively involved in the Auto-ID Center (e.g. UPS, US Postal Services). RFID is not the only field in which logistics companies do not seem to play a significant role. They are also absent from other industry supply chain initiatives such as GCI.

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1 *IBM (2002a)*
2 *Accenture (2002a)*
3 *IBM (2002c, d)*
4 *Byrnes (2003)*
5 *Accenture (2002c)*
6 *BAH (2004)*

These observations seem to be consistent with recent survey results. Lieb and Bentz[1] examine the requirements that large American manufacturers impose on their third-party logistics providers. One-third of the surveyed companies indicated that they are piloting RFID, another third intends to initiate pilots in the near future. However, the manufacturers do not expect much from the logistics companies: “Those executives who indicated their companies were currently committed to using the technology in their logistics operations were also asked what types of support, if any, that commitment would entail with respect to their 3PL providers. Interestingly, most said ‘none.’ Those who believed that some 3PL support would be necessary focused on a requirement that provider-managed distribution centers would have to be able to scan outgoing shipments.”

Assessment of financial impact of RFID

The conclusions regarding whether RFID at the case and pallet level will increase profits for the entire supply chain vary (see also chapter I.1). In general, it can be said that the initial enthusiasm has given way to a more differentiated assessment.

One reason for this is differing assumptions regarding the magnitude of improvements that can be achieved with RFID at the case and pallet level. In order to estimate the benefit, data is needed on the performance of (a) the current process and (b) the future process. This thesis refrains from mentioning any explicit figures because the performance of current processes varies and, due to a lack of large scale roll-outs that have been operational for several years, there is no data available on how RFID may actually affect process performance. Most estimates of potential improvements must therefore be treated as educated guesses.[2] As Kara Romanow[3] from AMR Research pointed out in March 2005, two months after Wal-Mart’s roll-out started: “It’s still too early to tell whether Wal-Mart will meet its goals. We really don’t know if [RFID] will impact [stock-outs].”

Those studies that estimate the financial impact of RFID usually sum up the operational savings, assuming that any improvements in process performance go directly to the bottom line. Bernstein Research[4] even tries to estimate the impact of RFID at the case and pallet level on Wal-Mart’s, Target’s and Costco’s earnings per share (EPS) in 2008. According to the estimates, RFID could increase EPS by between 1.2% and 1.9%. Except for a GMA study[5], the reports do not take into account that, for example, lower out-of-stock ratios do not necessarily translate into significant increases in sales when all competitors ultimately apply the technology (see also chapter III.8).

Table II-2: Frequently mentioned benefits of RFID in the FMCG supply chain

	Industry studies and trade publications									Company information			Survey results		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Σ
Handling efficiency	x	x	x	x		x	x	x	x	x	x	x	x	x	13
Out-of-stock	x		x		x	x	x	x	x	x	x	x	x	x	12
Inventory reduction	x	x	x				x	x	x		x*		x	x	9
Order reconciliation	x	x	x	x	x	x	x		x			x			9
Theft	x	x	x			x	x	x	x	x			x		9
Unsaleables		x	x				x	x	x	x					6
Production planning	x				x				x			x			4
Promotion execution					x		x	x	x						4
Traceability					x				x			x			3
Product diversion		x					x		x						3

* Improved internal inventory management

1 *Lieb, Bentz (2004), p. 10*
2 *see also Ozer (2005)*
3 *cited in Johnson (2005), p. 38*
4 *Bernstein (2004). Interestingly, their projections due not include any technology cost*
5 *GMA (2004)*

Analysis of existing publications on the benefits of RFID at the case and pallet level in the FMCG supply chain

Table II 2 is the result of an analysis of existing sources that deal with RFID in the FMCG supply chain. It provides a list of the most frequently mentioned benefits. Sources include various reports that deal with RFID in the FMCG supply chain. The list also includes the benefits that Wal-Mart, Tesco and Metro have publicly announced to initially focus on as well as the result of a survey conducted during the EPC Symposium in 2003. The list of reports considered in the table is by no means exhaustive: It does not include, for example, any reports from technology providers. The reason for this was to select only those applications and benefits of RFID that people with a deep understanding of the retail regard as worthwhile in contrast to applications and benefits that might become technologically feasible in principal, but are not – at least for the moment – seen as a priority.

Global ECR Scorecard KPI	Measure	Benefit of RFID in the FMCG supply chain
Category Share	% of total market versus target	No immediate application
Service Level / Fill Rate	% of items delivered as ordered	Order reconciliation
On-Time Delivery	% of orders delivered on time.	No immediate application
Inventory	Days	Inventory reduction
Out-of-stocks	% out-of-stock	Out-of-stock reduction Promotion Execution
Cycle Time / Flow	# of hours	No immediate application
Distribution Costs	% of sales Currency unit per physical case	Handling efficiency Theft reduction Unsaleables reduction
Data Synchronization	% invoices correct	No immediate application

Table II-3:
Global ECR Scorecard KPIs and benefits of RFID in the FMCG supply chain

The sources differ in various aspects. Some, for example, focus only on the retailer or the manufacturer; others do not clearly distinguish between benefits at the pallet and case level versus benefits at the item level. Despite the limitations, however, the list clearly shows that some benefits appear more often than others. In fact, increased handling efficiency and improved product availability are mentioned in almost every source.

Table II 3 relates these benefits to the Global ECR Scorecard key performance indicators[1]. It is evident that the RFID applications could help to improve a number of these performance measures.

1 *GCI (2003b)*

II.7 Summary

This chapter has provided an overview of how retailers and manufacturers currently manage the FMCG supply chain. Retailing in general is a low-margin business, and one major issue is cost efficiency. There is an increased emphasis on improving the overall supply chain and on collaboration between trading partners. Retailers and manufacturers increasingly share information, reassign decision rights where appropriate (e.g. when suppliers become responsible for inventory management in VMI systems), and try to reduce control steps. Companies have adapted their distribution systems and shortened lead times, lowered order quantities and increased delivery frequencies. They increasingly rely on information technology in intra- and inter-organizational processes. Communication and identification standards play an important enabling role, for example in order to implement automatic store ordering systems.

While not all companies have been successful in their efforts to adapt their supply chain, some have realized significant gains. This difference results partly from the fact that companies in the FMCG industry differ in the degree to which they have adopted the relevant practices and technologies.

The chapter discussed the relationship between RFID and the EAN.UCC system. The latter provides the baseline from which to judge any improvement efforts, including RFID. The chapter also looked at RFID and the EPCglobal Network as well as the Global Data Synchronization Network. RFID is just one component of the EPCglobal Network. So far, companies have not stated whether they will adopt the EPCglobal Network, and it may still take several years before the system becomes available.

A number of retailers have started to adopt RFID at the case and pallet level. However, roll-outs are still at an early stage. Based on a review of existing studies on RFID, company material and survey results, the most frequently mentioned benefits were identified.

These benefits and the underlying business pains are closely examined in chapter IV, using the evidence from the field research. The next chapter (chapter III) develops a theoretical framework on the impact of Auto-ID technologies on process performance. Throughout the upcoming chapter, some of the benefits identified in chapter II.6 illustrate specific aspects of the theoretical framework.

RFID is one specific example of an Auto-ID technology. This chapter presents a conceptual framework that analyzes the impact of Auto-ID technologies on process performance. The framework draws on complementarity theory and research on the value of information technology. A review of publications that deal with the impact of the barcode shows findings that are consistent with the theoretical framework. This indicates that the conceptual framework is applicable not only to study the impact of RFID, but Auto-ID technologies in general.

III.1 Introduction to complementarity theory and research on the value of IT

III.1.1 Complementarity theory

The explicit formulation of complementarity theory is often attributed to Milgrom and Roberts, and it has its roots in Economics. Complementarities exist when "doing more of one thing increases the returns to doing more of another."[1] Milgrom and Roberts develop a formal mathematical model based on the idea of complementarities in order to explain the emergence of modern manufacturing, which is, among others, driven by technological advancements.[2] This theory has been applied, among others, to analyze the impact of the barcode and EDI on the apparel industry.[3] Complementarity theory also provides a theoretical explanation for business process reengineering.[4]

One of the main concepts behind complementarity theory is that the objective function that a company intends to maximize can have more than one local maximum. Furthermore, a company may only be able to make discrete choices regarding the design variables (see Figure III 1).

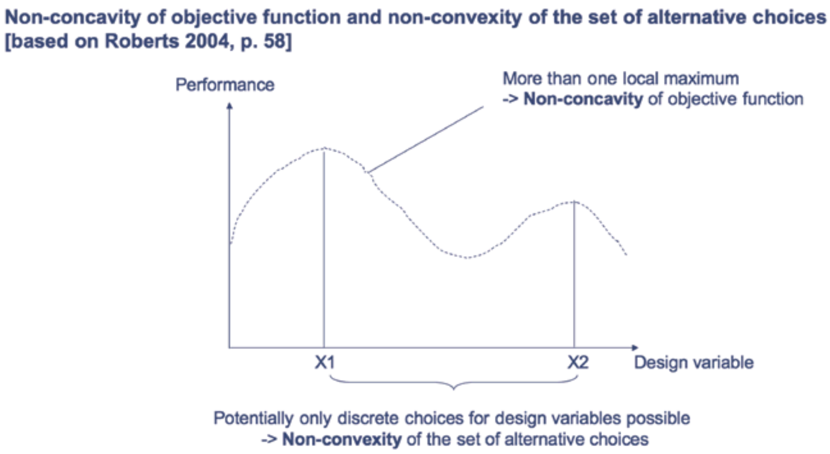

Figure III-1: Multiple optima and discrete choices[5]

Complementarity theory argues that a company has to select a coherent pattern of activities in order to maximize its profits. However, selecting a coherent combination does not necessarily lead to the maximum profit. There can be several coherent patterns, and only one of these patterns is likely to be optimal. Figure III 2 shows that two distinct coherent patterns (X1,Y1) and (X2,Y2) can exist at one point in time, and that it is impossible for a firm at one of these points to improve performance by changing only one of the variables. Figure III 3 is a two-dimensional representation that schematically shows the performance for the four coordinates depicted in the previous figure. The surfaces of the circles correspond with the performance level.

1 *Milgrom, Roberts (1995), p. 181; emphases in original*
2 *Milgrom, Roberts (1990)*
3 *see e.g. Hwang, Weil (1997)*
4 *Barua et al. (1996), Brynjolffson, Hitt (2000)*
5 *adapted from Roberts (2004), p. 58*

The phenomenon of changes in the coherent pattern can be illustrated with the example of lean production in the automotive industry: For a long time, mass production was the most efficient way to produce cars. However, after World War II, Japanese car manufacturers developed the concept of lean production. Although the mass production paradigm still constitutes a coherent pattern for producing cars, the lean production paradigm has become the coherent combination of activities that provides the highest potential profits.[1]

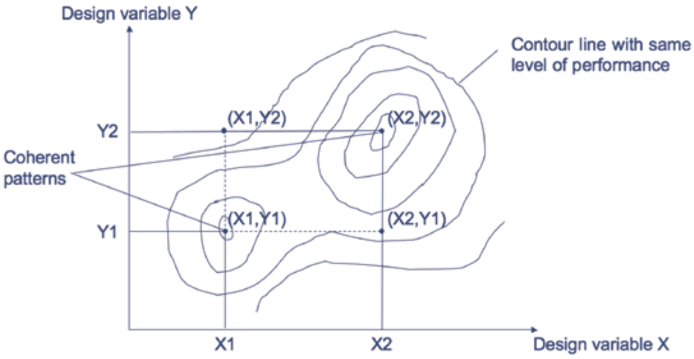

Figure III-2:
Multiple and distinct coherent patterns

This phenomenon is not only limited to the automotive industry, but is a general trend in the manufacturing industry. Milgrom and Roberts, who use the term "modern manufacturing"[2] to label this development, conclude that "in many industries these cumulative changes [in production technologies and customer needs] have made the modern manufacturing strategy much more profitable than the mass production strategy."[3] In such a situation, incremental improvements are likely to lead to a suboptimal outcome (local optima). What is required is a centralized decision to move from the current coherent pattern that is no longer optimal to the new pattern which has become optimal.[4] As many US and European companies have experienced, adopting only some methods from lean production and introducing them into a mass production environment has been extremely difficult.

Although these coherent patterns may exist, the specific choice of each variable that maximizes a company's profit can vary by company. Barua et al.[5] show that certain organizational variables, such as the existing IT infrastructure, can influence the magnitude of change: "Thus, it is evident that the one-size-fits-all nature of recommendations implied by many reengineering principles may be inadequate for handling a wide variety of organizational environments."

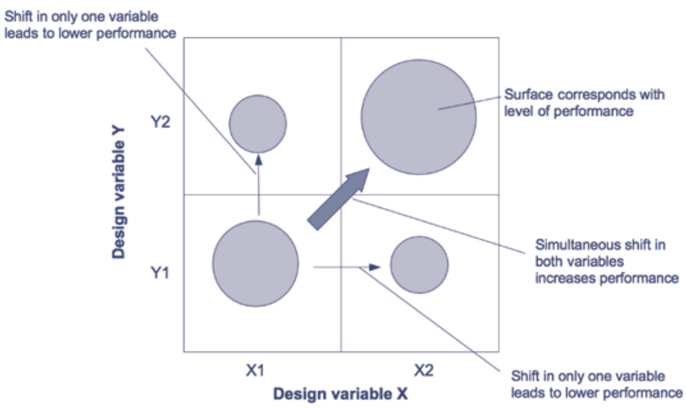

Figure III-3:
Two-dimensional representation of Figure III 2

1 *Womack et al. (1990)*
2 *Roberts (2004), p. 59*
3 *Milgrom, Roberts (1990)*
4 *Milgrom, Roberts (1992), p. 113*
5 *de Groote (1994), Milgrom, Roberts (1992), p. 112 ff*
6 *Barua et al. (1996), p. 413*

There are also several researchers in the operations management domain that promote concepts that are related to the basic idea of coherent patterns. For example, Shah and Ward[1] talk about bundles of interrelated and internally consistent manufacturing practices. They also recognize the role of contextual variables: Referring to Galbraith's information processing view[2], they state that "not all organizations can or should implement the same practices."[3]

The notion of "fit" is also common in management research. Contingency theory states that organizational structure needs to be aligned with variables such as technology, strategy, and the environment. The configurational perspective claims that some configurations of organizational variables are likely to occur together, and, in combination, lead to increased performance. In contrast to the contingency perspective, the focus is more on "internal fit" than "external fit" with the environment.[4] Porter also recognizes the importance of complementarities when talking about interconnected activity systems:[5] "A competitor seeking to match an activity system gains little by imitating only some activities and not matching the whole. Performance does not improve; it can decline."[6]

III.1.2 Value of information technology

The productivity paradox

Melville et al.[7] define IT business value as "the organizational performance impacts of information technology at both the intermediate level and the organization-wide level, and comprising both efficiency impacts and competitive impacts."
One outcome of the research on the business value of IT is the productivity paradox of information technology which says that although firms invest large sums in information technology, large-scale analysis often could not establish that these investments lead to increased performance. There are various explanations for this phenomenon, which include difficulties in measuring the effect of IT and measurement errors, time lags, redistribution of benefits, and mismanagement.[8]

Firm-level vs. process-level performance measures

Hitt and Brynjolffson[9] argue that the value of IT can be measured at different levels: It can be measured as changes in productivity (i.e. at the process level), in business profitability (i.e. at the company level) and in consumer surplus. Their analysis indicates that IT on aggregate has lead to increased productivity, but that it has not affected business profitability. Instead, consumers have benefited. Studies that focus on high-level financial measures such as profits or return on capital employed are therefore unlikely to lead to consistent results.

Business processes are likely to mediate the impact of information technology on performance.[10] As Wade and Hulland[11] conclude: "The strategic information technology research stream has found strong evidence for an indirect role for IT in firm performance. [...] Therefore, IS [information systems] researchers may find it particularly beneficial to use intermediate-level dependent variables at the business process, department, or project level."

1 *Shah, Ward (2003)*
2 *see e.g. Galbraith (1977)*
3 *Shah, Ward (2003), p. 131*
4 *Whittington, Pettigrew (2003), p. 126 ff*
5 *see ibid, p. 128*
6 *Porter (1996), p. 74*
7 *Melville et al. (2004), p. 287*
8 *Brynjolfsson (1993)*
9 *Hitt, Brynjolfsson (1996)*
10 *Barua et al. (1995), Clark, Hammond (1997)*
11 *Wade, Hulland (2004), p. 129 ff.*

IT as implementer and enabler

In his book on process innovation, Davenport[1] suggests making a distinction between the role of IT as implementer and as enabler. Often, processes already exist or are designed without detailed consideration of the technologies or systems that are available to realize the process. In these instances, IT (and other technologies and systems) are used as implementers. But IT can also allow companies to design new processes which only become possible because the technology offers certain capabilities. In these instances, IT is an enabler of process innovation. Figure III 4 schematically shows the difference in the role of IT as implementer and enabler.

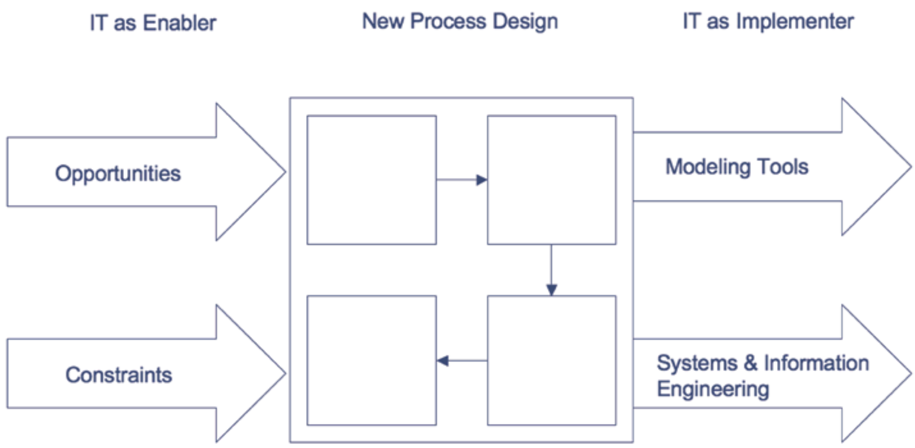

Figure III-4:
The role of IT in process innovation[2]

Whether a technology is used as implementer or enabler can affect the type of benefit that a company can expect to derive from it. Using IT as implementer is likely to lead to direct benefits, and using IT as enabler to indirect benefits at the process level. “Direct benefits are those that have a proximate and physically measurable link to the adoption of a technology. [...] Benefits from the adoption of a technology that alter the way business operations are conducted are considered indirect benefits. Adoption of the technology should be considered a necessary, but not sufficient requirement to achieving indirect benefits.”[3]

The introduction of EDI in the grocery industry can serve as an example to illustrate the differences between IT as enabler and implementer.[4] Retailers that rely on EDI as implementer, for instance, may use the technology to eliminate the manual transmission of orders via fax or mail. This can reduce order processing costs (e.g. the supplier does not have to manually enter the data into its information systems) and eliminate errors (e.g. the risk that the supplier enters the wrong quantity). Some retailers, however, have used EDI as enabler to redesign (or transform) their ordering process and have adopted VMI programs in which they have transferred the responsibility for managing inventory to their suppliers.

1 *Davenport (1993), p. 49 ff*
2 *adapted from Davenport (1993), p. 49*
3 *Weber, Kantamneni (2002), p. 312. There is a third type of benefits, strategic benefits, which is not considered here due to the focus on operational processes.*
4 *The following discussion draws on Clark and Stoddard (1996)*

Dimensions of IT business value

Some researchers have suggested that IT creates business value along three dimensions and leads to automational, informational, and transformational effects.[1] Automational effects enhance efficiency by substituting capital for labor. Informational effects lead to increased performance via improved capabilities to collect, store, process, and disseminate information which can lead to better decisions and higher quality. Transformational effects refer to the role of IT in facilitating process reengineering and redesigning organizational structures.[2] Dedrick et al. use barcode scanner technology in supermarkets as an example. The technology allows a cashier to process a transaction in less time (automational effect); the information that is gathered at the check-out can allow the store manager to better manage inventory (informational effect); and, ultimately, the technology may enable the company to redesign its supply chain (transformational effect).

Research on the value of IT and complementarity theory

Studies that use aggregated measures for IT usage and measure the impact of IT at the firm level often fail to provide an answer to the question of how IT affects performance. Mukhopadhyay et al.[3] observe in their study on the impact of optical character recognition and barcoding in mail sorting that "measurement of the IT impact at the application level [...] permits us to open up the 'black box' of IT usage[4] and examine how it may improve productivity and quality."

Detailed studies on how companies apply new technologies and practices can help to understand why some companies in an industry are able to improve business profitability, while others fail. This has lead researchers to closely examine the relevance of complementarities.[5] Brynjolfsson and Hitt[6] suggest that different research results "point to organizational complements such as new business processes, new skills and new organizational and industry structures as a major driver of the contribution of information technology."

Conceptual frameworks on the value of IT

Researchers have proposed several frameworks that conceptualize how IT can create business value. Melville et al.[7] derive an integrative model of IT business value based on a review of the existing literature. In their model, IT resources affect business processes which, in turn, affect business process performance. This relationship is influenced by the availability of complementary internal resources and the resources and business processes of trading partners. Industry characteristics can shape how companies apply IT and whether IT leads to improved organizational performance. For example, time-sensitive industries may benefit more from IT's ability to reduce cycle times than other industries. Furthermore, the reaction of competitors to the use of IT can differ due to, for example, differences in the degree of imitability. Country characteristics that can influence the attainment of IT business value include differences in basic infrastructure, regulatory and educational factors.

1 *Scott Morton (1991), p. 16 ff., Mooney et al. (1996), Dedrick et al. (2003)*
2 *Mooney et al. (1996)*
3 *Mukhopadhyay et al. (1997), p. 1657*
4 *Dedrick et al. (2003)*
5 *see e.g. Brynjolfsson, Hitt (2000), Melville et al. (2004)*
6 *Brynjolfsson, Hitt (2000), p. 45*
7 *Melville et al. (2004), p. 293*

Although they offer some insights, frameworks such as the one presented above are of limited value because they employ a very general concept of IT. Melville et al.'s definition of IT resources, for example, does not only include applications, but also IT infrastructure as well as technical and managerial skills. More useful for the purpose of this thesis are models that deal with the impact of specific technologies. In Davenport's model[1], an information technology initiative leads to a process change which, in turn, leads to an economic outcome. Such models, however, do not take the interrelationships between the technology and complementary technologies and practices into account. One example of such a model is presented by Clark and Stoddard[2] who examine the transformational impact of EDI on supply chain performance in the retail industry. They distinguish between direct and indirect benefits of EDI. Direct benefits result from the use of EDI in existing processes, whereas indirect benefits occur when trading partners use EDI to reengineer their business processes. Specifically, EDI enables them to implement a CRP process. They define this combination of process and technological innovation as transformational change which leads to improved supply chain performance. In fact, they see EDI and CRP as complementary, and simultaneous adoption of the two leads to much higher performance improvements than isolated adoption.

The complementary nature of IT and process changes was also recognized in a study of US labor productivity: "[IT] was often a necessary but not sufficient enabler of productivity gains. Business process changes were also necessary to reap the productivity benefits of inventory management, electronic data interchange, and scanning systems. The same was true in the case of wholesale distribution centers, where IT was necessary for exploiting the full potential of electromechanical material handling systems."[3]

What is lacking in these more specific models, however, is the recognition that not only complementarities, but also contextual factors influence the impact of IT. Mooney at al.[4] propose a model in which the organizational and competitive environment moderate the business value of IT. In their model, information technology affects operational and management processes which affect business value.

The models also differ in the level at which performance is measured. Whereas Davenport and Mooney et al. suggest measuring IT impact at the firm level, Clark and Hammond use process performance measures such as inventory and service levels.

III.2 Overview of the conceptual framework

This section presents a framework that can help to understand the impact of a new data capturing technology on process performance. The performance impact of the technology is mediated by the effect of the technology on business processes. This thesis distinguishes between three effects and incorporates the notion that complementarities and contextual factors can influence the outcome. The framework is depicted in Figure III 5. It takes many aspects of the models presented in the previous section into account. However, as the brief description already indicates, none of the models presented in the previous chapter captures all of the elements. Throughout the chapter, I use examples of applications of RFID technology in the FMCG supply chain to illustrate individual aspects of the framework.

In order to really understand the effect of a new data capturing technology, it is not sufficient to show a correlation between employing the technology and increased process performance. Instead, there is a need to understand how the inherent characteristics of the technology translate into increased performance – this means explaining the mechanisms that lead to certain outputs.[5] Therefore, the starting point for the examination of the impact of a new data capturing technology on process performance is an analysis of the capabilities of a new data capturing technology. These capabilities need to be considered in relation to the capabilities of an existing or competing technology. Depending on the application, the relevant capabilities may vary.

1 *Davenport (1993), p. 45*
2 *Clark, Stoddard (1996)*
3 *McKinsey Global Institute (2001), p. 4*
4 *Mooney et al. (1996), p. 75*
5 *Christensen, Raynor (2003)*

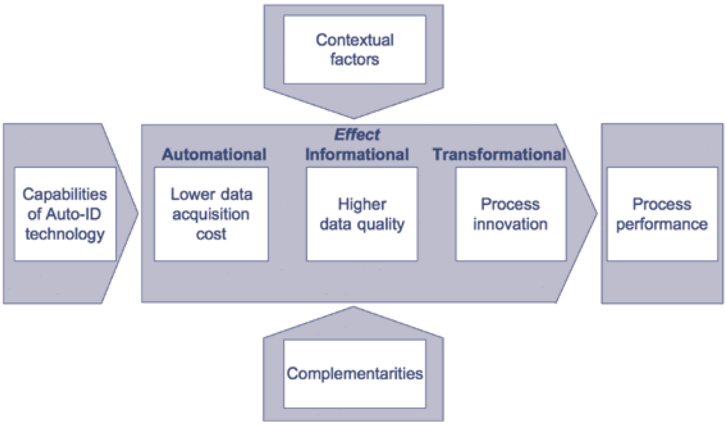

Figure III-5: Conceptual framework

The model suggests that a new data capturing technology can have an impact on processes in three different ways: It can lower the data capturing effort (automational effect), increase data quality (informational effect), and facilitate process innovations (transformational effect). Examples of RFID applications can illustrate the effects: RFID at the case level can eliminate the time for manually counting the number of cases on a pallet (automational effect), reduce the number of delivery errors (informational effect), and change the replenishment-from-the-backroom process (transformational effect).

The effects, however, do not occur under all circumstances, but are influenced by complementary and environmental factors. Depending on the presence or absence of these factors, the impact on process performance can vary. For example, the amount of time a retailer can save in the receiving process tends to be higher when the manufacturer ships mixed pallets instead of full pallets. For this application, the ratio of mixed to full pallets is a contextual factor. Additionally, a retailer that lacks certain complementarities or fails to invest in them may not be able to reap certain benefits. A retailer, for example, that does not yet have a store-level inventory management system or does not adapt its system so that it can distinguish between inventory on the shop floor and in the backroom could not implement the new backroom replenishment process.

A number of case studies conducted by Lindau and Lumsden[1] confirm that complementary investments can influence the value of barcodes or RFID. They examine the use of automatic data capturing systems in inventory management and find that the higher the technology content in each case, the better the results. Implicitly, this assumption is also prevalent in the work by Yao and Carlson[2] on the impact of real-time communication on inventory management. The authors describe the implementation of RFID in conjunction with the adoption of other technologies and practices, including warehouse management systems, EDI, and quick response.

III.3 Capabilities of Auto-ID technologies

McFarlane and Sheffi[3] define Auto-ID as the “automated extraction of the identity of an object.” According to AIM Global, an industry organization, automatic identification technologies support two common goals: They intend to eliminate errors in the identification and data collection process and reduce the time for data capturing.[4] One can argue that Auto-ID technologies (including human data entry), differ in the shape of the trade-off curves between the level of error and the time for data capturing (see Figure III 6 for an illustration). Advances in technology can, for example, lead to shifts in the curve to the upper right, allowing users to capture data faster, with fewer errors, or a combination of both.[5]

1 *Lindau, Lumsden (1999)*
2 *Yao, Carlson (1999)*
3 *McFarlane, Sheffi (2003), p. 3*
4 *www.aimglobal.org/technologies*
5 *The shape of the curves can vary and has been selected for illustration purposes only*

In order to effectively assess the potential of a new Auto-ID technology (i.e. to determine to what extent it leads to a shift in the trade-off curve), it is necessary to compare its capabilities with the capabilities of the technologies that are currently in use. In the FMCG industry, using barcodes is common, and, in a lot of applications, RFID effectively "competes" with the barcode. There are, however, areas in which barcode scanning is less common (e.g. mixed pallet picking). This means that, in these circumstances, RFID needs to be assessed against the capabilities of human data capturing.

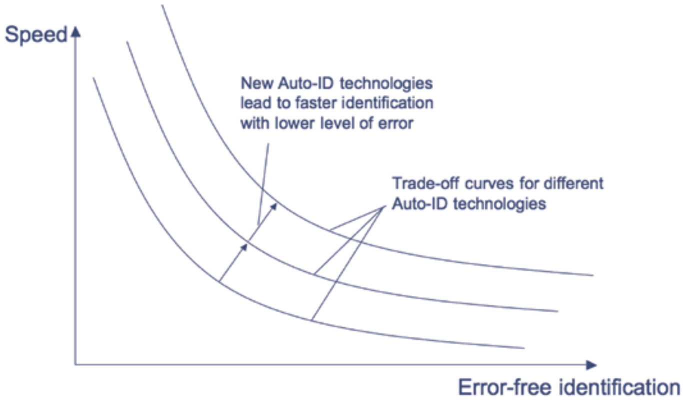

Figure III-6: Trade-off curves for different data identification technologies

Such comparisons will lead to a number of areas in which the new technology is superior to the existing ones. Compared to the barcode, for example, RFID can identify objects without line-of-sight at a high speed and offers the potential for bulk reading. However, these superior capabilities are not necessarily relevant in all applications: Whereas bulk reading is important in applications where several objects needs to be identified at once (e.g. identification of cases on a pallet), it is less relevant in others where objects are identified one at a time (e.g. identification of a single pallet that moves through the receiving gate).

III.4 Automational, informational and transformational effects

The framework distinguishes between three potential effects of Auto-ID technologies. The categories are not mutually exclusive. In some applications, introducing a new Auto-ID technology may both lower the variable cost of data acquisition (automational effect) and increase data quality (informational effect). Furthermore, a process innovation based on a new Auto-ID technology (transformational effect) may require higher-quality data than the previous process.

Before the individual effects are discussed in detail, the following section introduces the concept of data quality and discusses the relationship between data quality and the cost of data acquisition.

III.4.1 Data quality and the cost of data acquisition

Dimensions of data quality

Poor data quality can have far-reaching negative consequences for companies at an operational, tactical and strategic level.[1] There is a wide range of different data quality attributes, and often researchers choose data quality attributes intuitively. In contrast with these intuitive approaches, Wang and Strong[2] use an empirical approach to derive four data quality dimensions, each containing a number of attributes. They conceptualize data quality as "fitness for use" from a data consumer's perspective. The dimensions of data quality are: intrinsic data quality, contextual data quality, representational data quality, and accessibility data quality.

1 *Redman (1998)*
2 *Wang, Strong (1996)*

The capabilities of Auto-ID technologies lead to differences in identification speed and error rates (see chapter III.3). These differences are relevant in evaluating the performance of a technology in single events in which objects need to be identified. At the application level, however, the important measures are the cost of data acquisition and the level of data quality that different technologies provide. Data accuracy is only one attribute of data quality that a new Auto-ID technology can help to improve.

RFID technology in the FMCG supply chain, for example, can help to improve not only data accuracy, but also data objectivity (which belongs to the intrinsic data quality dimension) as well as timeliness and completeness of data (contextual data quality).[3]

- Data accuracy can be improved with RFID compared to barcodes, e.g. when objects that were previously not correctly identified at a certain stage in the supply chain can now be identified. For example, retailers may now be able to identify each case when it is picked and put on a mixed pallet. Previously, some picking errors were not detected. RFID can help to record any deviations between the physical content of the pallet and the picking list.[2]

- Data objectivity can be enhanced as the RFID tags are identified automatically without human intervention. This limits the possibilities for manual interventions and therefore can make the data more believable, e.g. when a retailer wants to prove to a manufacturer that certain products were not in a delivery.

- Timeliness can be enhanced as objects can be identified at the very moment when they pass a reader. For example, one retailer that took part in the research project reported that in some instances pallets in transit from the distribution center to the store are accidentally unloaded at a different store. As store personnel only count the number of pallets during the unloading process, but do not uniquely identify the pallets, the errors are not detected until the truck has departed. This time delay can lead to excess inventory at one store and potentially to out-of-stock situations at two stores. An identification of the pallets during the unloading process could eliminate these delivery errors.[3]

- Completeness refers to the depth, breadth and scope of available data. RFID can affect data completeness in different ways. First, it allows the tracking of objects at a lower level of aggregation. Whereas previously companies were only tracking production lots as the effort to keep track of every item was too great, companies can now in principle track each individual item through the supply chain. Second, it allows the tracking of the location of objects at a lower level of aggregation by introducing additional read points. Retailers, for example, can now realize a separation between back room inventory and shop floor inventory in their stores. Third, it can increase the ratio of objects for a given set of aggregation for which specific information is available. Companies may now, for example, be able to check every delivery for theft instead of conducting just random checks.

The data quality attributes are somewhat related. This is especially true for completeness of data. An increase in the completeness of data can, for example, lead to faster shelf replenishment from the backroom (timeliness) and a more precise picture of where products in the supply chain tend to disappear (accuracy).

The relevance of different data quality attributes varies by application. For example, timeliness of data can be critical for store replenishment processes. Store employees need to know on time which shelves they have to refill. It may be less critical in other situations, e.g. for invoicing as retailers do not usually pay for a delivery right at the moment when the products enter the distribution center or store.

1 *Fleisch et al. (2005) use a different classification to describe the impact of ubiquitous computing technologies on data quality. They distinguish between object granularity, time granularity, content, and location.*
2 *The following examples assume that there are no false positive or negative reads*
3 *It should be noted that RFID does not affect the time lag with which data is transferred after being acquired. This is an issue related to data distribution, not data acquisition.*

Data acquisition costs

A chart as shown in Figure III 7 can serve as the starting point for comparing the value of different Auto-ID technologies in specific applications. The chart depicts data quality on the x-axis and the cost of data acquisition on the y-axis. The costs of achieving a certain level of data quality vary according to the data capturing approach. Current approaches in the FMCG industry are often barcode-based. Therefore, the following considerations assume that a company needs to decide whether to continue using barcodes or invest in RFID technology.

There are certain fixed costs associated with using each data capturing approach. For example, RFID and barcode both require a certain reader infrastructure.[1] Another fixed cost component in the framework is the cost of the RFID tag and the barcode label. The latter costs are fixed in the sense that they do not vary with data quality. The fixed costs of RFID are higher than the fixed cost of barcodes due to higher reader and tag prices.

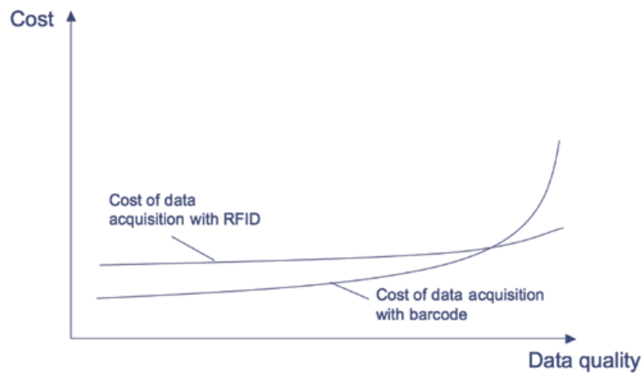

Figure III-7: Cost of data acquisition and data quality

The marginal cost of an increase in data quality is not constant, but increases for higher levels of data quality. This convex shape of the cost curve reflects the law of diminishing factor returns known from Economics[2] and is, for example, consistent with Spencer's[3] assumption in his paper on optimal data quality. The marginal cost for a given level of data quality is higher for barcodes than for RFID. In most applications[4], barcodes are scanned manually, and each scan causes labor cost.

RFID tags, on the other hand, can be read automatically at hardly any additional cost. The difference in marginal cost increases further at higher levels of data quality. Using barcodes, for example, allows retailers to keep track of their store inventory level. However, due to various factors[5], inventory data quality deteriorates over time until a physical inventory count is conducted that reconciles physical inventory and book inventory. Attempts to improve inventory data quality are relatively inexpensive if data quality is low. For example, retailers can educate their employees at the check-out counter to focus on correct product scans. This may substantially improve data quality, but there might still be a couple of scan errors. Removing these final errors can be rather expensive (e.g. by substantially slowing down the check-out process) or even be close to impossible. In contrast, as RFID does not require manual intervention, RFID at the item level could help to achieve high levels of data quality without substantially increasing marginal cost.

1 *When a company intends to increase data quality by introducing additional read points (i.e. increase completeness of data), the costs for the additional reader infrastructure are, of course, part of the variable cost*
2 *Samuelson and Nordhaus (1995), p. 112 ff*
3 *Spencer (1985)*
4 *Barcodes at both the case and pallet level are scanned automatically, for example, in some highly automated warehouses and distribution centers*
5 *see e.g. Raman (2000) and Fleisch, Tellkamp (2005)*

The precise shape of these (and also the following) curves may vary. Especially, in reality, the curves are likely to be discontinuous (see chapter III.1.1), i.e. a company cannot arbitrarily select a level of data quality. A company, for example, may achieve a picking accuracy of 99.5% in the current process that requires the picker to scan the picking location and manually input the number of cases that he has picked. If this level of picking accuracy is deemed too low, the company may switch to a process in which the picker has to scan the barcode on every case. This may instantly improve accuracy to 99.9%, but at significantly higher costs.

Cost benefit analysis: Data quality vs. data acquisition cost

Cost benefit analysis is one common approach to determine the optimal or needed data quality.[1] Researchers have, for example, developed decision theoretical models that examine under which conditions it is worthwhile to invest in more accurate information.[2]

The chart in Figure III 8 contains one cost curve and a second curve depicting the value that can be derived from a certain level of data quality (before taking the cost for data capturing into account). This curve can take on different shapes. In a number of instances, it may be concave. At higher levels of data quality, marginal increases in value are likely to be lower than at lower levels of data quality. This can be illustrated again with the example of inventory inaccuracy. Low levels of inventory inaccuracy (i.e. a high level of data quality for this data quality aspect) are unlikely to substantially affect product availability.[3] There is usually enough safety stock to compensate for small errors in inventory data. Furthermore, customers are likely to tolerate any out-of-stock situations and in most instances buy a different product.[4] However, with increasing levels of inaccuracy, product availability deteriorates. At some point, customers might become dissatisfied and abandon the store to shop elsewhere. Walter and Grabner[5] show, for example, that the likelihood that consumers switch stores or brands increases with repeated stock-out situations. In other instances, this curve is more or less a straight line. For instance, a retailer that does not detect shrinkage in its supply chain suffers the same loss for each stolen case, regardless of whether only one or several cases are stolen. The magnitude of the loss is not affected by data quality, when defined as the difference between intended delivery quantity and actual delivery quantity after the deduction of theft. (If the potential negative effect of theft on inventory accuracy, however, is taken into account, it can be argued that the curve for theft is strictly concave as well.)

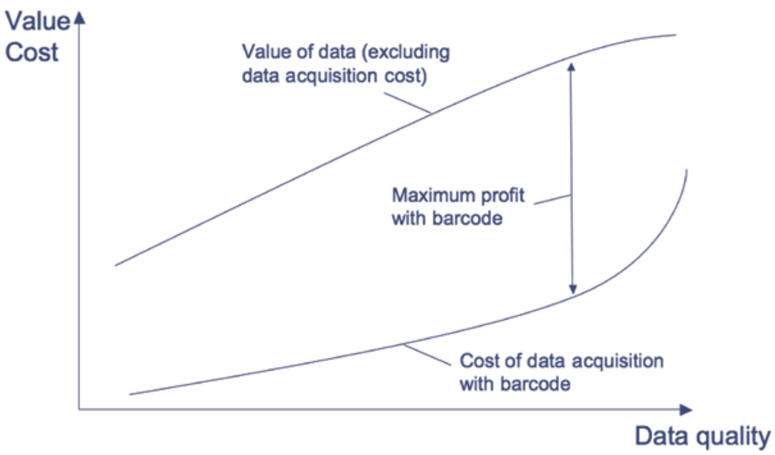

Figure III-8: Value of cost of data acquisition and data quality

1 *Spencer (1985)*
2 *see e.g. Raiffa (1968), p. 157 ff*
3 *see also chapter V.3. The mathematical model shows that product availability indeed falls more quickly at higher levels of inventory inaccuracy (i.e. lower levels of data quality).*
4 *see Gruen et al. (2002)*
5 *Walter, Grabner (1975)*

The optimum level of data quality is the point at which the marginal cost of data capture is equal to the marginal value. This is similar to models used in other areas of Economics (e.g. to determine optimal production quantities) or models used in operations management (e.g. to determine optimal order quantities).

Due to the increasing marginal cost of data acquisition (and – in many instances – falling marginal returns from higher data quality), companies may accept some inaccuracy, delay or incompleteness in their data. Researchers have recognized this trade-off between the cost for data acquisition and the value of the data: "The practitioners of effective SCM [supply chain management] always seek to achieve visibility in ways that balance the burden of data collection with the benefit of reacting in real time." There are, of course, situations in which companies try to achieve, for example, close to 100% accuracy as the marginal cost of inaccuracy is high compared to the marginal data acquisition cost. Furthermore, depending on the circumstances, some companies may require higher levels of data quality in their operations than others. Companies, for example, that operate in just-in-time (JIT) environments may place higher demands on data quality than their competitors with high inventory levels that can act as buffers. Such observations are consistent with some general theoretical findings. Decision theory, for example, offers some general rules concerning the optimal level of data quality: The more rudimentary the use of data, the lower the needed data quality, and the higher the negative consequences of low quality data, the higher the needed data quality.

III.4.2 Automational effect: Lower data capturing effort

One rationale for a company to invest in an automatic identification technology such as RFID is that it can lower data acquisition cost. The automational effect comes into play in situations in which data is already being captured. A new Auto-ID technology may lead to small gains in data quality (see Figure III 9), but this is not the primary focus of the application. An example is the use of Auto-ID technology in warehouse and DC operations. In the FMCG industry, a large number of companies apply logistics labels to pallets that contain an SSCC as unique identifier encoded as a barcode. The number provides a link to additional information on the pallet (e.g. its content) which is stored and processed electronically. Employees scan the barcode several times during the handling process in order to avoid mistakes and to verify that they have carried out certain tasks (e.g. that they have loaded a pallet on a truck).

As any errors in the process (e.g. mix-up of pallets, tasks that have not been carried out) are relatively expensive compared to the cost of scanning a barcode, the companies strive for nearly 100% correct identifications which is possible with today's barcode technology. An individual barcode scan is virtually error-proof (provided that the barcode can be read). The adoption of RFID would barely affect data accuracy or other attributes of data quality. The SSCC, for example, includes a check digit that can be used to check whether the number has been read accurately.
If the manual identification effort is sufficiently great, however, the technology may reduce the identification cost by eliminating the need for manual scanning.

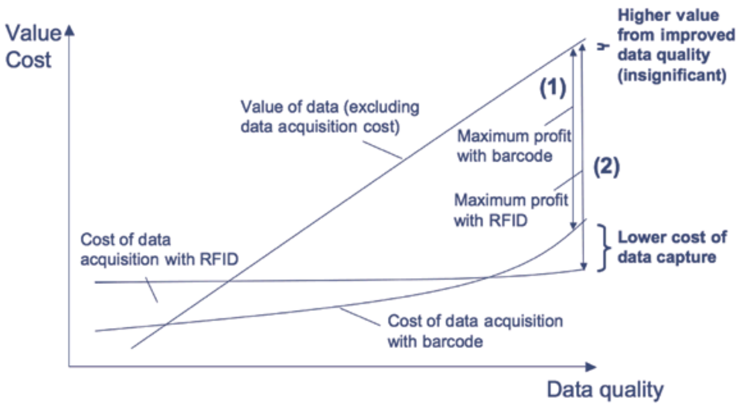

Figure III-9: Automational effect

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1 *Sengupta (2004), p. 46*
2 *Spencer (1985)*
3 *There are, of course, situations in which a barcode may not be readable, e.g. due to low printing quality or damaged labels. This is one of the reasons why the labels usually contain the unique identifier also in human readable form.*

Figure III 10 uses the two-dimensional representation introduced in chapter III.1.1 to illustrate the automational effect from the perspective of complementarity theory. A company can adjust two design variables: It can introduce a new data capturing technology (depicted on the x-axis), a new process (depicted on the y-axis), or both. This means that the design variables can be changed independently or simultaneously. The surface of the circle corresponds to optimal trade-off between the value of data and the cost of data capturing. Point 1 corresponds to the maximum profit achievable with barcode technology (see Figure III 9), point 2 the maximum profit with RFID technology. (For illustrative purposes, the differences in the surface of the circle between point 1 and 2 are larger than the differences in the optimum between the two points in Figure III 9.)

A company that automates data capturing simply substitutes one data capturing technology for the other in order to lower the data capturing cost. There are no further changes to the control system, and the process remains unchanged. Here, to speak in the terms of Davenport[1], a new Auto-ID technology such as RFID acts as an implementer for an already existing process (see also chapter III.1.2).

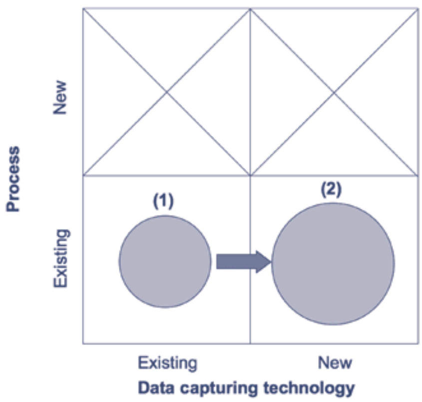

Figure III-10: New Auto-ID technologies as implementer

III.4.3 Informational effect: Higher data quality

An informational effect occurs if a new Auto-ID technology leads to an improvement in at least one data quality aspect which in turn leads to an increase in value (see Figure III 11). With the existing data capturing technology, this improvement would have been too costly to implement in order to be economically feasible. This does not mean, however, that the data capturing cost is necessarily lower than before. In some instances, the new technology may result in higher data capturing cost than was previously the case (although the cost is lower than it would have been with traditional technology given the same level of data quality). This reduces the net impact from higher data quality.

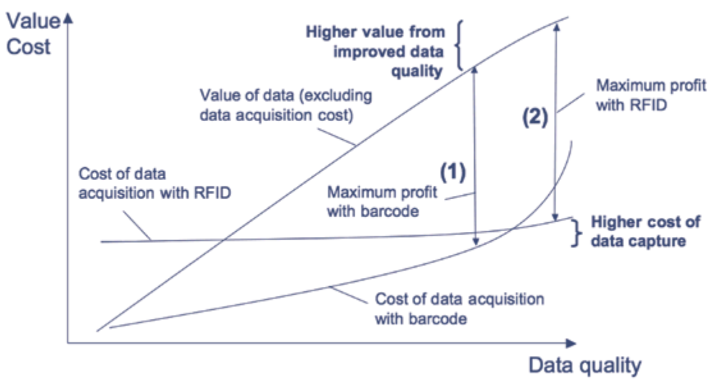

Figure III-11: Informational effect

1 *Davenport (1993)*

Companies need to trade off the cost of data capturing against the value of data, as mentioned before. In this context, it is useful to think in terms of quality costs. Quality costs consist of four categories: prevention cost, appraisal cost (i.e. inspection, testing, etc.), internal failure cost, and external costs.[1] A company that acts rationally will design its processes etc. so that it minimizes the total quality cost. A new Auto-ID technology with lower marginal data capturing cost can make it economically worthwhile for companies to focus more on prevention and thereby reduce appraisal, internal failure, and external failure costs. An increased focus on prevention in the context of Auto-ID technologies can mean that a company decides to spend more effort on identifying objects at distinct points in the supply chain in order to ensure that the right objects are at the right place.

An example of a process in which RFID at the case and pallet level can help to increase data quality is sales-based ordering systems in retail stores. These systems automatically determine order quantities based on the available inventory according to the store's inventory management system and forecasted demand. The systems rely on accurate data on incoming deliveries and from POS terminals. If inventory data is inaccurate, the system might order the wrong quantities. This can lead to stock-outs and excess inventory. Undetected delivery errors are one of the root causes of inventory inaccuracy. RFID can prevent delivery errors or at least allow store employees to detect these errors and thereby lead to more accurate inventory data (see also chapter IV.3).

Even though the discussion and a comparison of Figure III 9 and Figure III 11 show that there is a clear distinction between the informational effect and the automational effect, the new data capturing technology in both plays the role of implementer (see Figure III 10). As with the automational effect, decision rules and the underlying process do not change.

III.4.4 Transformational effect: Process innovation

A new Auto-ID technology can also make it economically feasible to realize new processes. This means that an increase in value does not result from the introduction of a new Auto-ID technology such as RFID alone, but from a simultaneous change in the process (see Figure III 12). As for the informational effect, a shift in the data capturing technology may (but does not necessarily) lead to higher data acquisition cost, but any additional costs are offset by an increase in value due to a transformation in the process control system.

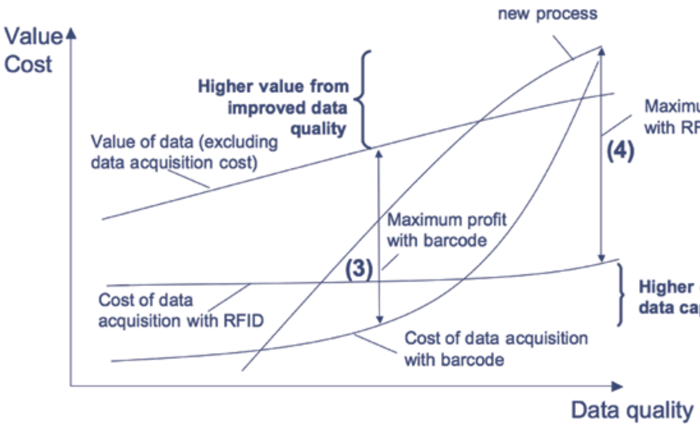

Figure III-12: Transformational effect

An example of a transformational effect of RFID is the replenishment-from-the-backroom process. With barcode technology, it is very costly to separate backroom from shop floor inventory when single cases are the relevant handling unit. RFID allows companies to record the movement of products between backroom and shop floor by reading the RFID tags on the case level at low marginal cost. This can lead to timelier shelf replenishment for products that are available in the backroom and hence increased product availability and higher sales (see also chapter IV.3 and V.4).

[1] *Heizer, Render (2004), p. 192, Garvin (1988), p. 79*

In a transformational effect, a new Auto-ID technology acts as the enabler of a process innovation (see Figure III 13). Enabling means that the implementation of the new process relies on the capabilities of the technology.

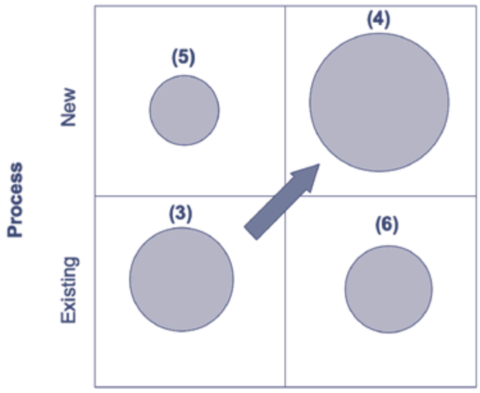

Figure III-13:
New Auto-ID technologies as enabler

As Figure III 14 shows, implementing the new process without investing in a new data capturing technology would lead to lower performance compared to the current situation. The potential profit that is achievable with barcode technology is lower than the profit in the current process. Also, in this example, simply exchanging the data capturing technology would lead to a net loss, although data quality would increase. The additional value that the company derives from higher data quality does not offset the additional fixed costs (e.g. investment in reader infrastructure) associated with the technology. It is, however, also possible that an investment in a new data capturing technology pays off without changing the process. In such instances, a company can take a phased approach without deterioration in performance: It can first replace the existing Auto-ID technology, which already leads to an improvement in performance, and, at a later stage, adapt the process in order to realize the entire value. In this situation, an Auto-ID technology such as RFID is both implementer and enabler.

The two-dimensional representation in Figure III 13 in which an Auto-ID technology acts as an enabler of process innovations bears similarities to a model presented by Clark and Stoddard.[1] The authors examine the relationship between technological and process innovation. Specifically, they look at the introduction of EDI and CRP and conclude that “process innovation and technological innovation can and do occur independently but that, combined, they enable much greater performance benefits for the channel.”

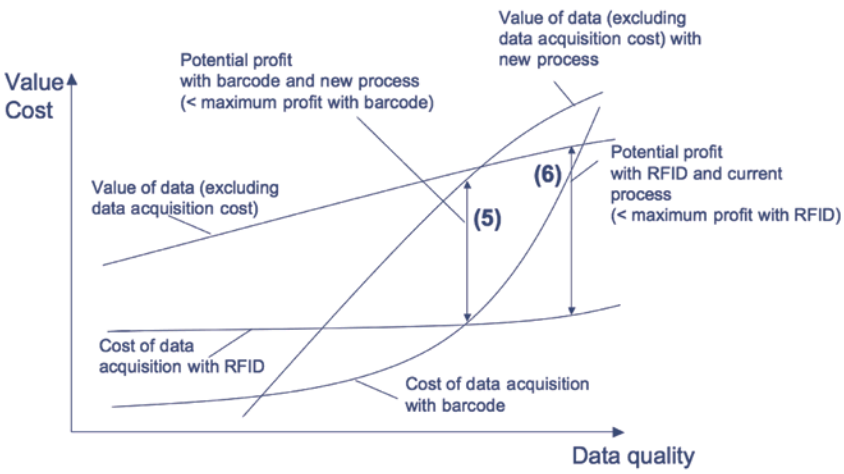

Figure III-14:
Changing only the process or the data capturing technology lowers performance

[1] *Clark, Stoddard (1996), p. 25*

III.5 Complementarities

Auto-ID technologies, process innovation, and complementarities

So far, it has not been discussed what actually constitutes a process innovation. The term becomes clearer when one thinks about Auto-ID technologies as one element of process control systems. In the context of this thesis, a process innovation enabled by Auto-ID technology requires a change in at least one element of the control system in addition to the change in the data capturing technology, and the change must not be economically feasible without the new data capturing technology. (Otherwise, RFID or any other data capturing technology would not be required as enabler.) The additional investments in changing the process control system constitute investments in complementarities.

The importance of information technology, in general, for control systems has been recognized for a long time.[1] Specifically for new data capturing technologies, Fleisch and Dierkes talk about digital management control loops.[2] They argue that sensors will become inexpensive and ubiquitous and – in combination with new actuators – help to improve existing and realize new closed-loop feedback control systems. The underlying assumption is that the goal of information technology is "sinnhafte Vollautomatisierung"[3] of both process control and the processes themselves.

Control systems

A control system consists of at least four elements:[4]

- A detector or sensor, a device that measures what is actually happening in the situation that is to be controlled.
- An assessor, which is a device that evaluates the significance of what is happening and determines a suitable action. Usually, this is done by comparing the information on what is actually happening with some predetermined standard or expectation of the desired state.
- An effector, which is a device that alters behavior according to the assessor's decision.
- A communication network for transmitting information between the detector and the assessor and between the assessor and the effector.

These general elements of a control system can be found both in organizations and in technical systems (e.g. thermostats). In organizations, Anthony et al. distinguish between management control systems used in managerial processes and task control systems used in operational processes. They define management control as "the process by which managers influence other members of an organization to implement the organization's strategies"[5], and task control as "the process of assuring that specified tasks are carried out effectively and efficiently"[6]. Many task control systems are scientific, which means that the relationships between cause and effect and the actions required when specific situations occur are known within acceptable limits. For some of these tasks, it is less expensive and more accurate to let machines control the task instead of human beings. In order to achieve full automation, it is necessary to automate all elements of a control system.

1 *Bruns, McFarlan (1987)*
2 *Fleisch, Dierkes (2003)*
3 *Mertens (1995), p. 48*
4 *Anthony et al. (1992), p. 4. This is just one possible classification. Other authors distinguish different elements. Beer (1988), p. 28 ff. and p. 39 ff., for example, identifies three fundamental components of a control system: the input setup (consisting of a receptor and a transmission channel), the output setup (consisting of a receptor and a transmission channel), and the network that connects these two systems and is responsible for decision-taking.*
5 *ibid, p. 10*
6 *ibid, p. 15*

Management control processes differ from scientific control systems in five ways:[1]

- The standard or expected performance is not preset, but the result of a conscious planning process.
- Management control is not automatic. Although some information can be gathered, transferred and evaluated automatically, the manager is usually involved at least partly in each of the elements. Specifically, she decides on whether any deviations between desired and actual state require action, and which action to take.
- Management control involves coordination of individuals.
- There are no clear rules how a manager should (and will) act in a given situation, and how the organization will respond to the manager's action.
- Control in organizations is not always exercised by external control devices or managers, but by self control of individuals.

Figure III 15 shows a conceptual model of an Auto-ID control system. (For an alternative conceptual model of a control system that specifically addresses Auto-ID technology, see McFarlane et al.[2].)

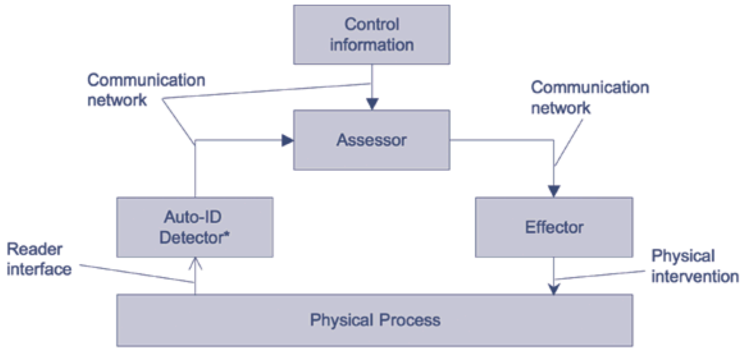

Figure III-15: Auto-ID control system

The role of an Auto-ID technology in task control is to capture data as input for decision-making (e.g. when retailers scan barcodes at the POS and use the data in their replenishment systems) or to control the proper execution of a process. The latter need for control of operational processes arises from disturbances in the real world that are not reflected in the realm of information systems.[3] For example, if the quality of logistics processes were perfect, there would be no need for a tracking & tracing system to record the physical flow of products (although such a system might still be worthwhile, not least to gather data that allows the company to check whether process quality remains perfect).[4] The role of Auto-ID technology in management control is to deliver data that can be used to adapt the process itself and to evaluate its design in a wider context. High-quality information on processes is an important element in improving a process (performance loop)[5] and in examining its relevance to the environment (relevance loop). The data may help a company to become aware of certain phenomena that it did not recognize before, or to measure a phenomenon that before it was only aware of.[6] As Simon Langford[7] from Wal-Mart states: "That's were the real value of RFID comes into play, in identifying specific pain points so your supply chain can function more effectively."

1 *ibid, p. 6 ff.*
2 *McFarlane et al. (2003)*
3 *see e.g. Fleisch, Dierkes (2003)*
4 *Stefansson, Tilanus (2000)*
5 *Davenport, Beers (1995)*
6 *Bohn (1994)*
7 *Bohn (1994)*

Full automation of control systems and the underlying processes may not be realizable (or profitable) in all instances. (This is precisely why Mertens[1] uses the qualifier "sinnhafte" (or reasonable) full automation.) A new Auto-ID technology may automate (or improve the automation of) data collection, and the data is communicated automatically, but there is no automation of the assessor or the effector element of the control system. This is especially true in management control systems. Automated decision making is easier to achieve in task control systems, as already mentioned, but physical execution often still requires human intervention. For example, fully automated warehouses and DCs are still rare so that a lot of the physical movement of products is still done by humans, even when data capturing is automated. To an even greater extent, this is true in store operations.

What constrains performance? – The example of SCEM

The term supply chain event management (SCEM) is frequently mentioned in articles about RFID applications in the supply chain.[2] An SCEM system constitutes an example of a task control system that interacts with the physical world. Otto[3] de-fines SCEM as "a management concept that helps managers to implement reliable inter-organizational processes, despite acting in an environment prone to disturbances." In contrast to a supply chain planning system, the aim of an SCEM system is not to re-plan and generate an optimal solution, but to generate a fast, rule-based response to an event that occurs in the actual execution of a process in order to minimize the gap between actual and intended result. Events are milestones in a process for which status reports are expected and are generated by detectors (e.g. Auto-ID detectors) placed at specific points in the process.[4] For example, an SCEM system may receive the message that a reader at the receiving gate of a DC has identified a pallet. The SCEM then checks whether the pallet has arrived at the right place at the right time by comparing the reader date with the information contained in the electronic dispatch advice. If the data match, the SCEM initiates the update of the inventory management system. In case of discrepancies, the SCEM system may additionally generate an alert.

The crucial point when discussing the role of Auto-ID technology in this context is to determine what element of the SCEM system constrains the system's performance. Missing and inaccurate data currently is a major constraint in tracking & tracing systems.[5] But would higher data quality automatically lead to better performance in inter-organizational supply chain processes? This view is supported by McFarlane and Sheffi[6] who regard low data availability and quality as a main constraint for supply chain event management systems. This judgment, however, contrasts with the empirical findings of Stefansson and Tilanus[7], based on the results of several case studies. They found that most current systems are rather unsophisticated and simply record data, i.e. act as passive tracking & tracing systems. Missing are even basic capabilities that would enable the system to generate alerts in case of problems in the execution of a process, let alone decision-making capabilities.

For a company that uses a passive tracking & tracing system, RFID may reduce the cost of data acquisition (automational effect). If the tracking & tracing data, however, is not used in process control, the company may not benefit from any informational effects. Furthermore, the company is likely to lack the prerequisites to realize any transformational effects. A first step towards improving these systems could be to provide them with planning and object-specific data (i.e. control information). This would allow the systems to detect deviations, e.g. delays in the execution of a task. A second step could then involve implementing rules that generate alerts in case of deviations or even decide on how to proceed in case of certain deviations, i.e. investing in the capabilities of the assessor. Only after the company has invested in these complementarities, it may benefit from the capabilities of RFID.

1 *ibid*
2 *see e.g. Datta (2003) and Fleisch et al. (2005)*
3 *Otto (2003), p. 4*
4 *Otto (2003)*
5 *Bretzke et al. (2002), p. 32*
6 *McFarlane, Sheffi (2003)*
7 *Stefansson, Tilanus (2000)*

III.6 Contextual factors

No single best way to manage operations

Contextual factors can influence the relationship between the independent variables (e.g. a new technology or practice) and the dependent variables (e.g. the change in process performance). This means that best practices are not necessarily applicable to all companies and industries, and that there might not be a single best way to manage a company. Lee[1], for example, describes how uncertainty affects the selection of the appropriate supply chain strategy. Companies that face high demand and supply uncertainties (e.g. in the semiconductor industry) may need agile supply chains, where efficient supply chains are favorable for the grocery and food industry.

There is also a variety of other factors apart from uncertainty, but these factors can vary considerably. There is no consistent set of contextual factors available that can be applied to a study of the impact of Auto-ID technologies. In their examination on the performance impact of quick response in specialty retailing, Palmer and Markus[2], for example, mention organizational size, firm ownership, product mix, centralization, vertical integration, and IT investment as some of the most common variables.

Contextual factors in the retail industry

In their analysis of retail margins in different countries, Burt and Sparks[3] identify various factors that can explain differences in performance. One example is the cost structure that companies face. Factors that affect the cost structure of retailers include retail buying power, distribution strategy, personnel costs, as well as land and property costs. Additionally, management and control structures can affect performance. For example, tight operational control and strong conformance requirements can foster so called economies of replication. Furthermore, the type and number of store formats, location of stores, as well as product range can influence performance. In general, logistics costs are lower if a retailer has to support only one store format, if stores are large and out-of-town, and if they carry only a limited number of SKUs. In addition, retailers that invest in technologies such as barcodes and EDI may have lower logistics cost than competitors. Another factor that can affect cost is retailer-supplier relationship: If manufacturers and retailers coordinate their activities, they can eliminate inefficiencies from the supply chain. Finally, legislation may also affect performance. In some countries, for example, it is difficult for companies to open large stores.

Differences in efficiency between supply chains

Differences in efficiency between countries can have profound impact on the potential benefits of new practices. A frequently cited example is ECR: A study by Kurt Salmon Associates[4] in 1993 estimated that ECR implementation could reduce throughput times in the dry grocery supply chain from an average of 104 days to 61 days in the USA. For Europe, GEA[5] conducted a study for the Coca-Cola Retailing Research Group Europe, using a similar approach. The study found that inventories for grocery products where much lower than the 61 days given as end-point for the US with full-scale ECR implementation, although – except for the UK – the European retail industry had not yet adopted ECR principles to any great extent. Inventory in the supply chain differed between European countries from 28 days in the UK to 46 days in Germany. Referring to the Kurt Salmon study and a report on supply chain cost in the US by Mercer Management Consulting, Fernie[6] remarks: “Much of what is contained in these reports on the US scene will not appear to be particularly innovative to the UK grocery retail sector.”

1 *Lee (2002)*
2 *Palmer, Markus (2000)*
3 *Burt, Sparks (1997)*
4 *KSA (1993)*
5 *Walker (1994)*
6 *Fernie (1994), p. 41*

In the US, Kurt Salmon estimated that ECR could save companies 10.8% of sales. This figure was larger than the total grocery supply chain cost in Europe (which vary between 9% and 10% of sales) as estimated by the GEA report around the same time. According to the latter report, ECR is estimated to offer a cost saving potential for the entire supply chain of between roughly 2.5% for Italy and Germany and 1.5% for the UK.
The example of inventory to sales shows that there are not only large differences between countries, but also between companies within one country: Whereas inventory turned approximately 13x per year for the average grocery retailer in the UK in 1992, the figure for Tesco was close to 30x, with other large UK grocery retailers not far behind.[1] In the US, inventory turns in supermarkets are estimated at 13x.[2] Other estimates are even lower: Bernstein Research[3] estimates that, in 2008, Wal-Mart reaches an inventory turnover of 9x and Target of 6.5x. With RFID, the figures may increase to 10x and 7.5x, respectively.
Individual efforts at one company can also affect what can be achieved with subsequent initiatives. Duffy[4] describes how Gillette redesigned its supply chain operations in 2002/2003. The redesign effort has eliminated several inefficiencies in the supply chain and lead to increased fill rates and reduced inventories.

III.7 Process performance

Process performance vs. firm-level performance measures

Chapter III.1.2 has argued that it is difficult to establish a relationship between investments in information technology and firm-level performance. The conceptual framework therefore only considers process performance measures to study the impact of Auto-ID technology. Hitt and Brynjolfsson[5] have shown that IT can improve productivity without leading to superior performance as any productivity gains are competed away. It may well be that RFID becomes essential in tomorrow's retail supply chain, but is a commodity which rather constitutes a strategic necessity[6] than a source for differentiation. As Carr[7] points out: "Commodities can be essential to business without being essential to strategy."

Recent research by Kulp et al.[8] ndicates that, for example, the competitive advantage that companies can derive from EDI is diminishing. They see this phenomenon as an indicator for an evolutionary process of supply chain integration: "Information sharing may have given companies a competitive advantage in the early- to mid-1990s, which constituted a first step in supply chain integration. Additionally, such information sharing still provides some initial benefits; it allows firms to remain competitive but may not be sufficient to excel and achieve supranormal margins. Working as partners, rather than simply transferring information between the parties, leads to the greatest benefits." Power and Simon[9] also generate ambiguous results for the impact of EAN product numbers and barcodes on products on firm-level performance measures, compared to a positive relationship between other enabling technologies such as EDI, SSCCs and logistics labels. They do not regard these results as unexpected, "given that all respondents would be at least using barcodes to some degree."

Process performance metrics

It is almost impossible to measure process performance in a single metric, and there is an abundance of performance indicators. Even if one only looks specifically at supply chain performance, there is no generally agreed set of metrics. The SCOR model provides an overview of relevant performance measures at different levels.[10] The Global ECR Scorecard is an example of a set of supply chain key performance indicators (KPIs) that are primarily targeted at the FMCG industry.

1 *Data from IGD Research Services, presented in Fernie (1994)*
2 *www.fmi.org. This figure excludes inventory in DCs which is likely to be one of the reasons why the figure is higher than the number of inventory turns for Wal-Mart.*
3 *Bernstein (2004)*
4 *Duffy (2004)*
5 *Hitt, Brynjolfsson (1996)*
6 *Clemons, Row (1991)*
7 *Carr (2003), p. 112*
8 *Kulp et al. (2004), p. 443*
9 *Power, Simon (2004), p. 571*
10 *Supply Chain Council (2000)*

In order to ensure a focus on supply chain performance, it is important that companies employ supply chain-wide metrics rather than local measures. Otherwise, there is a risk that every company in the supply chain focuses only on its internal operations and ignores potentially adverse effects on its supply chain partners (see also chapter II.2).

Beamon[1] distinguishes between two types of supply chain performance measures: first, qualitative supply chain performance measures, i.e. those measures for which there is no single direct measurement (such as customer satisfaction, flexibility, or supplier performance), and second, quantitative supply chain measures which are either based directly on cost or on some sort of customer responsiveness (e.g. fill rate).

The performance measures examined in this thesis belong to the category of quantitative performance measures. This thesis focuses on the impact of RFID on process performance which is often measured in non-monetary terms. Such non-monetary measures can be used to closely monitor and evaluate the actual process. As they often measure performance at a lower level of aggregation than monetary measures, they can be more useful when defining specific areas for improvement. Ultimately, however, potential improvements from RFID need to be quantified in order to compare the potential value with the cost of achieving the improvements.

Valuation challenges

In the end, a company is unlikely to invest in a new technology or a new process if the associated costs exceed the benefits that result from changes in non-monetary performance measures. While this approach is intuitively clear, it can be difficult to follow in the practical world as monetary quantification can be difficult. Companies are more likely to invest in areas that offer tangible benefits. Automational effects, in general, offer highly tangible benefits[2], but quantification of informational and transformational changes is often less straightforward because the benefits of these effects can be highly intangible. Failure to capture intangible benefits is sometimes made responsible for short-term orientation and inability to proceed with potentially valuable projects.[3]

Another complication is that companies need to take into account that there may be significant time lags before companies can reap the benefits of an investment in new technology as it may take them several years to implement the technology and make the necessary complementary investments. Furthermore, companies are likely to move down the learning curve and subsequently discover how to best apply the technology: “According to models of learning-by-using, the optimal investment strategy sets short-term marginal costs greater than short-term marginal benefits. [...] If only short-term costs and benefits are measured, then it might appear that the investment was inefficient.”[4] (As chapter III.8 on the barcode will show, there are in fact large differences between the initial assessment of the cost and benefits of the barcode and a re-evaluation 25 years later.) Finally, some of the benefits are uncertain at the time when a company makes an initial decision to invest, which may make it worthwhile to evaluate the investment from a real options perspective.[5]

Selection of process performance measure and the value of Auto-ID technologies

The selection of the process performance measure can influence whether or not a new data capturing technology is assumed to increase supply chain performance. This can be illustrated with the example of manual counting in the receiving process: A non-monetary performance indicator that directly measures the task, e.g. the time for counting a pallet, is likely to show an improvement. A more aggregated (monetary or non-monetary) performance measure, e.g. the total time spent in the receiving process, might not show an improvement as the gains in the execution of one task may not reduce the total effort, but simply increase organizational slack.[6] Finally, a monetary performance measure that recognizes both inputs and outputs might fail to show an improvement when the cost of the new process (e.g. the cost for RFID tags) outweighs the benefits (e.g. a reduction in the time spent in the receiving process).

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1 *Beamon (1998)*
2 *The terms direct and indirect benefits are often used synonymously with the terms tangible and intangible benefits*
3 *Toraskar, Joglekar (1993), Whiting et al. (1996)*
4 *Brynjolfsson (1993), p. 75*
5 *Amran, Kulatilaka (1999)*
6 *Brynjolfsson (1993)*

III.8 Impact of the barcode on the FMCG industry

The previous sections have dealt with the individual components of the conceptual framework. The following section describes the adoption of the barcode and its impact. The few available publications indicate, consistent with the conceptual framework, that

- companies have used the barcode both as implementer and as enabler of new processes;
- complementary investments and contextual factors have influenced the value of the barcode;
- the barcode has a measurable impact at the process level.

Adoption of the barcode in the retail industry

The initial impetus that led to the barcode as used today came from the US grocery industry. The first meeting of the Ad Hoc Committee on a Uniform Grocery Product Code took place in August 1970. The committee agreed on the format of a universal product code in 1971. However, the question of the symbolic representation was more difficult to resolve. The Symbol Selection Committee decided on a symbol in 1973. The first store to be equipped with barcode scanners at the check-out opened on June 26, 1974.[1] In Europe, manufacturers and distributors from 12 countries formed an Ad-Hoc Council in 1974, and the EAN association itself was founded in 1977.[2] The initial focus for the development of barcodes was the product level. Identification standards for logistic units did not become available until 1989.[3]

Barcodes on SKUs are now ubiquitous in large parts of the FMCG industry. However, adoption of barcode technology took several years. In the US, for example, at the end of the 1976, 77% of products sold in grocery stores contained a barcode[4], but in 1978, less than 1% of stores were using barcode scanners at the check-out[5]. Other sectors of the retail industry were slower in adopting the barcode. In a study of the apparel industry in 1992, only slightly more than 60% of apparel manufacturers reported that they applied barcodes at the item level, up from 22% in 1988.[6]

In contrast to these figures, diffusion of barcodes at the pallet level is still relatively low. A survey of manufacturers and retailers in the consumer goods industry in the German-speaking countries (Germany, Austria, and Switzerland) in 2002 revealed that only 52% of manufacturers and 19% of retailers use SSCCs in combination with EAN.UCC-128 labels[7].

The barcode as implementer and enabler

A study conducted by PwC[8] in the late-1990s distinguished between direct and indirect benefits of the barcode. It classified benefits such as faster check-outs, reduced check-out errors / loss prevention, and the elimination of price marking as direct savings. It can be argued that, in order to realize these direct benefits, the companies essentially used the barcode as an implementer for already existing processes, and that the savings result from automational effects (check-out efficiency, price marking) and to a limited extent from informational effects (check-out errors / loss prevention).

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1 *Brown (1997), p. 103*
2 *www.ean-int.org/history.html*
3 *Brown (1997), p. 229*
4 *Brown (1997), p. 111*
5 *Nelson (2001)*
6 *Abernathy et al. (1995)*
7 *CCG (2003b)*
8 *PwC (2001)*

Benefits classified as indirect savings include automatic reorder, shrink control, improved warehouse operations, improved DSD control, as well as inventory reduction and sales increases. With the exception of improved warehouse operations, which may include some automational effects, the savings mainly seem to result from process innovations (transformational effects) which were enabled by the barcode. Without the barcode, for example, it would be be almost impossible in most settings to generate sales data at the level of individual SKUs in order to implement automatic replenishment systems in retailing. Another example is automated sorting systems in distribution centers[1] which are used, among others, by Wal-Mart.[2]
Tibbett & Britten, for example, operates a distribution center for Wal-Mart in Canada in which an automated sorting system routes cases directly from the trailer at the receiving gate to the trailer at the shipping gate without any intermediate storage. This system requires barcodes at the case level and fixed readers that automatically identify the case on the conveyor.[3]

While other technologies, especially EDI, have played an important role as enabler as well, the impact of the barcode should not be underestimated: In their work on lean retailing principles in the apparel industry, Abernathy et al.[4] conclude: "Without such a low cost and accurate method to identify products at the checkout counter – and the reduction in the cost of scanning technologies that allow bar codes to be read – lean retailing would not be possible." Or, as Keh[5] states in his review of technological innovations in grocery retailing: "Possibly the most influential technology that has affected grocery retailing is the scanner system." Similarly, Clemons and Row[6] argue: "The introduction of scanner systems into the retail grocery trade has had far-reaching consequences throughout the industry. The information generated by these systems has altered the way grocers manage their business and dealings with manufacturers and is creating new mechanisms for product promotion."

Complementarities and contextual factors

For many practices in the retail industry, it is difficult to establish an unambiguous causal relationship between the barcode and the resulting change.[7] This reason for this is that companies need to invest in complementarities before they can realize the full potential of the barcode. Dunlop and Rivkin[8] ask rethorically: "How much of the change [...] should we credit to the Universal Product Code alone?" Apart from adopting other technologies, companies also had to make significant complementary investments in, for example, their distributions systems, and adapt their processes: "Through a combined use of product numbering, barcoding and EDI organisations have available the means to enable specific supply chain management practices such as quick response, cross docking, use of advance shipment notification (ASN), and vendor management of inventories."[9]

Contextual factors can also influence the value of the barcode, as some isolated examples suggest. The German hard discounter Aldi, for example, has been a late adopter of barcode technology. While there is no official information available on why the company finally introduced barcodes and scan-based check-outs, the fact that the company only sells around 600 to 700 SKUs might have played a role. Before barcodes were introduced, Aldi Nord had been using four-digit price look up-codes which check-out personnel had memorized to identify an SKU. The approach was very efficient, eliminated price marking and allowed the company to change prices without the need to retrain check-out personnel.[10] In principle, the POS terminals gathered SKU-specific sales data which, in principle, could have been used to implement an automatic store ordering system.

1 *Dunlop, Rivkin (1997)*
2 *Russel, Meller (2003)*
3 *www.tibbett-britten.com/cs/walm-can.php*
4 *Abernathy et al. (2000), p. 9*
5 *Keh (1998), p. 202*
6 *Clemons, Row (1991), p. 279*
7 *ibid*
8 *Dunlop, Rivkin (1998), p. 17*
9 *Power, Simon (2004), p. 567*
10 *Lebensmittel Zeitung (2000b)*

In specific circumstances, companies may also be able to implement cross docking without using barcode and other technologies, as Apte and Viswanathan[1] describe: "Information technology is not a prerequisite for implementing cross docking. For instance, full pallets and pre-sorted pallets may be cross docked with minimal visual control and without any elaborate systems or procedures. Also, when the number of items and number of outbound destinations handled by the warehouse are low, simple manual procedures are sufficient to implement cross docking. However, for large throughput rates and for cross docking of small packages and cases, information technology along with proper systems and procedures are essential."

The structure of the distribution system can also influence the value of barcode and other complementary practices. ECR Europe[2], for example, has published a report that examines the operational impact of unit load identification and tracking from factory to the store. The main practices considered are the use of SSCCs on logistics units, GTINs on transport units, and ASNs. The report estimates an average savings potential in handling cost of 2.65 Euro per pallet which amounts to a reduction of 35% compared to a manual receiving process without EAN.UCC-128 and DESADV.[3] The potential savings, however, drop to 1.50 Euro in those instances where the manufacturer makes direct-store deliveries of full pallets.[4]

Operational impact of the barcode

There is limited empirical evidence that tries to quantify the financial impact of barcoding. The results of a PwC[5] report suggest that the savings have been significant. The consulting company estimates that the direct and indirect effects of the barcode have lead to net savings of 5.64% of sales in the US grocery industry for 1997 (see Table III 1).

The PwC report used a similar methodology as a McKinsey study for the Uniform Code Council almost 25 years earlier. A comparison of the data shows an interesting fact: Whereas the estimate of hard (or direct) benefits as a percentage of sales remained relatively stable over time, the estimated soft (or indirect) benefits increased twelvefold. Furthermore, the estimates regarding the cost for barcode technology halved. Overall, the estimated net benefits as a percentage of sales were six times the initial figure.

Table III-1: Estimated benefits of the barcode 1975 and 1997[6]

	Savings as % of sales		
	1975	1997	Factor
Hard benefits*	3.13	3.45	1.1 x
Soft benefits**	0.29	3.44	12 x
Cost	2.50	1.25	0.5 x
Net benefit	0.92	5.64	6 x

* Main benefits: Faster check-outs, reduced check-out errors / loss prevention, elimination of price marking
** Main benefits: Automatic reorder, shrink control, improved warehouse operations, improved DSD control; inventory reduction and sales increase

1 *Apte, Viswanathan (2000), p. 299*
2 *ECR Europe (2000)*
3 *ECR Europe (2000), p. 52*
4 *ECR Europe (2000), p. 49, figure 20, and p. 50, figure 22. The value can be calculated by comparing the cost for DSD in the two figures.*
5 *PwC (2001)*
6 *own calculations, based on PwC (2001), exhibit 8*

A broader perspective: Auto-ID technology, competitive advantage, and industry structure

While the savings sound impressive, they have, from an industry perspective, not affected the profitability of the grocery industry. As Haberman[1] points out, most of the savings have been passed on to consumers, while "the grocery industry is still earning the same 1 percent to 1.25 percent on sales." This statement is consistent with research findings by Hitt and Brynjolfsson[2] who conclude that "there is no inherent contradiction between increased productivity, increased consumer value, and unchanged business profitability."

Although the potential operational benefits that companies can realize from investing in the technology and complementarities may increase over time. However, while the operational benefits may rise, the bottom-line impact is likely to decline over time as more and more companies adopt the technology. This development is shown schematically in Figure III 16: Although the total value as the sum of consumer value and business profitability from an Auto-ID technology rises, the value to companies declines over time, and consumers increasingly benefit from the technology through lower prices and improved service. With the introduction of a new Auto-ID technology such as RFID, this development is likely to start over again.

The time it takes companies to adopt and exploit technologies varies. Those companies that have the complementary resources and capabilities to actually put it to use are likely to derive a competitive advantage.[3] One of the companies that has been able to take advantage of technologies ahead of competition is Wal-Mart: "The technology that went into what Wal-Mart did was not brand new and not especially at the technology frontiers, but when it was combined with the firm's managerial and organizational innovations, the impact was huge."[4]

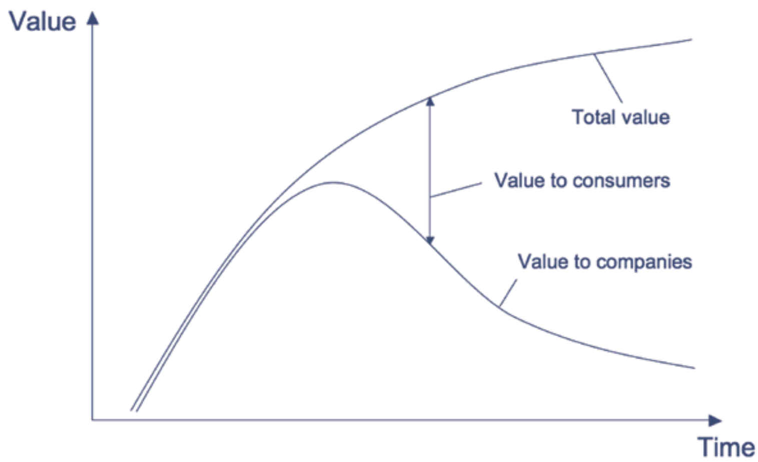

Figure III-16: Value of Auto-ID technologies over time

Between 1987 and the mid-1990s, Wal-Mart's market share had increased from 9% to 27% in the US, and its productivity advantage from 40% to 48%. Competitors adopted many of the innovations pioneered by Wal-Mart, including "economies of scale in warehouse logistics and purchasing, electronic data interchange (EDI), and wireless barcode scanning." They increased their productivity in subsequent years, but Wal-Mart was able to nearly maintain its lead (the productivity advantage dropped to 41% in 1999) by further increasing its efficiency.[5]

1 *Statement of Alan L. Haberman in a panel discussion moderated by Lawrence C. Russel, reproduced in Haberman (2001), p. 81*
2 *Hitt, Brynjolfsson (1996), p. 121*
3 *see e.g. Porter (1985)*
4 *Robert Solow, cited in Schrage (2002), p. 21*
5 *McKinsey Global Institute (2001), p. 2 and exhibit 5*

Beyond the process level, some researchers have suggested that, in the long term, the diffusion of barcode technology has supported developments that have lead to significant shifts in the structure of the retail industry. Dunlop and Rifkin[1] suggest that the barcode has contributed to a greater concentration in the retail industry, product proliferation, and a shift in power from the manufacturer to the retailer. The technology has increased efficiency in distribution networks, has reduced the cost of managing a large variety of products, and allows retailers to capture detailed sales data. It has also been suggested that barcoding has contributed to the emergence of superstores. Technologies such as barcode and EDI may enable retailers to realize scale economies in distribution. The increased need for coordination may be easier within a firm, which may explain why companies such as Wal-Mart have taken on some activities previously conducted by wholesalers.[2] McKinnon[3] suggests that EDI and barcode-based check-outs have enabled quick response practices. The adoption of quick response is one of six major complementary trends that have affected retail logistics.

Despite the growth of companies like Wal-Mart, traditional retailers or department stores have not disappeared. As complementary theory suggest (see chapter III.1.1), there can be multiple coherent patterns. However, over time, the pattern that offers the highest performance in certain market segments seems to have shifted towards those companies that can take advantage of the new technologies.

III.9 Summary

This chapter has derived a conceptual framework that analyses the impact of Auto-ID technologies on process performance. The framework distinguishes between automational, informational and transformational effects of Auto-ID technologies. Automational effects occur if companies use the technology to reduce data capturing cost. When the technology leads to an increase in data quality, the term informational effect is used. In these two instances, a new Auto-ID technology merely substitutes the existing data capturing technology. It acts as an alternative means to implement the current process. For transformational effects, the role is different. In these instances, the Auto-ID technology acts as an enabler and allows companies to realize new processes that were not economically worthwhile before.

The framework recognizes that contextual factors and complementarities can affect the impact of an Auto-ID technology. Organizational and environmental circumstances can limit the value that companies can derive from adopting the technology. Furthermore, in order to realize the value, companies must have certain complementary technologies and practices in place or have to invest in them.

This chapter has presented some evidence from the adoption of barcode technology in the retail industry that is consistent with the conceptual framework. The framework will be used in the following chapter to analyze the potential use and benefits of RFID technology in the FMCG supply chain.

1 *Dunlop, Rivkin (2001)*

2 *Holmes (2001). Somewhat in contrasts to Holmes, the McKinsey Global Institute (2001) reckons that the "big box" format introduced by Wal-Mart was independent of IT (which includes barcode scanning)*

3 *McKinnon (1996). He talks about "closely interrelated and, in most cases, mutually reinforcing trends" (p. 2)*

The following chapter describes how companies in the FMCG industry intend to apply RFID at the pallet and case level. The evidence was gathered during active involvement in projects with a number of companies.[1] The chapter focuses on the frequently mentioned benefits of RFID identified in chapter II.6. The conceptual framework (see chapter III.2) is used to structure the analysis of the potential applications.

IV.1 Research sample

Company background

The research sample consists of five companies, two manufacturers and three retailers.[2] Both manufacturers and one of the retailers are members of EPCglobal. They are also active members of several other industry initiatives such as GCI or ECR that promote lean retailing concepts. The retailer has been piloting RFID since 2003 and started to roll out RFID at the pallet level in 2004. The manufacturers have been part of the initial pilot and also engage in the first phase of the roll-out. In contrast, the other two retailers have not yet formally embraced RFID. They have evaluated the potential benefits of RFID, but have decided that there is no need to aggressively drive adoption. The projects showed that RFID can offer marginal benefits compared to best practice processes.[3] However, the companies do not want to start rolling-out RFID at a stage where there is still a need to invest significant resources for developing and testing the technology. Consistent with previous behavior, the companies do not regard themselves as first movers with regard to RFID. However, once new supply chain concepts and technologies have proven their value and the companies have decided to invest, they tend to act consequently.[4]
The selection of companies offers two advantages: First, all companies have already implemented or are at least in the process of implementing state-of-the-art supply chain processes and systems, including the use of barcodes. This made it possible to examine the additional benefits of RFID over existing barcode-based processes in supply chains that already operate efficiently. This helps to counter the argument that "[m]uch of the enthusiasm for RFID tagging projects came from a fundamental misunderstanding of the state-of-the-art in data collection technologies."[5] Second, the predominant view in the FMCG industry seems to be that retailers are to benefit from RFID, whereas manufacturers have difficulties in justifying the use of RFID. Working with retailers that take a more cautious approach towards RFID can help to overcome a potential pro-innovation bias[6]. Working with manufacturers that are actually taking part in roll-outs can help to overcome the prejudice that manufacturers have not found a business case for RFID because they do not know enough about the technology and have not looked hard enough. According to Lee et al.[7], "the more one hunts for value, the more [one] finds."

Global Foods is an international manufacturer of packaged food products with annual sales exceeding 20 billion Euro. It has several dozen different brands, some of which are global whereas others are only available in selected countries. The research covered one brand that includes 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. The specific plant that was examined during the research manufactures about 200 different products. The plant is located in central Europe. From there, products are sent to about 300 distinct delivery points in several European countries. The warehouse ships around 300 000 pallets per year. About two-thirds of the pallets are transferred to a Global Foods DC located adjacent to the warehouse. The DC is operated by a third party and ships around 450 000 pallets a year. It not only handles products produced at the adjacent site, but also from other sites. The products, in general, are stored before they are shipped. Approximately 30% of the pallets shipped from the DC are mixed pallets.

1 *In some instances, I use secondary sources to describe how other companies operate and intend to use RFID, primarily when the evidence from the action research does not cover these aspects*
2 *In order to ensure anonymity, the company names are disguised*
3 *The companies are still in the process of implementing some best practice processes and concepts. For example, both companies are actively driving the adoption of SSCC, EAN.UCC-128 barcodes and dispatch advices by their suppliers.*
4 *One example is the restructuring of the companies' distribution network in recent years. After it became evident that a network of central and regional distribution centers with extensive cross docking offers advantages, both companies invested heavily in new facilities and systems.*
5 *Gartner Research (2004b)*
6 *Rogers (1995), p. 100*
7 *Lee et al. (2005), p. 22*

Food Manufacturers is a large producer of a wide variety of food products that is active worldwide. Similar to Global Foods, the company sells consumer products under different brand names. The research involved one production facility that produces chocolate and related products. 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. 50% of the products for the national market are shipped as mixed pallets which are picked in a designated area in the warehouse.

Retail International is an international retail company that is active in more than 20 countries. The products sold by its distribution lines include consumer electronics, apparel, and groceries. The company has centralized purchasing and logistics operational units that serve several distribution lines. The project focused on one distribution line that operates medium-sized supermarkets and on dry goods. Due to their medium size, the supermarkets receive more than 80% of products from Retail International's DCs. The DC examined during the project provides dry goods with a high turnover (A products). The store receives three deliveries of between 8–12 pallets a week from this DC. The DC receives and ships around 330 000 pallets a year. Almost all shipped pallets are mixed pallets.

United Retailers is a large national retailer which operates more than 500 supermarkets of various sizes and a number of department stores. Additionally, the company owns several manufacturers of food and non-food consumer products. A large portion of the products sold in its supermarkets are private brands. The company operates two central distribution centers, one for dry goods, the other one for non-food and frozen products, and several regional distribution centers. The national DC for dry goods ships between 5 500 and 8 000 pallets daily. From the national DCs, the products are either delivered directly to the stores or cross-docked at the regional DCs. The regional DCs also distribute fresh products delivered directly to the regional DCs. The project examined the potential applications of RFID along the supply chain at the case and pallet level.[1] It looked at the process from the shipping gate at the manufacturer's warehouse via the national DC to the store receiving gate. The company also took part in two research projects conducted by students that focused on traceability of meat and fresh products.

Retail Corp operates more than 800 supermarkets. The company also owns department stores and a number of food producing companies. It is mainly active in one country. The company's distribution network consists of central distribution centers, mainly for non-food, frozen products and dry goods with low turnover ratios, and regional distribution centers that handle fresh products and dry goods with high turnover ratios. From its central distribution centers, the company delivers both directly to stores or uses the regional DCs for cross docking. Each of the ten regional DCs ships on average about 5 000 pallets[2] per day. The project evaluated the general potentials of RFID along the supply chain from shipping at the manufacturer to the receiving gate at the store.

The companies regard their supply chains as highly efficient. All three retailers have redesigned their distribution networks in recent years and have built a number of distribution centers. Distribution strategies vary by product category (e.g. dry goods versus fresh food) and volume (e.g. fast movers versus slow movers). Where appropriate, the retailers use cross docking. In their storage facilities, retailers and manufacturers employ wireless networks to transfer storage orders to fork lift drivers and picking orders to order pickers. The companies rely heavily on enabling technologies in their operations: In their internal operations, all companies apply barcodes at the pallet level. Some of the companies also use barcodes to identify storage or picking locations. The manufacturers both employ logistics labels including SSCC and EAN.UCC-128 barcodes and send dispatch advices. The three retailers can handle SSCC and dispatch advices from their suppliers at the receiving gate and are actively promoting the adoption of these enablers by their suppliers. Two of the retailers also use dispatch advices internally when shipping products from DC to store. All of the retailers use barcode scanners at the POS. Two of the retailers have already introduced automatic store ordering (ASO) systems for part of their assortment, while the third one is currently in the implementation process.

1 *The project also evaluated the potential benefits of item level tagging in the store. These results are not discussed in this thesis.*

2 *United Retailers and Retail Corp not only use pallets, but also roll cages. As this does not significantly affect the potential benefits of RFID, the term pallet is used throughout this thesis.*

Presentation of results

Figure IV 1 contains the list of benefits of RFID identified in chapter II.6 and shows which of these are discussed in the following sections. Chapter IV.8 deals with some of the benefits for which there are no specific examples from the field research. This is because the companies involved in the research did not regard them as a priority or did not see how the capabilities of RFID could lead to improved performance.

It is difficult to discuss the benefits of RFID entirely separate from each other. Here are just three examples: (1) Shrinkage not only leads to a loss equal to the value of the product, but can cause OOS situations at the retail shelf, both directly and indirectly via inventory inaccuracy. (2) Imperfect orders not only require a significant amount of labor for order reconciliation, but can also directly and indirectly contribute to OOS. (3) Tracing cases of products through the supply chain not only allows companies to issue more targeted recalls, but can also help to reduce some sorts of shrinkage in the supply chain.[1]

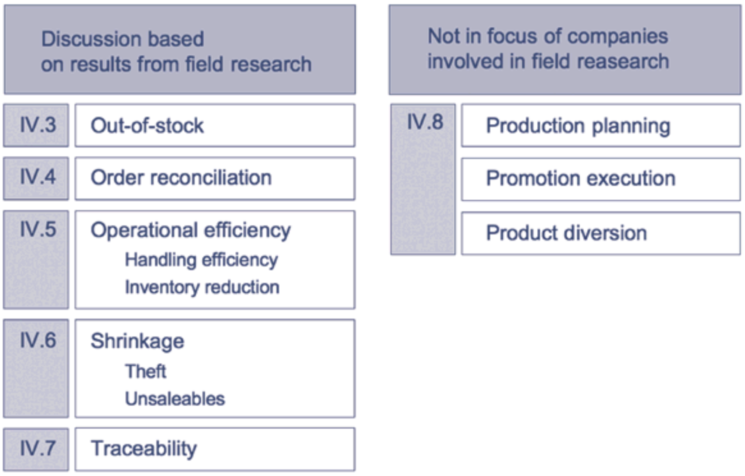

Figure IV-1: Presentation of results from field research

The sections on the individual benefits each start with some background information on limitations of the current processes and the magnitude of the problem that companies intend to address with RFID, followed by the examples from the field research. Each section ends with an analysis of the examples based on the conceptual framework.

The following discussion assumes that all RFID tags can be read when needed (i.e. no false negative reads), and that tags are read only when they are supposed to be read (i.e. no false positive reads). To date, however, there are a number of technical obstacles that prevent 100% correct reads, and it is still open whether the laws of physics may limit the applicability of RFID for certain products or in certain circumstances (see chapter II.4.2). Additionally, it is assumed that manufacturers use RFID in their internal processes. An implicit assumption in all applications is that RFID adoption has reached a critical mass so that it becomes possible to actually implement RFID-based processes. This might not be the case initially. Some manufacturers, for example, have introduced “slap & ship” approaches where they apply RFID tags only to selected products in order to comply with retailer mandates and do not use the technology in their internal logistics processes.[2]

Before discussing the effects and benefits of RFID, it is first important to understand the capabilities of RFID that the companies which took part in the research regarded as relevant in the context of case- and pallet-level tagging in the FMCG supply chain. This is the topic of the following section.

1 *Therefore, some repetitions in the following sections are hard to avoid. Experimentation with different ways to organize the following chapter, however, indicates that the current structure leads to a clearer presentation of results than a structure that would discuss individual steps in the supply chain process. Furthermore, the current structure looks at RFID more from a business perspective, starting with existing business issues and potential benefits rather than from a technological perspective that focuses on potential applications.*

2 *see e.g. Deloitte (2004a)*

IV.2 Relevant capabilities of RFID in the FMCG supply chain

In the FMCG supply chain, using barcodes is common, and RFID effectively "competes" with the barcode. RFID has some advantages over the barcode.[1] Discussions with company representatives showed that the most relevant capabilities of RFID in the FMCG supply chain are the ability to quickly identify objects without human intervention and without line-of-sight, which allows for bulk readings.

RFID technology offers a number of other capabilities which companies regarded as less relevant in the context of this research. These include read/write capability, counterfeit protection, and readability in adverse conditions:

- Read/write capabilities: The current application scenarios focus on read-only tags and do not assume re-writing the tag. The companies either separately attach an RFID tag or integrate the tags into logistics labels. In those applications that rely on information for individual cases or pallets (e.g. traceability), it is actually a prerequisite that the number remains unchanged until the case is put into the trash compactor or the pallet is broken up (e.g. during picking operations). Read/write tags could provide value at the pallet level if they were integrated into the pallet or if companies were to reuse the tags. However, at the moment, none of the companies intends to realize such a system.

- Counterfeit protection: RFID can be a means to prevent counterfeiting. For example, the FDA recommends RFID tagging in order to secure the drug supply chain.[2] However, while sometimes mentioned in reports, counterfeit protection is not among the most frequently cited benefits of RFID (see Table II 2). The companies that took part in this research project also did not mention counterfeiting of products as an issue. There may be three reasons for this. First, the regional scope was limited to Western Europe. Counterfeiting may be more significant in less developed countries. Second, the level of counterfeiting may be higher for high-value branded products such as apparel or watches than for grocery and related products. Third, effective counterfeit protection is likely to require item-level tagging, at least when consumers are to be given the possibility to check product authenticity. This does not say that RFID tagging at the case level cannot offer some protection. It may, for example, prevent counterfeiters from introducing cases with counterfeited products into the legal supply chain.

- Readability in adverse conditions: Although some companies admitted that there can be problems with reading barcodes, these problems, according to them, are in general negligible. The companies that took part in the research project did not consider readability as a general argument against barcodes. Sometimes, the problems result from inadequate printing quality. Adverse conditions such as high temperatures or humidity that can prevent the use of barcodes are relatively rare in FMCG supply chains. In some instances, condensed water, e.g. on frozen products, can make read ing barcodes difficult.

In the discussion on RFID, it is often stated that RFID allows for the unique identification of objects in the supply chain. Unique identification, however, does not require RFID technology. Unique identifiers such as an EPC could also be encoded as a (potentially 2-D) barcode[3] or simply be printed in human readable format onto items and cases. EPCglobal therefore clearly distinguishes between the tag data standard which defines how the SGTIN, the SSCC and other GS1 numbering schemes can be encoded in the EPC, and the air interface protocol standard that deals with RFID technology.[4]

In fact, RFID and the unique identification of objects are complements.[5] To date, except for SSCCs on pallets, companies in the FMCG industry rarely distinguish between individual objects. Instead, they print e.g. best-by dates or lot numbers onto SKUs and cases that separate batches. With RFID, it may become economically feasible to manage individual instances within a batch (or at least reduce batch sizes) as the technology makes it possible to automatically read the unique identifiers without human intervention or line-of-sight (see also chapter IV.7).

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1 *see e.g. ECR Europe (2000)*
2 *FDA (2004a)*
3 *GDI (2004), Schuster et al. (2004)*
4 *www.epcglobalinc.org/standards_technology/specifications.html*
5 *There is also a purely technical reason for using unique identifiers as they allow the RFID reader to separate the RFID tags that are in its field*

IV.3 Out-of-stock

IV.3.1 Background

Out-of-stock levels in the retail supply chain

Stock-outs at the retail store are still a major issue in today's retail environment. A recent study[1] estimates that OOS levels average 8.3%. The majority of OOS situations are caused at the retail store. Recent research estimates that wrong forecasting (13%) and ordering decisions (34%) are responsible for close to 50% of all OOS situations at the retail store. Another major reason (25%) for retail stock-outs is shelf replenishment: Products are in the store, but not on the shelf.

An ECR Europe study[2] shows that OOS levels at the upstream echelons in the supply chain are low compared to OOS levels at the retail shelves (see Figure IV 2). From a cost/benefit perspective, it may not even be desirable to achieve zero stock-outs at warehouses and DCs because eliminating all OOS situations would require holding more inventory. The manager of one of Retail International's DCs interviewed as part of the research, for example, stated that this DC has a target service level of 98% (the DC's performance was slightly better than that), exactly the figure mentioned in the ECR Europe study.

Figure IV-2:
Service levels along the supply chain[3]

There are different estimates on how stock-outs affect sales.[4] According to Emmelhainz et al.[5], consumers substituted one item for another in 73% of stock-out situations. Approximately 32% of consumers switched brands, while 41% purchased the same brand. The remaining 27% delayed the purchase, with roughly 14% buying the product at a different store. Brand and store loyalty can vary considerably by product. For some products, the impact of stock-outs on sales might be higher for retailers than manufacturers, and vice versa.

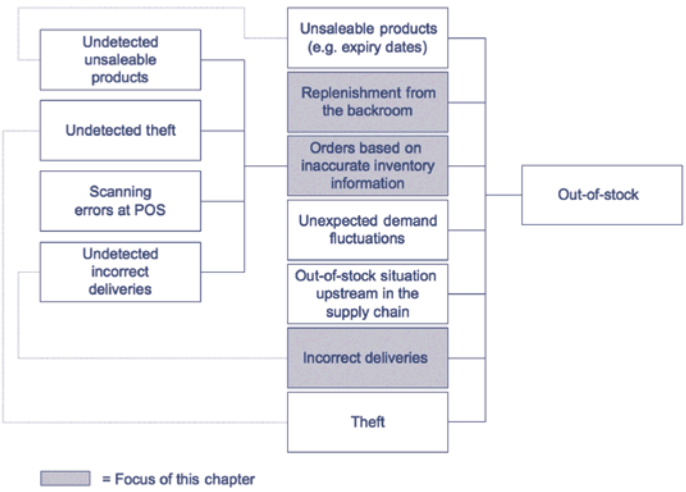

Figure IV-3:
Selected factors that influence stock-out levels

1 *Gruen et al. (2002)*
2 *ECR Europe (2003)*
3 *adapted from Wong, McFarlane (2003), p. 3, based on data from ECR Europe (2003)*
4 *see e.g. also Walter, Grabner (1975)*
5 *Emmelhainz et al. (1991)*

This thesis focuses on a few causes for stock-outs (see Figure IV 3) that can be addressed with RFID, predominantly at the case level:

- Replenishment from the backroom;
- Inaccurate deliveries to the store (which can cause stock-outs directly and indirectly);
- Inventory inaccuracy.

Replenishment from the backroom

As mentioned above, in about one fourth of OOS situations, the product is in the store, but customers do not find it on the shelf. This may be either because store employees or customers have misplaced the product or because there is additional inventory in the store backroom. In the FMCG industry, the focus is primarily on the latter cause in which stock-outs occur because store employees do not replenish products from the backroom in time.[1] For Wal-Mart, for example, knowing backroom inventory to reduce out-of-stock is reportedly the single most important benefit that the company expects from RFID.[2] Ed Shirley[3], Senior Vice President Global Value Chain & Global Marketing Resources at Gillette gives a similar statement in a presentation: "Take the supply chain efficiencies and cost savings that are there, but the real breakthrough is shelf availability and turnover ... enabled by store replenishment 'case' level tagging."

Conversations with retailers indicate that most of them try to avoid store backroom inventory and favor "one-touch replenishment" policies. In fact, Cooper et al.[4] identify the elimination of backroom inventory as on of three major areas of logistics innovation (apart from the use of IT for supply chain control and the outsourcing of non-core logistics activities) in the UK grocery industry starting in the mid-1980s.

There are a number of reasons why retailers nevertheless keep backroom inventory (apart from the fact that such a policy can avoid stock-outs): More products can be stored per unit of floor space in the backroom compared with the sales floor; backroom inventory can act as a buffer when deliveries are uncertain and lead times are long or when deliveries are imperfect; and, finally, for some bulky or high velocity products, there may not be enough shelf space available to move all products directly onto the sales floor.[5]

The availability and cost of backroom inventory can vary by region. In densely populated areas and countries, space is scarce and expensive. One example is Japan, where retailers such as Seven-Eleven are forced to deliver their products in the required quantity just-in-time.[6] In contrast, in less densely populated areas, space tends to be cheaper and transportation distances longer. This can make it more attractive for companies to store products locally. Products that can frequently be found in backroom storage areas include certain fast-moving goods (e.g. beverages, toilet paper), promotional items, and bulky products such as TV sets or printers, of which only one or two are placed on the shop floor at the same time.

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1 *The former potential cause may be of relevance in specific retail situations characterized by a large variety of similar products which customers frequently return to the shelf without buying them. Ton and Raman (2004), for example, observe this phenomenon for Borders Inc., a book store chain.*
2 *RFID Journal (2004c)*
3 *Shirley (2004)*
4 *Cooper et al. (1994), p. 101*
5 *Wong, McFarlane (2003)*
6 *Bensaou (1997)*

An analysis conducted by Kurt Salmon at the Extra Future store of the Metro Future Store Initiative showed that for all categories, at least part of the products delivered were stored in the backroom. For non-promotional items, the categories for which storage in the backroom was most likely were vegetables (24 of 36 delivered were stored in the backroom for longer than 12 hours), dairy products (5 of 13 pallets) and beverages (12 of 33 pallets). Promotional items were often stored in the backroom. There were differences in the movement of pallets between categories: For example, all pallets that contained vegetables were transferred almost directly (meaning within 12 hours after delivery) onto the shop floor and then returned if products were left. In contrast, the 12 beverage pallets were initially stored in the backroom before being moved onto the shop floor. Returning a beverage pallet once it was moved onto the shop floor was rather unlikely (1.5 of 33 pallets).[1]

There is no detailed data available on the level of backroom inventory in retail stores. However, two anecdotal findings suggest that the level of backroom inventory can in fact vary dramatically between retailers. If the Metro Future Store is representative of other Metro outlets, the example indicates that Metro stores between 20% and 25% of pallets delivered in the backroom. Assuming that a pallet stays in the backroom for two weeks and ten inventory turns per year, this gives an estimate of between 8% and 10% of store inventory in the backroom. This compares to a typical Wal-Mart store in which about one-third of inventory is stored in the backroom, according to a recent statement from a company representative.[2]

Inaccurate store deliveries

Inaccurate store deliveries can contribute towards stock-outs at the retail store in two ways. They can directly cause OOS situations when an SKU that is in short supply is missing from a delivery. This happens even when the store personnel detect the delivery error. Inaccurate deliveries that are not detected can also cause OOS situations indirectly as they lead to inaccurate inventory records.

The direct effect on product availability depends on a number of factors, including inventory levels at the retail store, order lead times, and delivery frequencies. A store with low inventory levels, for example, is likely to be hit harder by incorrect deliveries than a store with high inventory levels. A store that receives daily deliveries with a one day order lead time will be able to fill up the shelf the next day, whereas a store that receives deliveries only once a week is out-of-stock for the following seven days.

This assumes, however, that store personnel detect that the delivery was incorrect, which is not necessarily always the case. Direct store deliveries (as well as deliveries from the manufacturer warehouse to the retail DC) are, in general, closely inspected (see also chapter IV.4). This contrasts with the practices that the retailers that took part in the study as well as retailers such as Wal-Mart[3] employ for deliveries from their DCs. Store employees are not required to check the content of these deliveries as the manual counting of deliveries is regarded as too expensive.

Inventory record inaccuracy

The practice of not checking incoming deliveries from the retail DC is one cause of inventory record inaccuracy. The magnitude of the problem depends not only on the frequency of error, but also on the share of products that the stores receive via the retail DCs. Retailers such as Wal-Mart and Tesco, but also the retailers in this study, all operate their own network of distribution centers and tend to channel a large percentage of deliveries through this network, which increases the risk that delivery errors lead to stock-outs via inaccurate inventory records.

1 *Wolfram, Spalink (2004)*
2 *Progressive Grocer (2005c)*
3 *RFID Journal (2005c)*

Undetected delivery errors are, however, not the only cause for inaccurate inventory records. Shrinkage[1], including internal and external theft, process failures (e.g. out-of date and damaged products[2]), and vendor fraud; as well as scanning errors at the check-out[3] can all cause inventory inaccuracy when they are not detected. Employees can also create inventory record inaccuracy when they accidentally set inventory records to zero because they cannot find the product in the backroom.[4] (As this example shows, inventory record inaccuracy does not necessarily lead to higher stock-outs, but can also cause excess stock.)

Some of the causes for inventory record accuracy are hard to address with case level tagging and they are therefore not highlighted in Figure IV 3. While there are some specific areas in which RFID at the case and pallet level may reduce shrinkage[5], this is mostly in situations where shrinkage is currently already detectable (and, hence, employees can adjust inventory records accordingly). Finally, preventing scanning errors at the POS would require item-level tagging.

There is some empirical data available on inventory record accuracy in retail stores. Kang and Gershwin[6] report the results of a study conducted by a global retailer in several hundred of its stores. Inventory records were accurate for 51% of SKUs, and for 76% of SKUs, the deviation between physical inventory and inventory records was within a range of ±5 units. This means that for close to one in four SKUs, inventory records deviated from physical inventory by six or more units. Kang and Gershwin hypothesize that, due to shrinkage, inventory records tend to be below actual inventory levels. DeHoratius and Raman[7] examine inventory record accuracy at a multi-billion-dollar retailer. They found that the absolute difference between inventory records and physical inventory was on average close to five units. For 15% of SKUs, it was above eight items. This compares to an average target inventory of 14 units per SKU. Average inventory inaccuracy varied considerably by store, with a minimum of 2.4 units per SKU and a maximum of 7.9 units. The results of DeHoratius and Raman suggest that factors such as higher selling quantity, inventory density, and product variety are associated with higher levels of inventory record inaccuracy.

Raman[8] distinguishes between sales-related and supply-related sources of inventory inaccuracy. Sales-related sources are scanning errors, improper return processing, and shrinkage. Supply-related sources deal with problems in distribution processes. In order to get an idea of the magnitude of supply-related problems, the retailer conducted an experiment in which inventory was counted in a store that had not been opened yet. Independent auditors found that inventory was inaccurate for 29% of SKUs with a difference of 3.1 units on average.

1 *Hollinger, Langton (2004)*
2 *Beck (2002)*
3 *Raman et al. (2001)*
4 *RFID Journal (2005c)*
5 *see chapter IV.6*
6 *Kang, Gershwin (2004)*
7 *DeHoratius, Raman (2004)*
8 *Raman (2000)*

IV.3.2 Examples from field research

Current process

The following discussion focuses on the processes at Retailer International as United Retailers and Retail Corp essentially use the same processes. Any significant differences in practices between retailers are mentioned in the text.

Retailer International delivers approximately 80% of volume sold at the store under consideration via its own distribution centers.[1] Delivery lead time from the DC is usually two days. For most products, the store receives three deliveries a week; fresh products are delivered daily. At the DC, order pickers assemble deliveries using a pick-to-pallet approach. The company sends dispatch advices to the store once an order is complete. In contrast to deliveries from the DC, the store does not receive dispatch advices from manufacturers delivering directly to the store. The dispatch advice is used to update inventory levels in the inventory management system at the store the day the delivery is due to arrive. As already mentioned, there are no physical checks of incoming deliveries from the retail DC. In order to estimate picking errors, 1% of pallets are manually checked in the DC. Picking errors reach approximately 0.5%.

There are specific time windows in which the store receives deliveries. According to the company, the way store personnel behave if they suspect that a delivery from a retail DC is incorrect can vary. There seems to be no standard process in place. The pallets are first placed in the backroom and then moved onto the store floor for shelf replenishment. 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 backroom. This is because recording the number of cases that move between backroom and shop floor would be too expensive.
Cases that cannot be placed onto the shelves are returned to the backroom. Retail International intends to keep backroom inventory as low as possible. For most products, there are only a few or no cases in the stockroom. Large parts of the backroom inventory consist of promotional products and non-food items.

The company has implemented an automatic store ordering system for certain parts of its assortment. At the time of the analysis, the store ordering system only generated order recommendations. Store employees still moved around the aisles and manually checked the recommended order quantities. Products that go out of stock frequently are monitored more closely.

There is no possibility for store employees to check store inventory levels while they are on the shop floor. This means that they do not know whether order recommendations that seem too high or too low are potentially due to inaccurate inventory records. Similar to the receiving process at the store, there seems to be no consistent process in place that defines what employees are supposed to do when they suspect that inventory levels are inaccurate.
If employees detect that a stock-out is approaching for a product that might be available in the backroom, they are encouraged to replenish the shelf as soon as possible. In order to determine whether there might still be products in the stockroom, store employees rely on their memory.

Process with RFID

Retailer International expects that RFID at the case level can address the three root causes of OOS that have already been mentioned above (replenishment from the backroom, inaccurate deliveries to the store, inventory inaccuracy) by improving in-store processes and by preventing deliveries becoming inaccurate in upstream supply chain processes. The latter aspect will be covered in more detail in chapter IV.4.

Instances in which entire pallets go missing, are interchanged, or in which a store receives additional pallets are relatively rare. This means that the benefits of pallet-level tagging are likely to be limited.

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1 *The store belongs to a distribution line which operates smaller stores. For larger stores, the figure is lower*

The company has started to install readers at the store receiving gates which are intended to check delivery accuracy both at the case and pallet level. So far, the company receives RFID tags from selected suppliers at the pallet level. Case-level tagging is due to start by late-2005. For deliveries from the retail DC, it becomes possible to check the actual delivery quantity against the dispatch advice and record any deviations. While this does not eliminate the direct effect of missing cases on product availability, it can ensure that inventory records stay accurate and that the product is reordered. For direct store deliveries, the RFID-based checks will mainly substitute the existing manual checks and are therefore unlikely to affect product availability.

In its pilot implementations, the company has also placed an RFID reader at the gate between stockroom and store floor in order to improve the replenishment-from-the-backroom process. The reader records the movement of cases between the two locations. There is also an RFID reader next to the trash compactor where store employees dispose of empty cases. This reader can improve record keeping and help to ensure that all empty cases are appropriately accounted for.

The readers deliver the input data that allows the company to distinguish between shop floor and backroom inventory. The inventory management system can derive an estimate of the number of products available on the shop floor by combining the data on the flow of products from the backroom with POS data and generate an alert if shop floor inventory approaches zero. The separation of store inventory can also assist store personnel in keeping inventory records more accurate. During cycle counts, they can, for example, easily check whether the quantity of products on the shelf coincides with the inventory record for shelf inventory. In order for the system to work properly, Retailer International may have to equip its store employees with handheld terminals and install wireless networks in all its stores. Otherwise, there might be significant time delays before employees receive replenishment alerts, and they cannot, for example, check backroom inventory levels while on the shop floor.

The current stock-out rate at Retailer International's stores is about 4%, and the company estimates that it loses 1% in sales from stock-outs. There did not exist any detailed analysis on how the different root causes for out-of-stock contributed towards stock-outs. Initial estimates assume that RFID at the case level may cut OOS levels in half, leading to a potential increase in sales of 0.5%.

In principle, the same issues apply at United Retailers and Retail Corp. Statistics from United Retailers indicate that picking errors are comparable to Retailer International. However, regarding inventory accuracy and replenishment from the backroom, there are two differences between the companies: First, the extent to which the companies rely on automatic store ordering differs. For dry goods, United Retailers' system already generates orders without manual intervention. This increases the importance of accurate inventory data compared to a process in which store employees can manually check and adjust orders. In contrast, Retail Corp at the moment does not have a system in place that tracks inventory at the store. Ordering is still a manual task. In this instance, inaccurate inventory data does not affect product availability. (In fact, since inventory data is not tracked, there is no way to even compute inventory inaccuracy.) Second, both retailers reckon that they have already eliminated backroom inventory to a large extent and are going to reduce it further. This means that they do not see a separation of backroom and store floor inventory as a major issue that affects product availability.[1]

Wal-Mart intends to realize additional application scenarios with RFID. The company has developed a handheld RFID reader that can help to locate products in the backroom. The reader works something like a Geiger counter. Employees can point the reader at stacks of products, and the reader emits a sound signal if the correct case is within the reading range. The company also intends to process the unique case identifiers in order to keep better track of inventory movements in the store and to ensure accurate inventory levels.[2] If, for example, store employees do not move a case with a specific identifier onto the shop floor for a certain time, the system may initiate a search for the product and, if the case cannot be located, adjust the inventory level downwards as the content might have been stolen. If the case then reappears, the system can adjust the inventory level upwards.

1 *To some extent, the judgment at United Retailers may result from a lack of data and lack of awareness: A recent OOS study conducted at several of United Retailers' stores found OOS levels well above the company's perception (but still far below the approximately 8% OOS that Gruen et al. (2002) report).*

2 *RFID Journal (2005c)*

IV.3.3 Analysis

Table IV 1 summarizes how retailers intend to use RFID to reduce out-of-stock levels at the retail shelf. It uses the conceptual framework introduced in chapter III to analyze the individual applications and identifies the level of effect as well as contextual factors and complementarities that influence the value of RIFD.[1]

The first two areas in which retailers intend to apply RFID (reduced delivery errors and increased inventory accuracy) result in informational effects. In the third area, the technology enables a transformation of the replenishment-from-the-backroom process.

The table contains a number of contextual factors that influence the value of RFID. One factor is the level of picking errors. The more picking errors, the higher the potential value of RFID in reducing stock-outs, assuming that the technology can eliminate these errors to a large extent. However, delivery errors do not necessarily lead to stock-outs. High inventory levels at the retail store can buffer against the direct impact of inaccurate deliveries on product availability. Furthermore, delivery errors only cause inventory inaccuracy, which can harm product availability if they are not detected. This indirect impact is likely to increase with the ratio of deliveries from the retail DC.

For the in-store replenishment process, the potential value depends on, among others, the level of backroom inventory. The extent to which companies rely on backroom inventory partly reflects company-specific replenishment processes, but can also depend on factors such as promotional intensity (as promotional items are more likely to be stored in the backroom) and store density (as higher store density favors more frequent deliveries of small quantities due to the shorter transportation distances). Additionally, the frequency with which store employees check product availability and replenish products from the backroom, if needed, affects the value of RFID.

1 *The list of contextual factors and complementarities included in this and the following tables does not claim to be exhaustive. It is rather intended to direct attention towards some of the important aspects that companies should take into account.*

Problem area	Relevant tagging level	Level of effect	Contextual factors	Complementarities
Inaccurate deliveries	Case	Informational	Product margin (+)* Product margin (+)* Picking errors (+) Delivery lead time (-) Delivery frequency (-) Inventory levels (-)	Dispatch advices for DSD
Inaccurate store inventory	Case	Informational	Ratio of deliveries from DC (-) Picking errors (+) Cycle counts (-)	Store inventory management system Automatic store ordering System to adjust retail DC deliveries based on actual data Unique identification of cases
Replenishment from the backroom	Case	Transformational	Backroom inventory levels (+) Promotion intensity (+) Store density (+) Frequency of availability checks (-)	Separation of backroom and shop floor inventory Alert system for stock-outs at the retail shelf

* = These contextual factors apply to all three problem areas
\+ = An increase in the factor is likely to increase the potential value of RFID
\- = An increase in the factor is likely to reduce the potential value of RFID

Table IV-1: Analysis of RFID applications to reduce out-of-stock levels

There are also a number of complementarities, including dispatch advices from manufacturers that deliver directly to the store.[1] With RFID at the case level, but without dispatch advices, store employees still need to manually compare the actual delivery quantity (displayed, for example, on a monitor next to the receiving gate) with the physical delivery note.

Retailers that have not yet implemented store inventory management systems and sales-based ordering may lack the prerequisites to benefit from increased inventory accuracy. These companies may first have to spend some money to catch up from a technological perspective. Those companies that already have these systems may reach an additional increase in inventory accuracy if they keep track of the unique case identifiers. Retailers that want to transform their backroom replenishment process with RFID need to invest in new IT capabilities. They must adapt their inventory management systems so that they can separate backroom and shop floor inventory and implement rules that generate replenishment-from-the backroom alerts.

[1] *This thesis tries to identify complementarities that need to be in place at the information-processing level, rather than at the physical installation level which can include, for example, photo sensors that register when an object is coming close to an RFID reader and signals that indicate whether an RFID reader has successfully read a pallet tag or identified all cases on a pallet.*

IV.4 Order reconciliation

IV.4.1 Background

The previous section on out-of-stock already mentioned inaccurate deliveries from manufacturers as one pain point that can cause stock-outs. Due to changes of ownership, retailers tend to inspect deliveries from manufacturers closely. This means that most delivery errors are detected at the receiving gate.

This section looks specifically at the issue of delivery accuracy at the physical interface between manufacturer and retailer. A recent GMA study[1] in the US calculated that only 64% of customer orders are executed "perfectly". By perfect, the report means that the shipment is complete (i.e. contains the exact number of cases), on-time, damage-free, and accurately invoiced. The biggest problem is accurate invoicing. Only 75% of shipments are accurately invoiced. The second biggest obstacle is on-time delivery, with 10% of deliveries being late. In only about 2% of instances each, the shipment does not contain the correct amount of products or contains damaged products. A study by Lee et al.[2] in the consumer goods industry found that 33% of deliveries were disputed, with pricing issues again the main cause (47%), followed by gaps between items ordered and delivered (23%), missed deliveries (11%), quality of items delivered (9%), and substitution of item or packaging (8%).

Some of the costs associated with inaccurate deliveries increase total supply chain cost, whereas others mainly leads to a redistribution from the manufacturer to the retailer. The former costs include claims processing cost (e.g. cost for dispute resolution and for adjusting inventory and delivery quantities) at both the manufacturer and the retailer, additional freight cost for delivery of missing items or for returns of unwanted items, and potentially lost sales. The latter costs include late payment by the retailer or penalties.[3]

The business process measure considered here is the effort companies spend for reconciling imperfect deliveries. This excludes the direct cost of checking delivery accuracy which will be dealt with in chapter IV.5 on operational efficiency. As a large number of retailers, including the ones involved in the research for this thesis, distribute the majority of their products through their own DCs, the following considerations assume that the manufacturer delivers to the retail DC.
At a theoretical level, there are two ways to reduce the cost for reconciling imperfect deliveries: First, companies can increase the proportion of perfect deliveries, and second, they can reduce the processing cost associated with each imperfect delivery: "The avoidance of claims or at least a more efficient process to manage them is needed", as a representative of a large CPG manufacturer is quoted as saying in a recent EPCglobal[4] document.

This section describes how RFID can help to reduce the total cost for reconciling imperfect deliveries by improving the ratio of perfect deliveries via increased delivery accuracy and by reducing the cost for processing any imperfect deliveries (see Figure IV 4).

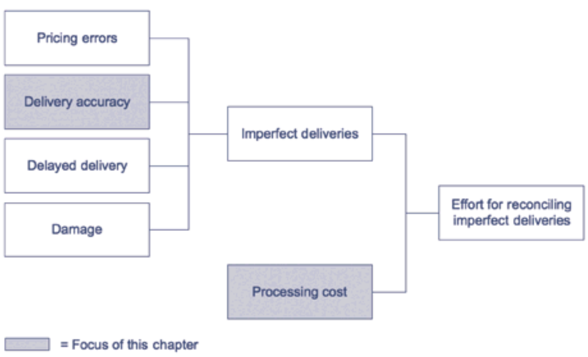

Figure IV-4: Selected factors that influence cost for reconciling imperfect deliveries

1 *GMA (2003)*
2 *Lee et al. (2005)*
3 *see e.g. Lee et al. (2005), EPCglobal (2004c)*
4 *ibid*

Delivery accuracy

Increasing delivery accuracy lies mainly in the responsibility of manufacturers. They have to ensure that they ship the right amount of product of the right quality, at the right time and at the right price.

Delivery errors can occur at the pallet and at the case level. Errors at the pallet level occur if a site receives too many or too few (mixed or full) pallets, or pallets that contain products in the wrong condition. The error may occur during the loading or unloading process. One important means to reduce the risk of delivery errors at the pallet level is to equip pallets with a barcode that contains a unique identifier and to scan this barcode during the loading and unloading process. Substituting RFID for barcode technology in these instances can reduce labor costs (see chapter IV.5). The impact on order accuracy, however, is likely to be limited to some exceptional situations. For example, DC employees may postpone scanning the pallet barcode during the receiving process when a lot of trucks arrive at the same time. If they offload a wrong pallet, they might detect the error only after the truck has left.

Errors at the case level are caused by picking errors and affect mixed pallets. Picking errors are usually calculated by dividing the number of incorrectly picked order items by the total number of picked order items. Picking errors can be divided into four categories, wrong product type, wrong product quantity, missing product, and wrong product condition (e.g. damage, wrong labeling).[1] In a survey of 75 picking systems in 35 companies from different industries, Lolling[2] found that the wrong quantity of products accounted for 45% of picking errors, followed by wrong type of product (40%), missing products (10%), and finally products in the wrong condition (5%). 37 of the 75 picking systems were from companies operating in the consumer goods industry, with an additional six from companies in the food industry.

The average picking error in the consumer goods industry was 0.3%, with the error rate of the best system below 0.1% and that of the worst system around 0.9%. Taking the average value as a basis and assuming ten order items per pallet and three pallets per delivery, the chance that a pallet contains at least one picking error is 3.0%, and the chance that there is at least one picking error in the delivery is 8.6%. The level of picking error as well as the distribution of error categories can differ by picking system (e.g. paper-based picking list, pick-by-light, pick-by-voice, picking via electronic picking list and mobile data capture). Furthermore, the level of picking error can vary significantly by picker.[3]

Processing cost

In many instances, imperfect orders lead to invoice deductions. Figures on the impact of invoice deductions on manufacturers in the US vary between 4.5%[4] and 9.9% of sales[5]. Deducting from this that RFID may increase overall margins in the FMCG industry by several percentage points overstates the potential: First, although a significant cost to manufacturers, it is a zero-sum game for the entire industry. Second, pricing issues are probably the single most important cause for invoice deductions, but are unlikely to be affected by RFID. Pricing accuracy may increase when the FMCG industry finally adopts the GDS Network to synchronize price information.[6]

1 *Lolling (2002)*
2 *Lolling (2001)*
3 *Lolling (2002)*
4 *Lee et al. (2005)*
5 *GMA (2002a)*
6 *GCI (2004)*

The relevant cost from a supply chain perspective is the money that retailers and manufacturers spend on resolving disputes and processing inaccurate deliveries. Dispute resolution costs can be significant[1], despite the fact that manufacturers tend to finally agree to the demands of their customers: According to a survey, manufactures deem 80% of deductions valid, and 82% of deductions are resolved in favor of the customer.[2] RFID could help to reduce processing costs if trading partners agree to use RFID data as a proof of delivery[3] and define a mechanism for sharing any discrepancies between the data at the point of shipment and the point of receiving. This would eliminate dispute resolution costs. Furthermore, the companies could use the data to automatically update internal systems.

IV.4.2 Examples from field research

Current process

The current process is described as exemplary for Global Foods and Retailer International. Global Foods ships full, layered and mixed pallets to its customer. The factory warehouse handles only full and layered pallets, while mixed-pallet picking takes place at the adjacent DC. Global Foods attaches logistics labels with EAN.UCC-128/SSCC to all pallets. The pallet-building process at the warehouse is automated: A palletizer, a special-purpose industrial robot, picks cases as they come down a conveyor and puts them on a pallet. The pallets are automatically shrinkwrapped after assembly. In the warehouse, fork lifts move the pallets from the palletizer to the storage or shipping area. Between the warehouse and the DC and inside the DC, there is an automatic pallet handling system that moves the pallets from the receiving gate to the storage area, and from there to the shipping or picking area. Picking is done manually, with the employees responsible for picking moving around the aisles. They receive their picking orders electronically. In order to ensure that the right product is picked, each picking place contains a barcode that the employee has to scan before picking. After the last case of a product has been picked, the employee manually confirms the number of cases. After the employee has picked the last order item, he goes to a special station where a logistics label is printed and attached to the pallet. At the end of the process, the pallet is shrinkwrapped semi-automatically, and the employee places the pallet onto the automatic transport system that moves the pallet to the shipping area. Before moving a pallet onto a truck, employees scan the barcode label attached to the pallet in order to ensure delivery accuracy at the pallet level.

The Retail International DC receives only full pallets of dry food products. When a truck arrives at the DC, the pallets are unloaded. During the receiving process, the company not only checks quantities against delivery documents, but also quality. During the quality check, employees check expiry dates and look for any physical damage to products. The physical quantity check involves 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 for. Additionally, there is a need to check the quantities on the delivery note against the underlying order (i.e. are all products that have been ordered listed in the delivery note?).

The Retail International DC receives EAN.UCC-128/SSCCs from about 40–50% of its suppliers. At the time of the analysis, the DC did not yet receive any dispatch advices from suppliers. The consistent use of EAN.UCC-128/SSCC and dispatch advices could already avoid a number of the manual steps in the receiving process: The electronic dispatch advice, sent before the delivery arrives at the DC, would include information on the content of the delivery, the associated order, and the SSCCs on the pallets that constitute the delivery. If DC employees did not find any discrepancies in the delivery quantity according to the dispatch advice or any quality issues, a simple scan of the EAN.UCC-128 barcode label would be sufficient to check in the pallet.

1 *IBM (2002b)*
2 *GMA (2003)*
3 *see e.g. GMA (2004), p. 15*

To ensure consistent labeling of pallets, a DC employee currently attaches a separate label to each one, even to those pallets that already contain a EAN.UCC-128/SSCC. The label contains several items of 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 to inform the warehouse management system that the pallet has been received. The barcode scan also creates a storage request. For full pallets, the company estimates that the current process of checking a pallet in takes about three minutes, including quality checks, label attachment, and the additional back-office work that involves physical handling of the delivery documents and manual data input.

Process with RFID

Global Foods and Retailer International expect some incremental improvements in delivery accuracy from RFID at the case level. At Global Foods, the fact that employees have to scan the location barcode prevents employees picking the product from the wrong picking location. (The automatic handling system ensures that the right pallet is at the right picking location.) However, employees may still pick too many or too few cases. An RFID reader placed at the hand fork lift could record the number of cases and thereby ensure that the right amount is picked, and the RFID data can act as proof of delivery that the right quantity has been shipped.[1] The companies do not assume any increase in delivery accuracy from introducing RFID at the pallet level.

Retailer International intends to install RFID readers at the receiving gates of its DCs. The reader would identify both the pallet tag and the tags on the individual cases. The combination of RFID at the case and pallet level, unique pallet identifiers, and dispatch advices could fully automate the check-in process (see chapter IV.5). The RFID data proves what the retailer has actually received, and there is no need to manually adjust delivery quantities in case of discrepancies. This reduces the processing cost for inaccurate deliveries.

Retailer International has not yet announced that its suppliers are required to include the unique case identifiers in their dispatch advices. This would potentially allow the company to verify delivery quantities at a later stage, for example during the picking process when only single cases are handled. This might be advantageous for products where a case read rate of 100% on mixed pallets is difficult to achieve.

So far, the companies have no clear idea on how RFID data might change the dispute resolution process between them. Ideally, the higher level of accuracy and objectivity that RFID data provides would to a large extent eliminate the time that each party invests in the dispute resolution process in order to find out what went wrong and who is responsible. Apart from institutional arrangements on how to deal with discrepancies (e.g. the companies could agree that any quantity differences result from theft during the transport and is carried by the manufacturer), this would likely require additional investments in information systems for data processing and exchange. The companies, for example, may need to define what messages the retailer sends to the manufacturer in case of discrepancies (e.g. whether to include unique case identifiers, as an EPCglobal document[2] proposes).

There are some differences between companies that can affect delivery accuracy, both at the pallet and the case level. Automatic storage systems, as deployed at Global Foods DC, reduce the risk of mishandling pallets without additional need for identifying the pallet. This contrasts with the two factory warehouses in which fork lifts move the pallets and fork lift drivers need to identify the pallets during the handling process.

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1 *If Global Foods also recorded the unique case identifiers and combined them with the expiry dates, the RFID data would also prove that it has sent products with a sufficient shelf life*

2 *EPCglobal (2004c)*

In the research sample, all companies pick to pallet, but even here one finds differences that can affect picking accuracy. At Global Foods, for example, employees scan the location barcode, which is not common in other companies. This additional step in the picking process reduces the risk that employees interchange products.

IV.4.3 Analysis

Table IV 2 uses the same structure as before to analyze how RFID can improve the order reconciliation process. Increased order accuracy from RFID at the case level can be classified as an informational effect as the underlying shipping and receiving processes do not change. There is simply a better match between the intended and actual delivery quantity.

The effect of RFID on order accuracy can vary by supplier or product category. Manufacturers that deliver primarily full pallets, for example, are likely to already achieve higher levels of delivery accuracy, especially if they have automated the pallet building process. Also, some products are more susceptible to theft which increases delivery inaccuracy. Furthermore, although not directly observable in the sample of companies, some picking systems (e.g. pick-to-light) seem to be inherently less error-prone than others, which reduces the potential advantage from RFID. Finally, two suppliers using the same processes can still differ in their delivery performance.

Problem area	Relevant tagging level	Level of effect	Contextual factors	Complementarities
Order accuracy	Case	Informational	Propensity of picking system for error (+) Supplier reliability (-) Proportion of full pallets (-) Shrinkage rate (+)	Real-time comparison of plan vs. actual cases picked
Processing of inaccurate deliveries	Case	Transformational	Product value (+)	Dispatch advices Unique case identifiers Systems for automatic dispute resolution

Table IV-2: Analysis of RFID applications to improve order reconciliation

RFID may transform the way trading partners resolve disputes over inaccurate deliveries. This assumes that trading partners accept data as proof of delivery and that automatic procedures can replace current manual processes. Capturing and sharing of the unique case identifiers can increase the level of confidence in the system as companies can exactly pinpoint which cases are missing or have been incorrectly delivered. The associated saving may increase with the value of the product as companies are likely to increase their effort when the disputed amount is high.

IV.5 Operational efficiency

IV.5.1 Background

Operating cost in the supply chain may be broken down into three categories: direct operating cost (e.g. labor at the DC and the store); cost of working capital (e.g. inventory); and cost of fixed assets (e.g. buildings). The following discussion focuses on how RFID at the pallet and case level can help to reduce data capturing cost, inventory levels, and the need for warehouse & DC space (see Figure IV 5).[1]

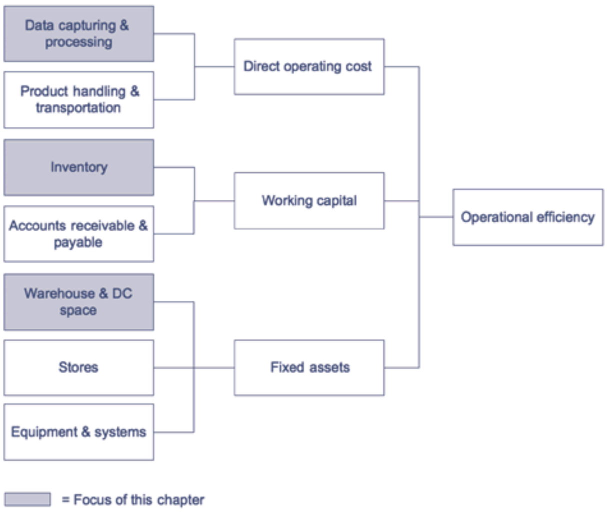

Figure IV-5: Selected factors that influence operational efficiency

There are no comprehensive figures that specify exactly the cost associated with each of the categories. Thonemann et al.[2] provide an exemplary cost structure for consumer goods (see Figure IV 6). The numbers suggest that the cost of distribution from manufacturer to retail store and for in-store logistics are much higher than the cost of holding inventory. They estimate that combined logistics costs for retailer and manufacturer account for 10% of end consumer price, followed by store cost (8%). Inventory costs are only 2% of sales. In total, one can argue that 20% of the product price the consumer pays goes into distribution.

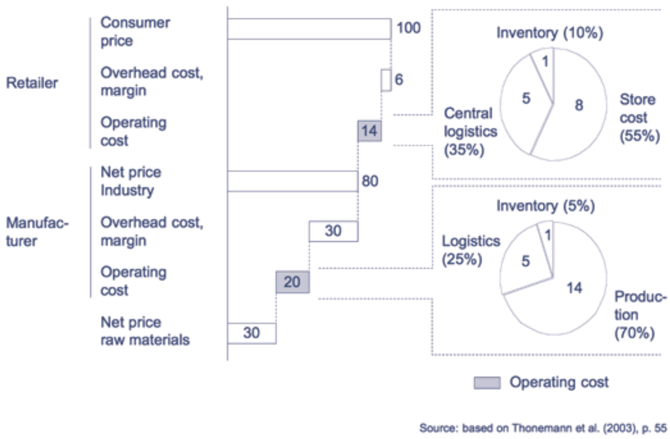

Figure IV-6: Exemplary cost structure for consumer goods industry[3]

1 *For a discussion of how RFID can improve the management of reuseable containers and other sorts of equipment, see Strassner (2005)*
2 *Thonemann et al. (2003)*
3 *based on Thonemann et al. (2003), p. 55*

Clarke[1] provides a breakdown of the direct operating cost for Tesco's part of the supply chain. His figures suggest that upstream distribution and store logistics account for almost the same proportion of cost. According to the figures, in-store logistics are responsible for 46% of the cost, followed by secondary DC operations (including order assembly) with 19% and retailer inbound logistics (including primary distribution) with 18%. The remaining part of the cost can be attributed to deliveries from DC to store (9%) and order management (8%).

There is evidence that indicates that labor costs account for a large part of the cost both in upstream distribution and store operations. The USDA Economic Research Service[2], for example, estimates that in the US 38.5% of the end consumer price are labor costs (this figure includes overhead labor). In the US, labor costs make up an estimated 58% of store operating costs.[3] For a typical DC, labor may account for 70% of total cost, followed by space and building (18%) and systems (9%)[4], which may be classified as a fixed cost.

Physical distribution involves making trade-offs between the three categories of operating cost in order to achieve a given level of service. Cachon[5], for example, examines the relationship between variables such as transportation (which can be considered as direct operational costs), inventory (working capital), shelf space (fixed assets), and product availability: "For instance, a retailer could choose to increase transportation utilization, thereby lowering its transportation cost, but that also increases the time interval between deliveries to a store. To account for less frequent deliveries, the store will either need to expand shelf space and inventory or sacrifice customer service." Another trade-off occurs if companies invest in fixed assets in order to reduce direct distribution costs. Examples include investments in warehouse automation such as automated transport and storage systems for pallets or automated sorting systems for cases.

Data capturing

Information capturing and processing technology has reduced direct distribution costs. Here are just a few examples: automatic store ordering systems have reduced the cost per order; transmission of orders and other documents via EDI has reduced data transmission cost and eliminated time for manual data verification and entry; barcodes reduce the time required to identify an object or a location; and wireless networks in warehouses and DCs allow the electronic transmission of orders to employees and have eliminated paper-based processes.

These changes have contributed towards a shift in the trade-off curves between the categories of operating costs in the retail industry and supported the redesign of distribution networks (see also chapter II.3). Retailers such as Wal-Mart, Metro and Tesco that actively drive the adoption of RFID have implemented practices such as frequent store deliveries with short lead times and cross docking at distribution centers.

The effect of technologies such as the barcode on handling efficiency has thus been twofold. First, the technologies have reduced the cost of data capturing and processing. Second, they have enabled companies to implement new processes such as cross docking (see chapter III.8) which has further increased handling efficiency by reducing the need to physically handle deliveries.

1 *Clarke (2002)*
2 *FMI (2004)*
3 *www.fmi.org/facts_figs/keyfacts/super.htm*
4 *IBM (2002b)*
5 *Cachon (2001), p. 211*

Inventory

Larson and DeMarais[1] distinguish between four types of inventory: cycle stock, safety stock, pipeline stock, and speculation stock. For the current discussion, the first three types of inventory are most relevant.[2] There are various ways in which retailers and manufacturers can reduce inventory levels in the supply chain.[3] For example, a reduction in demand variability or lead time variability reduces the need for safety stock; shorter lead times reduce the need for cycle stock and safety stock; reduced order quantities and more frequent deliveries reduce cycle stock; and consolidation of storage capacity decreases safety stock requirements.

One strategy for reducing demand variability is the sharing of POS and inventory information along the supply chain and the implementation of VMI programs. This is discussed in more detail in chapter IV.8. A network of regional DCs can allow retailers to increase the frequency of store deliveries and consolidate inventory.

Further reductions in inventory levels are possible when companies automate the ordering process. This allows them to replace intuitive ordering based on the experience of employees with scientific inventory models. These models can incorporate a number of variables, including actual demand patterns, upcoming promotions, or seasonal demand patterns.[4] The lower cost for placing an order can also foster an increase in delivery frequencies. Other areas in which inventory models may be applied include shelf space allocation in the store.

A final factor is inventory record inaccuracy. While inventory records that show higher levels of inventory than actual available can cause stock-outs (see also chapter IV.3), too low inventory records can contribute towards excess inventory (see also chapter IV.6).

Warehouse & DC space

There has been less emphasis on the role of RFID in reducing the amount of fixed assets. Some publications[5] mention that RFID at the pallet level may enable "chaotic" storage of pallets in the warehouse or DC which may reduce the storage space required.[6]

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1 *Larson, DeMarais (1999)*

2 *Speculation stock includes inventory accumulated in advance of, for example, an anticipated increase in price, shortage of supply, or increase in demand (e.g. for seasonal products or in advance of promotions (Larson, DeMarais 1999). Speculation stock may, for example, decrease if companies move to EDLC/EDLP policies and reduce the amount of promotions (see also chapter II.3).*

3 *These factors derive directly from standard inventory formulas presented in textbooks such as Silver et al. (1998)*

4 *see the forthcoming Ph.D. thesis by Alfred Angerer from the Kühne-Institute for Logistics, University of St.Gallen, for a detailed discussion of different types of ASO systems*

5 *e.g. McFarlane, Sheffi (2003) and Metro (2004a)*

6 *AMB (2004)*

IV.5.2 Examples from field studies

Data capturing

The manufacturers and retailers involved in the research expect some savings in direct operating cost, mainly labor, from adopting RFID technology at the case and pallet level. These savings result from substituting manual barcode scans and manual quantity checks. Previous chapters have already mentioned several areas in which manual barcode scans can be eliminated. For example, chapter IV.4 has described how RFID at the pallet level can eliminate the need for manually scanning logistics labels, and RFID at the case level automates quantity checks at the interface between manufacturer and retailer. The following description uses examples from Global Foods and Retailer International and mentions some additional areas in which labor can be saved. It also describes some instances in which reading RFID tags instead of barcodes might not provide much value.

At the pallet level, RFID eliminates the need for manual barcode scans not only in the receiving process, but also in the shipping process. At Global Foods, the savings from RFID may be much greater than the time it takes an employee to scan the barcodes. This is because Global Foods relies on a third-party company for transportation. Loading pallets onto the truck is done by the truck driver, supervised by warehouse personnel. There are logistics labels attached to each pallet that contain, among other things, an SSCC encoded as an EAN.UCC-128 barcode[1]. The barcode is scanned in order to ensure that the correct pallets are put on the truck. As Global Foods does not want to rely on the third-party truck driver to ensure that the right pallets are put on a truck, the scanning is done by warehouse personnel. The company fears, for example, that truck drivers will skip scanning the pallet barcodes if they are in a hurry. With RFID tags on pallets and RFID readers at the shipping gates, Global Foods can automatically identify the pallets that the third-party employee moves onto the truck. This might enable Global Foods to eliminate the need for warehouse personnel to supervise the loading process.

This process, however, applies only to one-third of the pallets that the warehouse handles. About two-thirds of the pallets are transferred to a Global Foods' DC located adjacent to the warehouse. The company uses a conveyor system for the transport. There are fixed-installed barcode scanners on the conveyor belt that scan the barcode on the logistics label. The company does not expect any benefits from RFID for the pallets moved to the adjacent warehouse because data capturing is already conducted automatically.

There are also hardly any savings from RFID in the pallet handling at the Global Food's DC itself as the DC is highly automated. This contrasts, for example, with Retailer International's DC where forklifts handle the storage and removal of pallets. At Retailer International, forklift drivers scan a pallet before moving it to the storage area. Once they have placed the pallet in the storage rack, they input a check digit for the storage location in order to verify that the pallet has been accurately placed. Here, RFID eliminates the need for manual pallet scans and for manual entry of the check digit.

RFID can also reduce data capturing cost at the case level in the picking process. Picking is still a manual task at Retailer International, and the process is very similar to the one at Global Foods' DC. One difference from a data capturing perspective is that order pickers at Retailer International do not scan the location barcode before they start picking an order line. This saves time (and reduces the potential saving from RFID), but increases the risk of interchanged cases. Once an order picker has picked all cases for an order line, he manually inputs the number of cases.[2] This step can be eliminated when an RFID reader records the tags that the employee puts on the pallet. At Global Foods, the potential savings are slightly higher because RFID at the case level also makes the scan of the location barcode obsolete.

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1 *If not stated otherwise, the term barcode refers to an EAN.UCC-128 barcode that contains an SSCC for pallets and to an EAN.UCC-13 barcode that contains a GTIN for cases.*

The fact that employees have to manually input the picking quantity can reduce picking errors (see chapter IV.4).
2 *Furthermore, it allows the employees to record any quantity discrepancies, e.g. if a product is not available*

Beyond the store receiving gate, none of the retailers expects any labor savings from RFID at the case and pallet level. This is because at the moment, none of the retailers records any data on the movement of pallets and cases inside the store. RFID at the case level may reduce the manual data capturing effort for processing returns (e.g. of promotional, seasonal or recalled products), but this has not come up as a priority during the field research.[1]

In the longer term, RFID may reduce the cost of inventory counts at warehouses, DCs and stores. So far, the companies did not regard this application as relevant. One of the reasons for this is that this would potentially require deploying a huge number of RFID readers.

Retailer International, similarly to Retailer United and Retail Corp, is still in the process of rolling out dispatch advices and logistics labels with SSCC and EAN.UCC-128 barcodes with its suppliers. The company has combined the introduction of RFID with the adoption of these practices: Suppliers that want to start delivering RFID-tagged products to the company first need to adopt dispatch advices and logistics labels with EAN.UCC-128/SSCCs. Dispatch advices allow the company to process incoming deliveries more efficiently. Consistent labeling – whether barcode- or RFID-based – will eliminate the need to apply separate barcodes to incoming pallets.

Inventory

The companies do not expect inventory levels to fall due to the introduction of RFID at the case and pallet level. They do not see that RFID affects variables such as order lead times and lead time variability, or delivery frequencies. RFID may speed up some processes (e.g. the receiving process), but these increases in speed are in the range of a few minutes, whereas order-to-delivery lead times between manufacturer and retail DC as well as between retail DC and store are still several hours and often amount to days.[2] Similarly, RFID can reduce the cost of data capturing, but the cost reduction (e.g. in the receiving process) is unlikely to be significant enough to warrant an increase in shipping frequencies.

Retail Corp mentioned prioritized treatment of trucks arriving at the DC as a potential application. Although such an application would not directly address lead time variability, it could potentially reduce extra waiting time for trucks that carry products in short supply. However, discussions showed that it would be impractical to open the trailer and read one or more RFID tags just to find out which load the truck carries. In this case, other scenarios seem preferable[3]: The truck drivers could, for example, key in the order number at the entrance gate. Alternatively, the truck might electronically submit the information, for instance via an RFID tag mounted to the truck. United Retailers, for example, has installed an RFID-based truck identification system at one of its distribution centers.

The companies also do not expect an improvement in forecasting accuracy and do not believe that RFID will lead to more direct store deliveries or contribute to a proliferation of VMI programs, as some researchers[4] have suggested. In most instances, the POS and inventory data that might help to implement DSD or VMI and improve demand visibility is already available. Retailers, in general, already today possess the data on inventory levels and product movement at the DC and the store (apart from the movement of products between backroom and shop floor). Already in the mid-1990s, for example, Procter & Gamble sold more than 40% of its products via VMI programs.[5]

Most VMI programs today involve only the retailer DC[6], where – according to the companies – current processes already ensure that inventory records and product movement data (on which manufacturers rely to determine order quantities) are relatively accurate. RFID may only provide some minor improvements in accuracy, which would benefit both products under VMI programs and products managed by the retailer to a similar extent as both rely on accurate system inventory records.

1 *Traceability is discussed in chapter IV.7*
2 *see also Smaros et al. (2004)*
3 *The scenarios assume that the manufacturer has sent an electronic dispatch advice*
4 *see e.g. Lee et al. (2005)*
5 *Cooke (1998)*
6 *Mei (2004)*

Implementing a VMI system at the store level is complicated by a number of obstacles that are hard to address with RFID at the case and pallet level. One involves measuring the service level of a VMI program. Due to potentially inaccurate inventory records, simply using inventory records to determine whether a product is available on the shelf may not accurately reflect reality. Furthermore, the manufacturer might end up paying penalties for low service levels that are a result of inaccurate inventory records over which the company has no control. These problems are not unlike the problems associated with scan-based trading[1] and might not be resolved until item-level tagging is available.[2]

Small improvements in store inventory management may result from RFID at the case level. Inaccurate inventory information can not only cause stock-outs, but also lead to excess inventory, e.g. when DC employees interchange cases or store employees order additional products because they cannot find specific cases in the backroom.

Warehouse & DC space

The research presented little evidence on how RFID at the case and pallet level reduces the need for fixed assets. The findings indicate that RFID is not required for "chaotic" put-away of pallets. Highly automated DCs as the one from Global Foods, but also less automated ones such as Retailer International's already allow for such optimized storage. (Retailer International nevertheless tends to store pallets close to the picking place from which this product is picked. This is in order to minimize the distance that forklift drivers have to drive when removing the pallet.)

An example from Global Foods shows how RFID at the pallet level may reduce the need for warehouse space. The company envisions using RFID tags to realize a new process for loading pallets onto trucks at the factory warehouse. Instead of assembling pallets prior to the truck's arrival, the forklift drivers would provide the pallets just-in-time when the truck arrives and move them directly onto the trailer. This would not only eliminate labor, but also free up some of the space in the shipping area that is currently needed for the temporary storage of pallets. Currently, Global Foods rents additional storage space at a separate location because there is not enough space available at the factory warehouse. If they can productively use the freed-up space in the shipping area, this may reduce the need for outside storage space.

IV.5.3 Analysis

Table IV 3 provides a summary of how RFID might affect the operational efficiency of the FMCG supply chain. There are several areas where RFID at the case and pallet level can reduce the manual data capturing effort by automating product identification. The potential savings from automated data capturing increase if the current level of DC automation is low. They also increase with the effort that a company currently spends on aligning the information flow with the physical flow of products. As the example of the picking process shows, some companies choose to spend more on identification in order to reduce the risk of discrepancies. The identification effort also rises with the length of the supply chain as the number of "touching points" increases. In general, data capturing costs are also higher in areas with high labor costs. Finally, regulation can drive data capturing costs when it forces companies to record and store data on product movements in the supply chain (see also chapter IV.7).

1 *see e.g. Retail Forward (2001)*
2 *Gartner Research (2004c)*

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AUTO-ID LABS

Problem area	Relevant tagging level	Level of effect	Contextual factors	Complementarities
Data capturing: Manual product identification	Pallet and case	Automational	DC automation (-) Integration of third party (-) Identification effort (e.g. picking) (+) Length of supply chain (+) Labour cost (+) Regulation (+)	-
Data capturing: Paper-based delivery documentation and pallet labeling	Pallet	Transformational – RFID as catalyst	Adoption of dispatch advices (-) Adoption of logistic labels (-)	-
Inventory: Inventory accuracy	Case	Informational	Delivery accuracy (-) Backroom inventory levels (+)	-
Warehouse & DC space	Pallet	Transformational	Alternative use for warehouse space (+) Reliability of truck arrival time (+)	Timely information on truck arrivals Adaptation of warehouse management system Schedules detailing truck arrival times

Table IV-3: Analysis of RFID applications to improve operational efficiency

The examples from the field research also indicate how RFID at the pallet level may transform the shipping process and thereby free up storage space. In order to actually implement the new process, several complementary factors need to be in place. The company has to adjust the warehouse management system. The system must not generate transport orders before a truck is available for loading. This requires timely information on when a truck is about to arrive in order to reduce truck waiting time before the loading process starts. Potentially, the company would need to enforce very strict schedules for trucks in order to avoid these instances.

If truck arrival times are unreliable, there is a risk of congestion at the shipping gate and additional truck waiting time compared to the current situation. Conversely, there might be times when only a few trucks arrive and there is excess fork lift capacity. Currently, the shipping area acts as a decoupling point that buffers for these variations. Another contextual factor that influences the final value of this application is whether the company can find alternative uses for the additional warehousing space.

Retailer International has made it mandatory that its suppliers introduce SSCCs and dispatch advices before they adopt RFID. This reduces the need for paper-based delivery documentation and separate pallet labels. In this specific example, RFID takes on a role that is distinct from the role as implementer or enabler. It helps to drive a change in the receiving process that does not depend on RFID. As an ECR Europe[1] report shows, SSCCs encoded as barcodes and dispatch advices can reduce operating cost along the supply chain. Despite the potential advantages, adoption is still rather low.[2] According to the 4th ECR D-A-CH Monitor[3], only 39% of manufacturers and 31% of retailers were using SSCCs and dispatch advices. This figure is likely to overstate the true level, as companies often apply certain practices with selected trading partners only.[4]

IV.6 Shrinkage

Shrinkage can be defined as "[i]ntended sales income that was not and cannot be realized."[5] Comparing shrinkage levels can be difficult as definitions vary. Companies, for example, do not necessarily include detected theft during cycle counts (e.g. when store personnel detect empty packages), or damage and spoilage in their calculations of shrinkage levels. Reportedly, this leads to the interesting fact that sometimes well-organized companies report above-average shrinkage rates, simply because they keep accurate track of all types of shrinkage that occur between cycle counts.[6] Furthermore, these measures usually do not include the indirect effects, e.g. lost sales due to inventory inaccuracy caused by shrinkage. Another source of variation is the treatment of price changes: Not all companies keep track of price changes and are therefore able to adjust their shrinkage measures for the effects of price variations.[7]

This section looks specifically at how RFID can address two sources of shrinkage: product theft and unsaleables resulting from out-of-date and damaged products (see Figure IV 7).

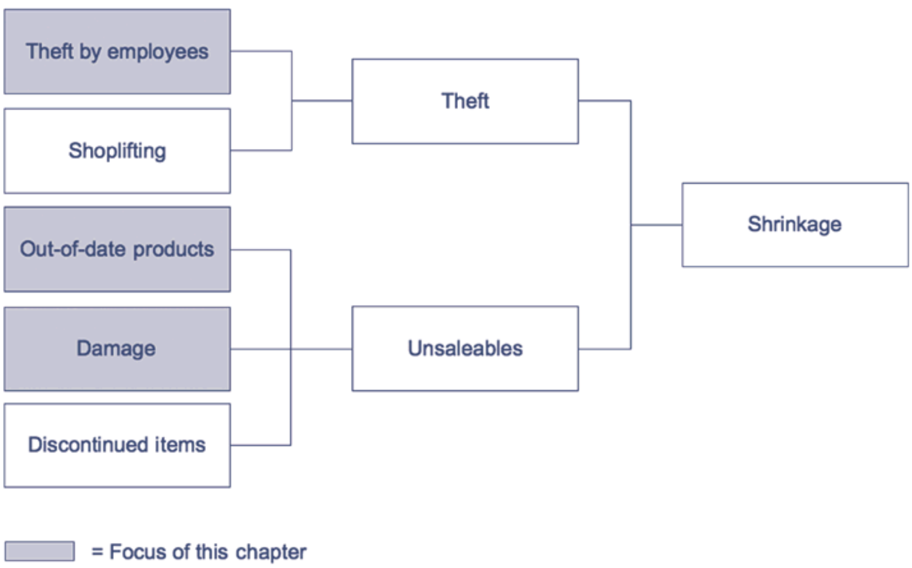

Figure IV-7: Selected factors that influence shrinkage

1 *ECR Europe (2000)*
2 *If the introduction of barcode-based SSCCs and dispatch advices can reduce cost, the question arises why a catalyst such as RFID is required to drive adoption. This aspect will be briefly addressed in chapter 0.*
3 *CCG (2002)*
4 *see Lebensmittel Zeitung (2000a)*
5 *Chapman, Templar (2004), p. 4*
6 *Chapman, Templar (2004)*
7 *EHI (2004)*

Theft

A recent European[1] survey examined four components of shrinkage: process failures, internal theft, external theft, and vendor fraud. Process failures include damaged products, expired products, and price mark-downs. Retailers surveyed in 18 European countries estimate shrinkage within the FMCG supply chain at 1.84% of turnover. The main cause of shrinkage was external theft (38%), followed by process failures (27%), internal theft (28%) and supplier fraud (7%). The survey found that, when looking at the retailer only, 93% of shrinkage occurs at the retail store versus only 7% at the distribution center.

According to a survey by Hollinger and Davis[2] in the US, shrinkage in the retail industry amounted to 1.7% of sales in 2002. The survey is based on responses from 118 retailers. For supermarkets/grocery, the figure is 1.5%. The authors identify four sources of shrinkage: employee theft (48% of all shrinkage), shoplifting (32%), paperwork and administrative errors (15%), and vendor fraud (5%). Paperwork and administrative errors include largely losses due to pricing mistakes. Vendor fraud occurs mainly when supplier personnel are responsible for shelf restocking.

A recent study[3] found evidence that most of the theft is done by professional actors, that there exist organizations that handle stolen products, and that stolen products may re-enter the legitimate supply chain in various forms. The study also discusses several attributes that influence the attractiveness of a product for thieves. In general, there are two categories of attributes. One deals with the stealability of products (i.e. the effort needed to take it), the other with the value of products to thieves. Batteries and razor blades, for example, are highly attractive to thieves and among the most frequently stolen products. Kang and Gershwin[4] report that theft rates for these products approach 8% and 5% of sales, respectively.

Theft rates can vary by country. The European Theft Barometer[5] attempts to measure retail crime across Western European countries. The study estimates that retailers in 2002/2003 lost on average 1.37% of turnover due to shrinkage. The country with the lowest level of shrinkage was Switzerland (0.89%), followed by Austria (0.98%). The country with the highest level of shrinkage was the UK with 1.69%.

There exist various strategies for fighting theft by disrupting the market for stolen FMCG. One strategy is to reduce the vulnerability of the supply chain, another is to discourage commercial buyers from purchasing potentially stolen products. Market observers, however, express scepticism regarding the effectiveness of security measures.[6] According to Beck [7], research on the effect of EAS tags on theft provides mixed results, and he suspects that "their future role in managing stock loss throughout the supply chain remains limited." Professional thieves in particular are likely to know about the strengths and weaknesses of security systems and find ways to circumvent such measures.

Unsaleables

An industry survey by the Joint Industry Unsaleables Steering Committee[8] provides data on the level of unsaleables in the US retail industry. According to the survey results, which are based on responses from over 60 manufacturers and retailers, the cost of unsaleable food and grocery products amount to 1% of sales in the US. Damage is the biggest cause of unsaleables with 63% of all unsaleables, followed by expired (16%) and discontinued items (12%). The rate of unsaleable products can differ by product category: Frozen products, for example, reported an unsaleable rate of 0.9%, whereas the rate for refrigerated products was 1.7%. Unsaleable rates for health and beauty care and general merchandize had even higher unsaleable rates (1.9% and 2.2%, respectively), which was attributed to frequent new product introductions, shifts in fashion component, seasonality, and short shelf life.

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1 *Beck (2004)*
2 *Hollinger, Davis (2002)*
3 *Perpetuity Research et al. (2004)*
4 *Kang, Gershwin (2004)*
5 *CRR (2003)*
6 *Perpetuity Research et al. (2004)*
7 *Beck (2002), p. 37*
8 *Lightburn (2002)*

A recent report from GMA and FMI[1] identifies several causes that affect the level of product expiration in the supply chain: inventory rotation does not occur 100% of the time; practices for encoding expiry dates on cases and products are not standardized; companies do not always capture and use the available information on expiry dates in their warehouse management systems; and new product introductions that require stock-piling before launch and have shorter shelf life times for quality reasons.

IV.6.1 Examples from field research

Shrinkage has been a topic in the discussions with all manufacturers and retailers. In general, the companies reported that shrinkage was no serious issue in the supply chain up to the store, and that the use of RFID at the case and pallet level provides only limited benefits.

Theft

The attractiveness of a product to thieves depends, as described, on the stealability of the product and its worth to thieves. According to the assessment of the companies involved in the research, RFID at the case level does not materially affect the stealability of products, i.e. the effort it takes thieves to come into possession of a product. The companies agree with the findings presented above that the majority of theft occurs at the store and believe that theft mostly occurs at the item level. Even when theft occurred at the case level[2], they expect professional thieves to know about the limitations of technology and remove or destroy the RFID tag when stealing the product. Thieves may also remove the tag from the case and than stick it between the remaining cases on the pallet or steal the items without the case. In this scenario, an RFID reader at the receiving gate of the retail DC, for example, would indicate an accurate delivery, although some cases are missing. In these situations, traditional means to secure deliveries might be superior to RFID. One company reported that thieves often damage the shrinkwrap foil when they remove cases from a pallet, which makes it easy to detect the theft by visually inspecting the pallet.[3]

Although RFID at the case level might not deter thieves in the short term, it may nevertheless allow companies to make theft more difficult in the longer term. RFID can provide manufacturers and retailers with a clearer picture of where theft at the case level occurs. Food Manufacturers, for example, mentioned that theft can occur during transportation, but is difficult to prove. Higher data accuracy and objectivity may help companies to pinpoint weak points in the supply chain and assign responsibilities to devise appropriate anti-theft mechanisms.[4]

The companies also believe that, at present, RFID at the case level has little influence on the worth of stolen products to thieves, the second category of attributes that determines the attractiveness of products to thieves. According to their view, tagging cases does not reduce the worth of products to thieves as it does not prevent them from selling the products afterwards.

The companies involved in the research did not yet consider how RFID, in combination with a unique identifier on each case and the remaining components of the EPCglobal Network, could help to fight theft. The EPCglobal Network (see chapter II.4) may transform the way companies prevent thieves from reintroducing stolen cases into the legitimate supply chain. If implemented by a larger number of companies, the system could allow potential buyers to check the history of a case, provided that the company has access to the data and all previous parties handling the product scan the RFID tags.[5]

1 *GMA, FMI (2003)*
2 *The companies do not expect that RFID at the pallet level can help to fight theft*
3 *Shrinkwrapping is common, especially for mixed pallets, to secure cases from falling-off during transportation*
4 *see Larsson and Qviberg (2004) for a case study on RFID for reuseable asset management at an IKEA distribution center. As the authors describe, IKEA suspects that shrinkage occurs while the reuseable containers are in the possession of the third-party logistics provider. Although IKEA can theoretically invoice the logistics provider for the loss, the company so far was not able to enforce the policy as it lacked data which could actually prove that the logistics provider is responsible.*
5 *Even a tracking & tracing solution is not entirely proof against fraud, as Staake et al. (2005) demonstrate*

Companies such as Retailers United believe that the full potential of RFID to combat theft lies in item-level tagging. There are several ways in which RFID at the item level may help companies to predict, detect, and prove theft.[1] Item-level tagging may also increase sales for certain products as it reduces the need for defensive merchandizing.[2]

Unsaleables

The companies that took part in the research reported that unsaleable rates in the supply chain were already quite low. The Retailer International DC examined during the research, for example, stated that product write-offs are below 0.005% for dry products and 0.1% for fresh products. The main cause for products becoming unsaleable is physical damage, and to a lesser extent product expiry.

RFID could help to reduce out-of-date products if it led to proper stock rotation and to an increase in inventory turns which would increase the remaining shelf life of products once they arrive at the store. The following discussion focuses on the first point, while chapter IV.5 dealt with the potential impact of RFID on inventory levels.

The policies to ensure proper stock rotation in the supply chain up to the store are similar among the companies. Both manufacturers attach logistics labels to their pallets after production. These logistics labels contain, among others, the expiry date encoded as EAN.UCC-128 barcode. The information is also available in the warehouse management system and ensures proper stock rotation. Process failures which lead to a misplacement of pallets are rare. In principle, the time delay before a company discovers the actual location of a pallet could be so great that the company cannot sell the products on the pallet any longer or sell them only at a discount. While true in theory, however, this risk is negligible in actual operations, according to Global Foods, even though the company does not use location barcodes to verify storage locations in its warehouse.

On the retail side, companies tend to manage inventory on a first-in-first-out (FIFO) basis, as the example from Retailer International shows. At the receiving gate, DC personnel still conduct manual checks of expiry dates. These dates, however, are not used by the inventory management system. These checks ensure that all products that enter the DC have a certain minimum remaining shelf life which can vary by product category. As long as manufacturers have established adequate practices for stock rotation in their warehouses and DCs, the FIFO rule ensures that products with the shortest remaining shelf life are shipped first.

The effort for manually checking expiry dates could be reduced already today if suppliers would consistently use GS1 standards for pallet labeling and information exchange. These standards allow manufacturers to incorporate expiry dates into dispatch advices sent as EDI messages or represent them as EAN.UCC-128 barcodes attached to pallets.[3] This information would also allow Retailer International to replace the FIFO policy and implement proper stock rotation rules based on actual expiry dates.

At the store level, once products arrive at the backroom, there is a risk that FIFO policies break down. For example, store employees may replenish the shelves with products from the latest delivery and not from existing backroom inventory. RFID at the case level, in combination with data on the unique case identifiers in each delivery, can prevent this practice. This application, however, is not yet a priority among retailers. Even Retailer International, which has started to roll-out RFID at the case level and is in the process of placing RFID readers between backroom and shop floor in order to improve product availability, is not yet considering the issue of stock rotation at the retail shelf.

1 *Koh et al. (2003b)*
2 *Lee et al. (2005)*
3 *EAN (2003). The latter is difficult to apply for mixed pallets*

Delivery errors from the retail DC are a potential further source for unsaleables as incoming store deliveries are not checked (see also chapter IV.3). Additional and interchanged cases lead to excess stock for some products which the store might not be able to sell before it expires. (Return deliveries from the store to the retail DC cause a lot of administrative effort and are therefore too expensive if discrepancies are low.) This may even lead to situations in which the total product value is lost, as evidence from Retailer International confirms. The different distribution lines (and individual stores) vary in the number of SKUs they sell, but receive a large number of products from the same DCs. If a store accidentally receives cases with an unlisted SKU, these products are often simply destroyed. RFID may help to avoid these errors or at least help to detect the errors during the store receiving process.

The field research offers little evidence of how RFID at the case and pallet level may prevent the physical damage of products. RFID is an identification technology and does not measure any environmental parameters.[1] The potential of RFID to prevent damage at the case and even pallet level may be limited to products that require specific storage conditions (e.g. chilled and refrigerated products). An example is the supply chain for fresh fish and meat at United Retailers and Retail Corp.[2] These products need to be kept at low temperatures through the entire supply chain.

Problem area	Relevant tagging level	Level of effect	Contextual factors	Complementarities
Theft	Case	Informational (stealability) Transformational (value to thieves)	Country-specific theft rates (+) Attractiveness of products to thieves (+) Product value (+)	Unique case identifiers Access to case history along supply chain
Unsaleables: Out-of-date products	Pallet (DC) Case (store)	Transformational – RFID as catalyst (DC) Transformational (store)	Perishability (+) Stock rotation at DC (-) Backroom inventory levels (+) Inspection intensity (-) Product value (+)	Expiry dates by pallet and case Inventory management system based on expiry dates at DC and between store backroom and shop floor
Unsaleables: Damage at store	Case Pallet during receiving process	Transformational	Need for specific storage conditions (+) Product value (+)	Information on storage conditions by SKU Separation of backroom inventory based on storage condition
Unsaleables: Excess stock	Case	Informational	Perishability (+) Inventory turnover (-)	-

Table IV-4: Analysis of RFID applications to reduce shrinkage

1 *There are, however, RFID tags with an additional temperature sensor and logger. These tags are usually active, and do not fall into the scope of this thesis.*

2 *The following example draws on information from a bachelor thesis by Manuel Ottinger*

As long as the products are in the truck or storage facility where temperature is centrally controlled, both retailers do not see any major problems in ensuring proper storage conditions. There can, however, be problems at the interfaces: For quality control purposes, the retailers equip selected deliveries with temperature loggers that record the temperatures history along the supply chain. Retail Corp found that employees did not always move products directly to the cool storage room after the products arrived at the store. The results indicated that temperatures sometimes increased to a level that could affect product quality.

At the case and pallet level, RFID tags can be used to generate alerts when delays in the storage process occur. This requires readers at the receiving gates and at the entrance to cold storage rooms. Additionally, the inventory management system needs to be able to distinguish between the different storage areas in the backroom and requires information on the storage conditions for each product.

IV.6.2 Analysis

Using RFID to reduce shrinkage can lead to informational as well as transformational effects (see Table IV 4). In most instances, case-level tagging is required. The research findings indicate that RFID may act as a catalyst for implementing stock rotation based on actual expiry dates.

In order to address most of the problem areas, companies need to make complementary investments. Companies may reduce the attractiveness of products to thieves once they can access the history of cases they receive. In order to prevent out-of-data products, some applications require additional information such as expiry dates by case.

Contextual factors that influence the benefit of RFID include differences in theft rates between countries and the value of products as well as perishability of products, the need for special storage conditions, inventory turnover, backroom inventory levels, and inspection intensity.

IV.7 Traceability

IV.7.1 Background

Traceability systems for products can help to (a) improve supply management through better tracking of products, (b) facilitate the tracing of products for food safety and quality, and (c) differentiate and market food products that require consumer trust in either product or process attributes (e.g. organically grown products).[1]

This section looks specifically at how RFID can reduce the cost of product recalls by limiting the amount of recalled products and by reducing recall processing cost (see Figure IV 8). In addition, RFID can also reduce the on-going data capturing cost for an existing traceability system by automating product identification which has already been described in chapter IV.5.

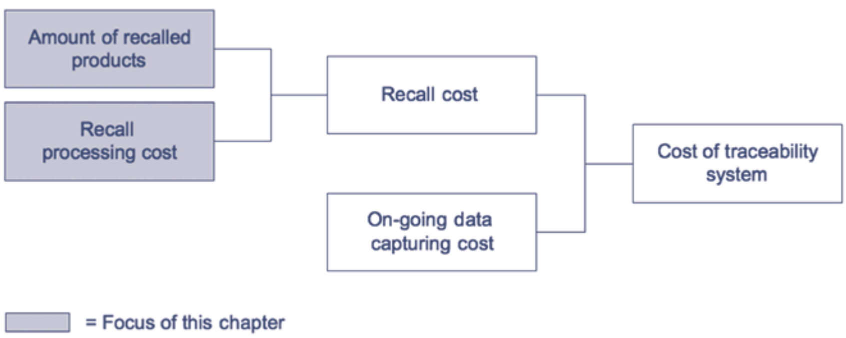

Figure IV-8: Selected factors that influence the cost of traceability systems

1 *FSA (2002), Golan et al. (2004)*

The impact of improved traceability has already been an implicit topic in a number of chapters. For example, chapter IV.6 describes how traceability of unique cases may improve stock rotation. Furthermore, there is little indication so far that companies will use RFID at the case and pallet level to improve product traceability in order to differentiate their products. Therefore, these aspects are not covered in this section.

RFID might offer opportunities for differentiation at the item level.[1] In Japan, Ishii Food, a medium-sized food producer, already allows its customers to retrieve detailed information on the company's products via the Internet. Consumers that enter the Guarantee-of-Quality telephone number and the quality assurance date printed on the product packaging into the "Open Ishii" website receive detailed information on ingredients, genetically-modified elements and allergens, as well as information on agricultural chemicals inspections and production locations.[2]

There is no single metric that can measure the performance of a traceability system. Performance measures include reliability, rapidity, precision, coherence, and cost.[3] Essentially, companies have to weigh the additional cost of an improved traceability system against the associated benefits (assuming that the companies already fulfill the legal requirements).
One potential financial benefit of improved traceability is lower recall costs. Recall costs may be calculated as the cost per recall times the risk of a recall. Furthermore, a company that believes superior traceability is a means to differentiate its offering from competitors may try to estimate the impact on sales and margins.

Government regulation is an important driver for the implementation of traceability systems. In 2002, the European Union passed a regulation[4] that demands traceability of food along the entire supply chain in order to improve consumer safety. The regulation became effective in January 2005.[5] Article 3 of the document defines traceability as "the ability to trace and follow a food, feed, food-producing animal or substance intended to be, or expected to be incorporated into a food or feed, through all stages of production, processing and distribution." (An overview of alternative definitions for traceability is provided by van Dorp[6].) Specifically, articles 18 and 19 describe the requirements for traceability systems. Companies in the food business (whether they are producers, processors or distributors) have to record from whom they receive food products and to which businesses they supply food products. This requirement has two implications: First, companies do not have to trace their products through the entire supply chain. They are responsible only for their own operations and the interface with the adjacent trading partner. Second, retailers are not required to record to which consumers they sell products, as consumers are explicitly excluded. If a company has reason to believe that there are quality problems, it has to initiate procedures to withdraw the products under consideration from the market, which can include informing the consumer. It also has to inform the authorities.

The EU regulation does not specify what the traceability system has to look like. For example, it does not specify how companies should define batch sizes. Therefore, trade organizations such as ECR Europe[7], CIES[8], and CCG/ECR D-A-CH[9] have developed traceability guidelines that specifically address the EU regulation. General traceability guidelines have also been developed by EAN International[10]. The documents advocate the use of different elements of the EAN.UCC system, specifically identification schemes such as GTIN, GLN, SSCC, and application identifiers; data representation mechanisms such as EAN.UCC-13 and -128 barcodes (and potentially RFID in the future), and EDI messages. Tracing of pallets can be ensured by applying unique identifiers such as SSCCs.

1 *FSA (2002), Golan et al. (2004)see e.g. Pretzel (2005)*
2 *Ogawa et al. (2003)*
3 *EAN (2003)*
4 *EU (2002). The EU regulation 178/2002 is not the only rule that deals with consumer safety and food. There are, for example, special rules for meat and fish.*
5 *As this thesis has involved only European companies, I only consider the EU regulation in the following. In the US, an FDA regulation requires companies to install traceability systems within 12 months of December 2004. The background of this regulation is the risk of bioterrorism (see e.g. FDA (2004b)).*
6 *van Dorp (2002)*
7 *ECR Europe (2004)*
8 *CIES (2004a)*
9 *ECR D-A-CH, CCG (2004)*
10 *EAN (2003)*

In 2004, a survey[1] of companies in the food sector found that more than 90% of manufacturers were installing traceability systems. These companies said that internal quality control and retailer demands are more important to them than the EU regulation. In contrast to manufacturers, only 35% of retailers stated that they were investing in traceability systems. The study concludes that retailers seem to rely on manufacturers' traceability systems or believe that their existing systems are sufficient.

There are certain situations in which traceability becomes difficult. One example is order picking.[2] In principle, companies can ensure traceability in the picking process by recording the SSCC of any pallet from which products have been taken and associating it with the SSCC of the mixed pallets on which the product is placed. (Alternatively, employees may scan the GTIN of the picked cases and manually record a lot code.) Such a traceability system, however, requires a large amount of manual data capturing. An alternative approach is to use a time window-based traceability system.[3] Companies, for example, record the time when a pallet is placed in the picking zone. The traceability system than infers that any mixed pallet assembled in the time interval until the next pallet is put there contains products from this pallet.

Although traceability systems allow companies to issue targeted recalls, the success of these systems in the practical application can be limited. There seems to be a tendency among retailers to remove more products than required in case of a recall. In fact, one of the recommendations included in the CCG / ECR D-A-CH guidelines states that retailers should only send back those products that have the same GTIN as the recalled product, and, if possible, limit the returns to the specific batches that are affected.[4] RFID at the case level, which can reduce the data capturing effort and lower the risk of mixing up cases, may help to limit the amount of products that retailers return to manufacturer or destroy compared with today.

IV.7.2 Examples from field research

In general, the companies involved in the research stated that the legal requirements regarding traceability do not constitute a problem.[5] The processes are described are exemplified for Global Foods and Retailer International.

Current process

As part of its internal quality process, Global Foods had already installed adequate systems both in its upstream and downstream operations well before the EU legislation. The company's system closely resembles the systems recommended by industry organizations mentioned above. Throughout its downstream operations, it uses logistics labels at the pallet level that include an SSCC, encoded in an EAN.UCC-128 barcode. Employees can get information on the content of the pallet, including batch number, via the SSCC. The logistics labels on full pallets can also contain information on the batch in plain writing and encoded in an EAN.UCC-128[6]. The size of a batch differs by product. Criteria that the company uses to distinguish batches include production times or specific customer orders.

According to Retailer International, one challenge at the present time is to implement consistent practices across the industry. In upstream operations, for example, not all suppliers employ pallet labels. The company therefore attaches separate barcode labels to pallets that facilitate traceability. In their picking operations, both companies use a time window-based approach to ensure traceability.

1 *Lebensmittel Zeitung, Deloitte (2004)*
2 *Another challenge for traceability are continuous production processes when companies want to trace the origin of the ingredients that went into the final products. In these instances, traceability via unique identifiers breaks down. Here, companies can apply specific rules for defining production batches in order to ensure traceability (ECR Europe 2004).*
3 *ECR Europe (2004)*
4 *ECR D-A-CH, CCG (2004)*
5 *The following example draws on information from a diploma thesis by Alexander Mirow*
6 *The EAN.UCC-128 provides a number of so-called application identifiers that indicate what type of information is encoded in the barcode. Examples include the unique identifier (SSCC), batch number, and expiry dates.*

At the time of the research, Retailer International stated that it could take the company several hours to provide traceability information.[1] There was no standard process and IT application in place that allowed the company to quickly retrieve the existing traceability information. The company saw this as an area where further investments were needed.

Process with RFID

Global Foods did not expect that RFID would improve traceability. The company has so far only looked at pallet level tagging. According to the company, traceability would break down if employees at the DC put the wrong logistics label on a pallet, but reckoned that this risk essentially stayed the same with RFID, assuming that companies integrate the RFID tag into the logistics label.[2]

In contrast to Global Foods, Retailer International explicitly mentions improved traceability as one of the benefits from RFID. The company envisions that RFID could potentially enable the traceability of individual cases. This could lead to more targeted recalls as such an approach does not require any "safety margin" compared to a time window-based approach. Furthermore, it becomes easier for employees to distinguish cases that are affected from those that are not affected. This is especially relevant when cases become the relevant handling unit, for example in the store. Instead of manually comparing batch numbers printed on cases or individual products, employees can simply scan the RFID tag on the case.

This approach is likely to limit the amount of products that are removed, especially in cases where the products do not directly pose a health risk. Reasons for a recall can, for example, be as prosaic as low printing quality on the packaging. In these instances, more complete traceability information may indeed limit the number of recalled products. If there is a risk to consumers, however, or a company has made it public that it is recalling a product, Retailer International states that retailers are likely to remove from the shelf all products of that SKU and possibly even other SKUs from the same supplier and return them to the manufacturer. One reason for this is that retailers apparently do not want to risk that the recall harms consumer confidence in their operations.[3] Consumers may not know exactly, for example, which SKU has been recalled and that only a certain batch is affected. If consumers still see products of the manufacturer in the shelf, they might incorrectly assume that the retailer has failed to remove the recalled products.

RFID at the case level can also reduce the cost of processing recalls in existing traceability systems as it eliminates the need for manually counting the number of cases that a store returns.

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1 *The interviews on which this paragraph is based were conducted in mid-2003*

2 *The company sees employee education as the main way to prevent these errors*

3 *Producers may also act cautiously in case of quality problems. Internally, Food Manufacturers, for example, has discussed whether to reduce batch sizes, but has decided against it. The reason was that the company would recall a larger quantity than seems necessary in the first place just to make sure that the recall does not miss any products.*

IV.7.3 Analysis

RFID at the case level can enable companies to replace the current time window-based traceability systems, thereby reducing the amount of recalled products and potentially increasing differentiation from competitors (see Table IV 5). Traceability systems based on unique case identifiers require that the companies can associate the unique case identifier with a specific batch.

Problem area	Relevant tagging level	Level of effect	Contextual factors	Complementarities
Amount of products recalled	Case	Transformational	Accuracy of time window-based traceability systems (-) Publicity of recall (-) Potential health risk of recalled product (-) Qualification of store personnel (-) Backroom inventory inventory level (+)	Association of batch number to unique case identifier Batch size reduction
Recall processing cost	Case	Automational	Frequency of recalls (+) Amount of products recalled (+)	-

Table IV-5: Analysis of RFID applications to improve traceability

The performance of the RFID-based traceability system (measured as the amount of products recalled) can improve if companies reduce batch sizes. Assume, for example, that currently one pallet with 100 cases equals one batch and that the manufacturer initiates a recall for this batch. The manufacturer knows exactly which retailer has received the pallet. This retailer may have sent one case each to 100 of its stores. Each of the stores is assumed to have two cases of the product in its inventory, one affected, one unaffected. As the retailer does not want to risk that some products are accidentally not removed, the company may decide to recall the entire 200 cases. With RFID, the retailer can check whether the affected case is still in the backroom. If the content of the case is not yet on the shelf, it may instruct its stores to only return the one case. If the chance of the case being in the stockroom is 50%, this reduces the recall amount to 150 cases. Now assume that the manufacturer reduces the batch size to half a pallet. With a time window-based approach, there is no way the retailer can decide which of the 100 stores has received products from each batch and therefore still has to recall 200 cases. With RFID, the retailer could make this distinction and recall only 75 cases. Reducing the batch size in combination with RFID, therefore, could cut the amount of recalled products in half.

Factors that can influence the value of improved traceability include the accuracy of the current traceability system, whether recalls are public or involve a health risk (which would increase the chance that retailers remove products rather indiscriminately from the store), and the relevance of detailed traceability information to consumers.

IV.8 Production planning, promotion execution, and product diversion

The following chapter describes the potential impact of RFID on production planning, promotion execution, and product diversion. The benefits are only treated briefly as they were not among the benefits that the companies involved in the research focused on.

IV.8.1 Production planning

For common products and during normal operations, manufacturers of fast-moving consumer goods still employ make-to-stock policies in production. Despite investments in flexibility, factory warehouses or other storage facilities still act as decoupling points (see chapter II.3). Manufacturers therefore have to forecast demand in order to plan production.
There are several ways in which information sharing, channel alignment and operational efficiency can contribute to better forecasting. This includes making demand and inventory data available to upstream suppliers, introducing VMI concepts, and reducing lead times.[1]

As Table II 2 showed, improved production planning is a frequently mentioned benefit of RFID. However, none of the companies involved in the research could provide any details on how RFID would affect this process.[2] Interestingly, while Metro mentions this benefit in its official guidelines for the RFID roll-out[3], a detailed business case study that the company conducted with Procter & Gamble[4] lists improved production planning neither as a tangible nor intangible benefit.

It seems that sources claiming that RFID will improve forecasting and production planning tend to confuse data acquisition and data sharing. Lapide[5], for example, states that "RFID tagging will make it easier to assemble vast quantities of accurate downstream data as an input to this type of multi-tier forecasting process. The data can include warehouse inventories and withdrawals, inventory replenishments, and product consumption."[6] The statement fails to recognize that – with the exception of data on the movement of products between store backroom and sales floor – retailers with modern warehouse and store inventory management systems already possess the data. Lee et al.[7] simulate a specific supply chain in which the manufacturer is responsible for replenishing the retail DC. They show that availability of data on inventory levels at the DC (in addition to POS data) can eliminate stock-outs and reduce inventory levels at the retail DC. However, although the authors discuss the potential improvements under the label of RFID, they have to acknowledge that the relevant data already exists today.

RFID may, however, act as a catalyst that leads retailers to share more information with suppliers. Sharing of data on consumer demand, for instance, is still limited. Global Foods, for example, states that it receives POS data from some retailers, but that it has not yet reached a critical mass so that the data would actually influence production schedules.

RFID may, however, act as a catalyst that leads retailers to share more information with suppliers. Sharing of data on consumer demand, for instance, is still limited. Global Foods, for example, states that it receives POS data from some retailers, but that it has not yet reached a critical mass so that the data would actually influence production schedules.

1 *Lee et al. (1997)*
2 *As noted in chapter IV.5, the companies involved in the research do not expect RFID at the case and pallet level to shorten lead times or lead to an increase in the number of VMI programs*
3 *Metro (2005a)*
4 *Ebling, Scharr (2004)*
5 *Lapide (2004), p. 18*
6 *In order to gather data on product consumption, RFID at the item level is of course required*
7 *Lee et al. (2004)*

Retailers may provide manufacturers with access to additional data on product movement in order to – at least partly – compensate them for the RFID tag cost. Although, to my knowledge, this proposition has not yet been voiced explicitly in the discussion on RFID, the idea sounds plausible. A statement from Lapide[1] supports this view: "Wal-Mart is promising its suppliers information on products as they arrive and leave their warehouses, stores, and store stockrooms, in addition to the Point-of-Sale (POS) data it currently provides." The point also receives some support from a more theoretical perspective: In one of the seminal articles on the bullwhip effect, Lee et al.[2], among others, have suggested that manufacturers may offer discounts to those retailers that offer to share data.

So while RFID is not necessary for providing this information, it can nevertheless increase the quality of the data that the retailer provides. Apart from increased accuracy, RFID at the case level can provide manufacturers with a more complete picture of product movement between backroom and shop floor. However, while this data may be of significant value in store operations (see chapter IV.3), there is some dispute whether this data will change upstream processes.[3] The incremental value of higher data quality is likely to deteriorate along the supply chain. In order to ensure that production reflects actual demand, for example, manufacturers may not gain much from data on the movement of products between store backroom an shop floor when they already receive POS data.

IV.8.2 Promotion execution

A GMA study[4] on OOS in DSD categories found that stock-outs almost double for promoted products. As promotional items are often stored in the backroom, RFID at the case level may be especially valuable to retailers that conduct frequent promotions (see also chapter IV.3). Additionally, RFID at the case level and potentially even the pallet level can eliminate the risk that consumers come to the store to buy an advertised product the day the promotion starts and cannot yet find it on the shop floor.[5] Evidence from the field research indicates that retailers tend to distribute promotional products in advance of the promotion. Store employees then have to make sure that the products become available the day the promotion starts. A reader between backroom and store floor could allow retailers to implement an application that sends an alert when there are delays in the process.

While these applications may have some value, they are, in essence, simple extensions to the general backroom replenishment process based on RFID. Beyond this, none of the companies involved in the research currently envisions any specific scenarios on how RFID at the case and pallet level could improve promotion execution. Food Manufacturers mentioned that it would be interested in receiving data on whether the product the customer bought came from the standard shelf or from a promotional display, and this would require item-level tagging.

IV.8.3 Product diversion

Product diversion can be defined as the "undesired proactive re-routing by third parties to arbitrage price differences across national boundaries and across sales channels by 'short-circuiting' the supply chain"[6]. The phenomenon is somewhat related to trading in gray markets – markets "in which a firm's products are sold or resold through unauthorized dealers"[7].

I am not aware of any studies that quantify the magnitude of diversion in the FMCG industry. While selected publications mentioned that RFID can help to mitigate the effect of product diversion, the companies in the research sample did not mention this area as a priority.

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1 *Lapide (2004), p. 18*
2 *Lee et al. (1997)*
3 *GMA (2004)*
4 *GMA (2002b)*
5 *RFID may also be used in the same way to ensure that store employees move new products onto the shop floor at the right time (see e.g. RFID Journal (2005m))*
6 *Lee et al. (2005), p. 11*
7 *Antia et al. (2004), p. 63*

RFID could help to detect product diversion, for example, if manufacturers could retrieve the unique case identifiers[1] of the products that retailers have in their DCs and stores. However, as long as it does not become a prerequisite for doing business to share data at this level of detail, the potential of RFID may be limited. Given current industry practices, retailers – especially those that engage in product diversion – are unlikely to share information at that level of detail (see also chapter IV.6 on shrinkage). Furthermore, companies that do not want to be found out can still remove the RFID tag from the case, destroy it, or make it unreadable.

Antia et al.[2] describe the difficulties two companies faced in their technology-driven attempts to fight gray market activities: Already in the late-1980s, Lotus put serial numbers on the packaging of its products. Gray marketers reacted by simply defacing the number. Puma experimented with special fibers in the laces of its sports shoes, but did not take into account that actors in the gray market started to sell shoes without laces.

IV.8.4 Analysis

Table IV 6 summarizes the potential applications of RFID at the case and pallet for the remaining benefits that were not described in the previous chapters.

Problem area	Relevant tagging	Level of effect	Contextual factors	Complementarities
Production planning: Availability of downstream data on inventory levels and product movement	Case and pallet	Transformational – RFID as catalyst	Flexibility of production (+)	Link between trading partners to exchange information (e.g. retailer extranet)
Promotion execution: Movement of products onto shop floor	Case, potentially also pallet	Transformational	Promotional intensity (+) Reliability of store processes (-)	Link between promotional data and unique case (potentially pallet) identifiers
Product diversion	Case	Transformational	Level of diversion (+)	Sharing of traceability information across trading partners

Table IV-6: Analysis of RFID applications to improve production planning and promotion execution and to reduce product diversion

1 *IBM (2002b) mentions reduced product diversion as a potential benefit of RFID at the pallet level. However, the unique identifier on a pallet is easy to change by applying a new logistics label to an unchanged pallet, and changes anyway once the content of the pallet changes (e.g. during mixed-pallet picking).*

2 *Antia et al. (2004)*

With the exception of promotion execution, the research found no evidence that companies will derive any benefits from RFID in the short- to medium-term. RFID may, however, act as a catalyst that increases the level of information sharing in the supply chain, which can benefit manufacturers in areas such as production planning. Those manufacturers that have invested in flexible production systems and can adjust production volume and mix based on actual demand may benefit particularly from the additional information. In the longer term, assuming that industry practices change, RFID at the case level may become an effective means to prevent product diversion.

IV.9 Discussion and summary

Relevance of benefits

RFID at the case and pallet level can mitigate a number of significant problems in today's FMCG supply chain and increase overall efficiency. The experience from the field research indicates that companies in the FMCG industry currently focus on only a few of the potential benefits of RFID that were identified in chapter II.6. This includes out-of-stock, order reconciliation, and handling efficiency.

The technology, however, is no panacea and will not fully eliminate these problems. For example, retailers and manufacturers spend considerable time on order reconciliation. As industry data points out, most of the problems with order accuracy are related to disputes over prices, which RFID is unlikely to affect. Here, other initiatives such as GDS might have a bigger impact.

There are a number of instances (theft, unsaleables, traceability) in which RFID at the case and pallet level can lead to smaller improvements, and others which the companies involved in the research did not regard as relevant. The latter includes inventory management, production planning, promotion execution, and product diversion.

Automational, informational and transformational effects

Many of the performance improvements that the companies explicitly mentioned rely on the informational effect of RFID. The companies also intend to use RFID in order to reduce the manual data capturing effort (automational effects). This means that, as of today, retailers and manufacturers primarily regard RFID as an implementer that can help them to improve the level of data quality and reduce direct labour cost in current processes. There are a number of examples (see Figure IV 9) where RFID might enable new processes, i.e. lead to transformational effects, but these applications are often still rather vague ideas on how to use the technology than specific plans for implementation. This does not imply, however, that companies are not going to realize these applications in the medium to long term. One notable exception is the replenishment-from-the-backroom process which is a high priority for companies such as Retailer International.

RFID as catalyst

The field research points to a new role of RFID that has not yet been recognized in the literature: In some instances, RFID acts as a catalyst. This means that it helps companies to realize benefits in the supply chain that do not rest on the capabilities of RFID. RFID acts as a catalyst, for example, when Metro requires that its suppliers adopt dispatch advices and SSCC in conjunction with the introduction of RFID or when Wal-Mart increases the amount of information it shares with suppliers.

This argument can explain why some companies mention benefits in conjunction with the adoption of RFID that do not rely on the capabilities of RFID. It would be short-sighted to simply claim that companies act irrationally and do not understand the technology's capabilities and its limitations.

The question remains why a catalyst is needed in the first place. Research on management fashions offers some insights. Abrahamson[1] defines management fashions as "transitory collective beliefs that certain management techniques are at the forefront of management progress." He argues that management fashions can play an important role in drawing attention to certain subjects that companies have neglected. It can be argued that RFID does exactly that.

Examples	Role of RFID	Description
Replenishment-from-the-backroom process Automatic order reconciliation based on "proof of delivery" Product tracing based on unique case identifiers	**RFID as enabler**	RFID allows companies to realize new processes or implement new decision rules that were not economically feasible with previous technology
Introduction of dispatch advices Increased information sharing between trading partners	**RFID as catalyst**	RFID supports the introduction of new processes, but the processes themselves do not necessarily require RFID

Figure IV-9: Examples of transformational effects of RFID

A catalyst can be especially valuable when more than one party is involved and cost and benefits are unevenly distributed. The status quo may prevail unless an external impetus forces the parties to reconsider the situation and start to discuss how they can jointly reach a higher level of efficiency in the supply chain. This may include some form of redistribution of cost and benefits between parties, as the example of information sharing illustrates. Retailers are, for example, aware that the information on inventory levels at their stores and DC and on the internal movement of products can be of value to manufacturers. However, there is still a reluctance to share this information (see chapter II.3), and retailers might not want to provide the information for free. A catalyst such as RFID may lead retailers to rethink their information sharing policies. Retailers may also use information sharing as a way to compensate manufacturers for the cost of RFID tags. Providing access to this information has some advantages for retailers compared to financial subsidies, including the fact that it does not affect cash flow. Furthermore, the data has no predetermined value, and manufacturers need to find ways to derive value from the data in their process which may also benefit retailers. Figure IV 9 mentions a number of transformational effects of RFID, distinguishing between the role of RFID as enabler and catalyst.

1 *Abrahamson (1996), p. 254*

Complementarities

The examples show that companies need to consider complementarities when examining the potential of RFID. It is useful to think of RFID as one component of a control system (see chapter III.5). Companies that want to realize the benefits of RFID may need to alter additional components of their control systems before they can take advantage of RFID.

It seems that the necessary investments in complementarities increase – not necessarily in their amount[1], but in their complexity[2] – when companies intend to realize new, RFID-enabled processes. For example, retailers that want to improve product availability by introducing a separation of backroom and shop floor inventory may need to change their inventory management system so that it can distinguish between the two storage locations, update their inventory management system more frequently with POS data, implement rules that specify when the system needs to generate alerts, install wireless networks in their stores and equip store employees with devices that allow them to receive the alerts, and finally define processes that ensure that employees can replenish the shelves in a timely manner. Realizing transformational effects can additionally require changes not only in internal systems and processes, but also inter-organizational or even industry-wide adaptation. Trading partners, for example, may need to install systems that automatically reconcile order discrepancies based on RFID data as proof of delivery. In order to prevent stolen products re-entering the legal supply chain or companies engaging in product diversion, the companies in the FMCG industry might have to agree to trace unique cases through the entire supply chain and give trading partners selected access to this information.

This contrasts with certain automational and informational effects that companies can realize, for instance, by simply substituting barcode technology or other manual data capturing with RFID. An example of the former is unique pallet identification, and for the latter delivery accuracy checks.

Type of complementarity	Examples
Technologies and practices that are necessary in order to realize new processes enabled by RFID and not yet common in the FMCG industry	Unique identifiers at case level Expiry dates and lot number by case Distinction between backroom and store inventory in store inventory management systems
Technologies and practices that are common in the FMCG industry, but have not been implemented industry-wide	Advance shipping notes Warehouse management systems Store inventory management systems Automatic store ordering Wireless networks in DCs and stores

Table IV-7: Examples of complementarities to RFID at the case and pallet level

1 *One obvious complementary investment in order to take advantage of RFID tags on objects is that companies have to install RFID readers at those points where they want to identify objects. At current reader prices, this can result in substantial hardware cost.*

2 *The Oxford English Dictionary (www.oed.com) defines complex, as opposed to simple, as "[c]onsisting of or comprehending various parts united or connected together"*

The research also shows that some companies lack certain complementarities that would allow them to take advantage of RFID as implementer. For example, Retail Corp has not yet implemented an automatic store ordering system, partly due to the lack of an inventory management system that keeps track of stock levels at its stores. Until the company has implemented these systems, the impact of RFID on product availability is limited to the direct effect of fewer delivery errors. The indirect effect of fewer delivery errors via higher inventory record accuracy does not yet play a role for Retail Corp, simply because the company as of today does not keep any inventory records at the store level.

Table IV 7 lists some complementarities to RFID at the case and pallet level. The table distinguishes between two types of complementarities: those technologies and practices that are necessary in order to realize new processes enabled by RFID and not yet common in the FMCG industry, and those that are already common in the FMCG industry, but have not been implemented industry-wide. It is important to note that the former technologies and practices often build upon the latter.

Contextual factors

The previous sections identified contextual factors that affect the impact of RFID at the case and pallet level on process performance. Figure IV 10 lists several of these factors and arranges them into four categories.

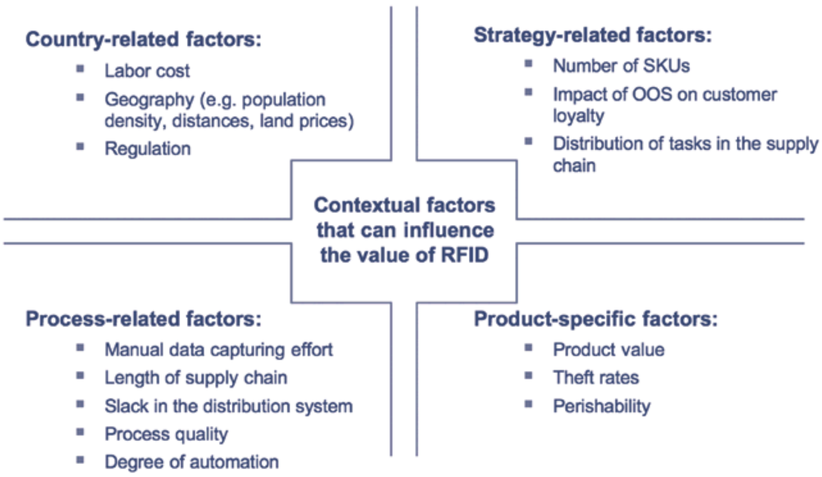

Figure IV-10: Selected contextual factors that can influence the value of RFID at the case and pallet level

Country-related factors influence the value of RFID through differences in labor cost, geography, and regulation:

- *Labor cost:* The higher the labor cost per hour, the more expensive manual activities become. Using RFID to reduce data acquisition cost may be more suitable in areas with high labor cost.

- *Geography:* Geographical factors may affect the value of RFID in different directions. On the one hand, high population density and land prices as well as short distances between stores favour frequent deliveries. An example is Seven-Eleven in Japan with lead times of less than one day and up to three deliveries a day.[2] In a JIT environment, there is less margin for error. Furthermore, more and smaller deliveries need to be handled which leads to more data being processed. Hence, the value of RFID is likely to be higher in countries such as Japan than in countries such as the US. On the other hand, as the example from Wal-Mart in chapter IV.3 suggests, even very efficient retailers may tend to store more products in the backroom if distances are high, which would increase the potential value of RFID for shelf replenishment from the backroom.

1 *One could argue that RFID may act as a catalyst for implementing an ASO system. However, for Retail Corp, the question of whether to invest in such a system was seen as independent from any potential introduction of RFID.*

2 *Bell, Hogan (2004)*

- Regulation: The tighter the regulation on aspects such as food safety, the more important is complete data on, for example, the origins of a product. An example of regulation that might drive the adoption of RFID is the EU regulation concerning traceability.

Process-related factors refer to the use of certain supply chain practices:

- Manual data capturing effort: Companies differ in the effort they invest in manual data capturing, including identification of objects, counting, and manual data entry. The higher the current effort, the higher the potential value of RFID to reduce data capturing cost.

- Length of the supply chain: The more stages are involved in the distribution of a product, the more need for data capturing and the higher the risk of error. RFID may provide more value in long supply chains.

- Slack in the distribution system: In general, the less slack in the distribution system, the greater the need for reliable processes and the greater the dependency of supply chain processes on high data quality. This makes RFID more attractive. Slack is reduced, for example, when companies eliminate buffers (e.g. by reducing safety stock) and interlink their operations (e.g. by adopting cross docking).

- Degree of automation: The higher the degree of automation, the lower the potential value of RFID. Highly automated warehousing systems do not require frequent manual identification of objects, and there is little potential for human error.

- Process quality: The lower the process quality, the higher the potential value of RFID. In any situation, however, it needs to be assessed whether there is no other alternative available that can improve process quality at lower cost.

Strategy-related factors include:

- Product density: The more SKUs a store carries in relation to its size, the less shelf space is available for each product. This increases the frequency with which employees have to replenish shelves. Retailers may either store these products in the backroom or deliver smaller quantities. In both cases, the frequency with which each of the processes is carried out and, hence, the frequency of delays and errors, increases. Furthermore, if employees replenish shelves from the backroom, the risk of error increases with the number of products that an employee needs to monitor.

- Impact of OOS on consumer loyalty: RFID can improve product availability. The impact of stock-outs on sales depends on consumer reaction. Some retailers and manufacturers are likely to be more adversely affected by stock-outs as the risk that consumers switch stores or brands, respectively, can differ. The higher the negative impact of stock-outs on consumer loyalty, the more beneficial is RFID.

- Distribution of tasks in the supply chain: The larger the share of distribution activities that is performed by the manufacturer, the higher the potential value of RFID in the supply chain. For example, it takes more time at the retail DC (or the store, in case of DSD) to check a mixed pallet than a full pallet. In contrast, self-distributing retailers that conduct picking operations internally tend not to count mixed pallets as there is no transfer of ownership at the store receiving gate.

Characteristics of the product can also influence the value of RFID. This includes:

- Product value and margin: The higher the value of the product, the higher the loss if a product is stolen or becomes unsaleable. Similarly, the higher the margin, the higher the loss if a product is not available for sale.

- Theft rates: The more products that are stolen, the higher the potential gain from RFID. This assumes that the technology can help companies to directly prevent theft or to detect weak points in the supply chain.

- Perishability: RFID can be a means to ensure that store employees replenish the products with the shortest remaining shelf life first. The shorter the shelf life of a product, the higher the risk that failures in proper stock rotation lead to unsaleables.

The contextual factors are interrelated. These interrelationships can lead to situations in which one factor affects other factors that indirectly work in the opposite direction and partly offset or even (over-)compensate the hypothesized relationship. Consider, for example, the impact of product value on the sales loss from stock-outs. For a given OOS level, the higher the value of a product, the higher the sales loss if the product is not available. However, as DeHoratius and Raman[1] show, the higher the value of a product, the more accurate the inventory records. This means that, potentially, stock-outs caused by inaccurate inventory information are much lower for high-value products than for others (see Figure IV 11).

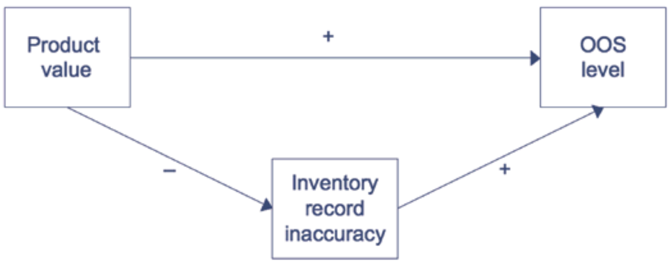

Figure IV-11: Example of direct and indirect effect of a contextual factor that work in opposite directions

Summary

Based on the results of projects with a number of companies in the FMCG industry, this chapter has described how companies intend to apply RFID at the case and pallet level. The companies see RFID technology both as an implementer and enabler. They currently focus mainly on informational and automational effects of RFID. The number of new, RFID-enabled processes that companies actually intend to realize seems still limited, however. Not all potential benefits of RFID are seen as equally important. The companies currently prioritize applications that lead to benefits in areas such as product availability, order reconciliation and handling efficiency.

The project work highlighted that the adoption of RFID might foster changes in the FMCG industry related to RFID, but for which RFID is not a prerequisite. In these instances, RFID acts as a catalyst and may lead to additional transformational effects. Examples include the introduction of dispatch advices and increased data sharing by retailers. One possible explanation for this phenomenon is that RFID draws management attention to certain neglected areas between companies.
The chapter identified a number of contextual factors as well as complementary technologies and practices that can affect the value of RFID. The research points out that, due to country-, process-, strategy- and product-related circumstances, some companies may find it more difficult to benefit from RFID, while others may have to invest in complementarities before they see an improvement in operational performance.

1 *DeHoratius, Raman (2004)*

The following chapter shows how companies can quantify the potential benefits of RFID at the case and pallet level. It provides one example each for an automational, informational and transformational effect. As increased product availability is among the most frequently mentioned benefits of RFID at the case and pallet level (see chapter II.6), the models that deal with the informational and transformational effects of RFID focus on this issue.

V.1 Quantification of benefits

It is difficult to generalize about the potential cost saving and revenue potentials from the introduction of new technologies in retailing. To a large extent, the impact of a new technology depends on contextual factors and the availability of complements. The previous chapter has highlighted this aspect. This thesis therefore focuses on the identification of potential benefits, analyzes how companies intend to realize these benefits, and develops exemplary mathematical models to illustrate the potential value of RFID data, but does not provide any specific estimates regarding the magnitude of benefits.

Mathematical models that allow companies to quantify the potential benefits from RFID are of great practical relevance. Several of the companies involved in the research tended to classify, for example, improved product availability as an intangible benefit of RFID and valued the benefit at zero. This severely affected the companies' assessment of the advantageousness of RFID. Other companies attached a value to this benefit, but could not provide any explanation as to how they derived that value.

The challenge of quantifying the benefits from RFID applies mainly to informational and transformational effects that result from higher data quality. Determining the opportunity cost of poor data quality can be difficult, but improves the chances for getting support for RFID activities and enables the monitoring of progress. As Dale and Plunkett[1] state for quality in general: "A knowledge of quality costs helps managers to justify the investment in quality improvement and assists them in monitoring the effectiveness of the efforts made. Quality costing expresses an organization's quality performance in the language of the board, the senior management team, shareholders and financial institutions – money."

V.2 Automational effect: RFID and the order reconciliation process

The extent to which tangible and intangible benefits are prevalent differs between investments. Investments aiming at efficiency are likely to have a high proportion of tangible benefits. In these instances, traditional cost/benefit analysis is likely to work well.[2]

Benefits resulting from automational effects are highly tangible as one data capturing technology is simply substituted for another. In the case of the receiving process, a company can calculate the potential benefit of RFID at the case and pallet level by estimating the number of pallets a company receives each year from external suppliers and the time spent to identify the pallet, check the delivery quantity, and do random tests of expiry dates. Depending on the process, companies may use slightly different or additional parameters. Companies may also apply more detailed data, for example, by distinguishing between mixed and full pallets, receiving at the retail DC or store, or different types of supplier. For example, companies that conduct supplier evaluations may find that the effort for order reconciliation differs, depending on supplier delivery performance. There are different methods for deriving the estimates, including time-and-motion studies, interviews with floor-level employees and supervisors, and data from a company's enterprise resource planning (ERP) system.

1 *Dale, Plunkett (1991)*
2 *Whiting et al. (1996)*

The analysis seems straightforward, but the results nevertheless need to be regarded with care. One question that arises is, for example, whether the savings, which often amount to only a few seconds, add up so that a company can actually save personnel in the process. Furthermore, there might be alternatives to RFID in order to improve the process. Finally, a company needs to decide whether it wants to include benefits that arise from RFID acting as a catalyst as, for instance, Metro and Procter & Gamble have done.[1]

The following example (see Table V 1) highlights how the decision whether or not to include the role of RFID as a catalyst can change the assessment of benefits from RFID. Consider the receiving process at a retail DC (see chapter IV.4). In order to verify delivery quantities, DC personnel need to check the number of products on a pallet. This process involves a number of steps, including counting the number of cases, finding the product in the delivery documentation (or vice versa), comparing the physical quantity with the quantity according to the delivery documentation, and handling the delivery documentation.

Activity	**Process alternatives**			
	Visual inspection and paper-based delivery note	Visual inspection and dispatch advice	RFID at case level and paper-based delivery note	RFID at case level and dispatch advice
Count no. of cases by product	3 min	3 min	0 min	0 min
Find product in delivery documentation	1 min	1 min	0 min	0 min
Compare physical quantity with quantity in delivery documentation	1min	1 min	1 min	0 min
Handle paper-based delivery note	2 min	0 min	2 min	0 min
Total	**7 min**	**5 min**	**3 min**	**0 min**

Table V-1:
RFID as catalyst – Quantity checks at receiving gate

Table 5-1 assigns fictitious values to each of the activities. There are four alternative processes, resulting from the fact that quantity checks are either done via visual inspection or via RFID at the case level, and that the company receives the delivery documentation either paper-based or electronically via dispatch advices. As dispatch advices are not widely adopted (see chapter II.3), the current process often resembles the first scenario with visual inspection and paper-based delivery notes. To check each pallet, the retailer needs seven minutes. If the company already received dispatch advices, the effort would drop by two minutes to five minutes as the handling effort for paper-based delivery notes is eliminated. Introducing RFID at the case level could potentially help to automate the entire checking process and save the remaining five minutes.

[1] *see Ebling, Scharr (2004)*

A number of retailers, including the retailers in the research sample, have been trying to pursue electronic delivery documentation for several years, with mixed results. In order to drive adoption, Metro has made it mandatory for suppliers to implement electronic dispatch advices before they start with RFID tagging.[1] The company effectively uses RFID as a catalyst to drive a practice that it has found difficult to introduce before.

A company that includes the benefit from adopting dispatch advices in the business case for RFID can present higher potential savings than a company that only considers the benefits that flow directly from RFID. The former approach can make it easier to justify an investment in RFID. While there exist good reasons to include these savings, some of the retailers choose not do follow this approach and took only those savings into account that resulted from the capabilities of RFID.[2] Instead of a savings potential of seven minutes, the latter companies assumed that RFID was introduced after they had finished the roll-out of dispatch advices and calculated with five minutes only. While the difference does not sound much, incorporating the additional two minutes means that the benefits associated with the roll-out of RFID increase by 40%. A company that wanted to justify the introduction of RFID at the case level with improvements in order reconciliation may find that this difference determines whether the business case is positive or negative.[3]

V.3 Informational effect: RFID and inventory inaccuracy

V.3.1 Introduction

Chapter IV.3 provided some background on out-of-stock levels in the retail industry and its causes. It identified inventory record inaccuracy as one source of retail stock-outs that can be addressed with RFID technology. Inventory record accuracy, however, only becomes important for retailers that use sales-based ordering systems for shelf replenishment. These systems estimate actual inventory and demand in order to make replenishment decisions. If inventory accuracy is limited, the performance of these systems deteriorates. As a recent report[4] speculated, inaccurate inventory records may be one of the reasons why OOS levels have not fallen over the last decades, despite investments in automatic store ordering systems[5].

The current roll-outs of RFID technology in the FMCG industry focus on the case and pallet level. At this level of tagging, RFID is unlikely to completely eliminate inventory inaccuracy. RFID, primarily at the case level and to a lesser extent at the pallet level, is likely to increase inventory accuracy by increasing delivery accuracy from DCs to stores and by allowing the store to check delivery quantities at the receiving gate. To a limited extent, RFID may also increase inventory accuracy by allowing companies to prevent products going out-of-date in the backroom (see chapter IV.6). Companies may not be able to achieve 100% accurate inventory records until item-level tagging is available and the companies have installed smart shelves in their stores.

The analytical model presented in this chapter seeks to quantify the impact of inventory record inaccuracy on product availability, using some basic formulas from inventory theory.

1 *see Metro (2005a)*
2 *The example also demonstrates the complementary nature of these two investments. The savings from simultaneously investing in both technologies (seven minutes) are higher than the sum of the individual savings (two minutes plus four minutes). This means that a company that has already implemented dispatch advices gains more from an investment in RFID than a company that still relies on paper-based delivery documentation.*
3 *If one assumes 60 cases per pallet, 0.05 Euro per RFID tag and 30 Euro per labor hour, the net benefit, ignoring any other cost than the cost of RFID tags, is 0.5 Euro in the former, and -0.5 Euro in the latter approach*
4 *Gruen et al. (2002)*
5 *see e.g. Smaros et al. (2004)*

V.3.2 Related work

There is little research in the supply chain and inventory management literature that deals with the impact of inventory inaccuracy. Most traditional inventory models do not take inventory inaccuracy into account.[1] In recent years, partly motivated by the development of RFID technology, there has been a renewed interest in inventory inaccuracy in the retail industry. Research so far has focused on (1) devising appropriate inventory counting policies (when to conduct inventory counts, how much to count), (2) determining how to adjust safety stocks and replenishment policies in order to adjust for inventory inaccuracies, (3) examining the parameters that influence the impact of inventory record inaccuracies on product availability and other performance measures, (4) studying the root causes of inventory inaccuracy and their influence on inventory inaccuracy, or combinations of the above.

Researchers have taken three different approaches to study the phenomenon: analytical models, simulation studies, and empirical research. Analytical models often focus on the first two aspects. Early research on inventory inaccuracy was conducted by Iglehart and Morey[2]. They develop a formula for selecting an appropriate frequency of inventory counts and devise a policy on how to adjust safety stock in order to account for inaccurate inventory records. Morey[3] develops an estimate of the impact of inventory inaccuracies on service levels. He considers three strategies for dealing with inventory inaccuracies: increase the frequency of inventory counts, increase safety stocks, and initiate efforts to determine and eliminate the root causes. Kök et al. develop an inspection and replenishment policy. In their model, the order-up-to level depends on whether or not an inventory count has been conducted in the period. This heuristic can partly compensate for inventory inaccuracy.[4]

The model presented here extends an approach to measure the impact of inventory inaccuracy on product availability briefly presented by Raman[5]. In his paper, Raman assumes that inventory record inaccuracy occurs due to errors in shipment and at the POS terminal. He suggests that the errors in individual periods accumulate over time and create an additional source of uncertainty on top of demand uncertainty. Using the well-known safety stock formula, Raman calculates the difference in the probability that an item is out-of-stock with and without inventory inaccuracy.

Simulation studies are mostly concerned with the second, third and forth aspect: Fleisch and Tellkamp[6] examine the impact of different causes of inventory inaccuracy. Inventory records become inaccurate due to low process quality, theft, and items becoming unsaleable. The results indicate that an elimination of inventory inaccuracy can reduce supply chain costs as well as the out-of-stock levels. The findings suggest that theft has the biggest impact on product availability. Kang and Gershwin[7] simulate the impact of shrinkage on product availability. They find that stock losses can cause stock-outs. Their results indicate that inventory inaccuracy has a greater impact on product availability in lean environments which are characterized by short lead times and small order quantities. The authors also examine compensation strategies and conclude that these strategies can effectively deal with inventory inaccuracy. Brown et al.[8] simulate the effect of inventory inaccuracy in a material requirements planning (MRP) environment. They look at the frequency of error, the magnitude of error, and the location of products.

1 *DeHoratius, Raman (2004)*
2 *Iglehart, Morey (1972)*
3 *Morey (1985)*
4 *For an overview of some related articles see Kang and Gershwin (2004)*
5 *Raman (2000)*
6 *Fleisch, Tellkamp (2005)*
7 *Kang, Gershwin (2004)*
8 *Brown et al. (2001)*

The authors conclude that frequency of error has a consistent and dominant impact on the performance measures that were used. (The performance measures are the percentage of late units and inventory cost.) However, location and magnitude of error can also affect performance depending on the supply chain configuration. Krajewski et al.[1] assess the impact of several factors on the performance of an MRP system and compare this with the performance of a Kanban system. Inventory inaccuracy is introduced to the system by incoming and outgoing deliveries. A certain percentage of deliveries is assumed to be inaccurate. The authors use the amount of labor needed, the inventory level, the amount of past due demand, and the percentage of late orders as performance measures. Krajewski et al. conclude that inventory inaccuracy had less impact on the performance than anticipated. Of the factors considered, a reduction in batch sizes combined with shorter setup times had the single most important impact on performance.

The aim of the model presented here is similar to Kang and Gershwin. Their paper intends to show that (a) inventory inaccuracy can cause out-of-stock situations, (b) lean environments are especially vulnerable to inventory inaccuracy, and (c) compensation strategies can partly reduce the impact of inventory record inaccuracy. However, the approach in this thesis differs from theirs: While Kang and Gershwin conduct simulation experiments, this thesis presents an analytical model. Furthermore, the research of Kang and Gershwin assumes that inventory inaccuracy is caused by shrinkage only, i.e. physical inventory is always below inventory records. This assumption is not required in the model presented here.
The following section describes the basic model without inventory inaccuracy. Then, inventory inaccuracy is introduced into the model and different strategies as to how companies can compensate for inventory inaccuracy are discussed. A numerical example illustrates the impact of inventory accuracy on stock-out levels.

V.3.3 Model without inventory inaccuracy

The basis for the model is a continuous review, order point, order quantity (s, Q) inventory control system for a single product without substitution.[2] The company aims to satisfy a specified fraction of demand P by choosing an appropriate reorder point s, given a prespecified order quantity Q and replenishment lead time L.[3] If the company cannot satisfy demand, it loses the sales on this product.

1 *Krajewski et al. (1987)*
2 *see Silver et al. (1998), p. 253 ff. and p. 268 ff*
3 *This case is different from the case in which the company aims for a specified probability of no stock-out during a replenishment cycle*

The reorder point s is determined as follows:

$$s = x_L + SS$$

with x_L the expected demand over the replenishment lead time and SS the safety stock.

x_L is assumed to be normally distributed with a standard deviation of _$_L$. When the expected demand per period is x and the standard deviation of demand per period is _. x_L and _$_L$ are given by

$$x_L = L \cdot x$$
$$\sigma_L = \sqrt{L} \cdot \sigma$$

The formula for the safety stock SS is

$$SS = k \cdot \sigma_L$$

with k known as the safety factor.

In order to satisfy P percent of demand, k is chosen so that[1]

$$G_u(k) = \frac{Q}{\sigma_L} \cdot \frac{1-P}{P} \quad ,$$

with Gu(k) a special function of standardized normal distribution that is used to find the expected shortages per replenishment cycle.[2]

V.3.4 Model with inventory record inaccuracy and no compensation

Inventory inaccuracy measures the difference between physical inventory and inventory level according to the inventory management system. The variable can take on both positive and negative values. While positive values indicate excess stock, negative values can lead to unintended stock-outs as the actual inventory position is below the intended inventory level.

Figure V 1 shows an example of the development of inventory records and actual inventory between two inventory counts. It is assumed that inventory records are accurate after an inventory count has been conducted. In each period, there is a certain tendency for inventory records to become inaccurate. Over time, the inaccuracies in inventory records accumulate. If the actual physical inventory tends to be below system inventory – as in the example – the actual reorder points are lower than intended. This means that the risk of additional stock-outs increases over time.

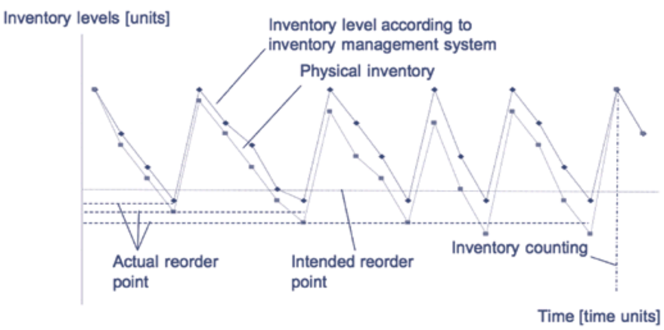

Figure V-1: Illustrative development of inventory records and actual inventory levels between two cycle counts

1 *see Silver et al. (1998), formula 7.29, p. 268*

2 *see Silver et al. (1998), p. 255*

The change in inventory accuracy per period is assumed to be an independently and identically normal distributed variable[1] with a mean of IIA and a standard deviation of $_{IIA}$. The mean inventory inaccuracy IIA_n n periods after the last inventory count and the standard deviation $_{IIAn}$ are

$$IIA_n = n \cdot IIA$$
$$\sigma_{IIAn} = \sqrt{n} \cdot \sigma_{IIA}.$$

In order to determine the service level in period n with inventory record inaccuracy and without compensation, the new SS_{1n} can be calculated as follows:

$$SS_{1n} = SS + IIA_n = k \cdot \sqrt{L} \cdot \sigma + n \cdot IIA$$

The reorder point s_{1n} in period n according to the inventory record is still s. However, the expected actual reorder point s_{1actn} in period n, after adjusting for the expected inventory inaccuracy, is

$$s_{1actn} = x_L + SS_1 = s + IIA_n.$$

The combined standard deviation of demand over the lead time and inventory inaccuracy after n periods $_{1Ln}$ is

$$\sigma_{1Ln} = \sqrt{L \cdot \sigma^2 + n \cdot \sigma_{IIA}^2}.$$

This provides the following formula for the new service factor k_{1n} in period n

$$k_{1n} = \frac{SS_1}{\sigma_{1Ln}} = \frac{k \cdot \sqrt{L} \cdot \sigma + n \cdot IIA}{\sqrt{L \cdot \sigma^2 + n \cdot \sigma_{IIA}^2}},$$

and for the new service level P_{1n} in period n

$$P_{1n} = \frac{Q}{\sigma_{1Ln} \cdot \left(G_u(k_{1n}) + \frac{Q}{\sigma_{1Ln}} \right)} = \frac{Q}{\sigma_{1Ln} \cdot G_u(k_{1n}) + Q}.$$

[1] *Research, however, suggests that the distribution of inventory inaccuracy shows a positive kurtosis (i.e. a higher "peakedness" than the normal distribution, see Johnson et al. (1981))*

V.3.5 Model with dynamic compensation for mean of inventory inaccuracy

One strategy for coping with inaccurate inventories is to compensate the reorder point for the mean inventory inaccuracy in period n. This means that the new reorder point s_{2n} in period n according to the inventory record is

$$s_{2n} = s - IIA_n .$$

By adjusting the reorder point, the expected average reorder point s_{2actn} in period n is equal to s again.

Effectively, this strategy means that the safety stock SS_2 is equal to the initial safety stock SS.

Therefore, the safety factor k2n in period n becomes

$$k_{2n} = \frac{SS}{\sigma_{1Ln}} = \frac{k \cdot \sqrt{L} \cdot \sigma}{\sqrt{L \cdot \sigma^2 + n \cdot \sigma_{IIA}^2}} ,$$

and the new service level P_2 in period n is

$$P_{2n} = \frac{Q}{\sigma_{1Ln} \cdot G_u(k_{2n}) + Q} .$$

V.3.6 Model with dynamic compensation for mean and standard deviation of inventory inaccuracy

The compensation strategy described above does not take the additional uncertainty due to the standard deviation of inventory inaccuracy into account. When both mean and standard deviation of inventory inaccuracy are considered, the safety stock can be adjusted so that the percentage of demand satisfied P_{3n} in period n is equal to P.

The safety factor k_{3n} in period n is chosen so that

$$G_u(k_{3n}) = \frac{Q}{\sigma_{1Ln}} \cdot \frac{1-P}{P} .$$

The adjusted safety stock SS_{3n} in period n is

$$SS_{3n} = k_{3n} \cdot \sigma_{1Ln} ,$$

and the resulting reorder point s_{3n} in period n is

$$s_{3n} = x_L - IIA_n + SS_3 .$$

The expected actual reorder point s_{3actn} in period n becomes

$$s_{3actn} = x_L + SS_{3n} .$$

V.3.7 Model with static compensation for mean and standard deviation of inventory inaccuracy

The two compensation strategies described so far require dynamic adjustments of reorder points as inaccuracies in inventory records accumulate over the time between two inventory counts.

An alternative strategy would be to adjust buffer stocks for the worst case so that the service level in every period is at least equal to the desired service level P. This means that $P_{4n} > P$ for all $n < N$ and $P_{4N} = P$, with N as the number of periods between two inventory counts. In this policy, the safety factor k_4 is independent of n and can be calculated as

$$G_u(k_4) = \frac{Q}{\sigma_{1LN}} \cdot \frac{1-P}{P}.$$

In order to calculate the safety stock SS_{4n} in period n, one needs to take the difference between the expected mean inventory inaccuracy after N periods and the one after n periods into account:

$$SS_{4n} = k_4 \cdot \sigma_{1LN} - (IIA_N - IIA_n)$$

The resulting reorder point s_{4n} in period n is

$$s_{4n} = x_L - IIA_n + SS_4 = x_L + k_4 \cdot \sigma_{1LN} - IIA_N .$$

The expected actual reorder point s_{4actn} in period n becomes

$$s_{4actn} = x_L + SS_{4n} .$$

Another alternative would be to use a heuristic and select the service level so that the average safety level P_{avg} in all time periods between two inventory counts is equal to P, i.e.

$$P_{avg} = \frac{1}{N}\sum_{n=1}^{N} P^i \overset{!}{=} P,$$

with P^i the safety level in period i. This would result in service levels above P in the periods after an inventory count has been conducted which subsequently fall below P.

V.3.8 Numerical example

The numerical example assumes a product with a mean demand per period x=50, a standard deviation of demand per period _=5, an order quantity Q=50, and a lead time L=0.5 periods.[1] The desired service level P is 0.975, i.e. the company intends to satisfy 97.5% of demand during a replenishment period. It is assumes that the company conducts inventory counts every 50 periods, and that so far half the time between two inventory counts has elapsed, i.e. n=25.[2] The mean inventory inaccuracy that occurs in each period is IIA=-0.2 units (this corresponds to shrinkage rate of 0.2/50=0.4%), and the standard deviation of inventory inaccuracy _IIA=0.4. This means that the change in inventory accuracy falls with a probability of roughly 95% between +0.6 and -1.0 units per period. After 25 periods, the standard deviation of inventory inaccuracy is 2.[3]

Without inventory inaccuracy, the company reaches the desired service level if it chooses the safety stock SS=0.27 units.[4] With inventory inaccuracy, the service level decreases by 6.6%-points from 97.5% to 90.9%. This is because the company has effectively lowered its expected actual reorder point to 20.27 units from 25.27 units as it has not taken into account that expected actual inventory at the reorder points is 5 units lower than inventory records suggest.

With compensation for the mean inventory inaccuracy, the service level is 97.1% or 0.4%-points below the target level. The reorder point increases to 30.27 units, which corresponds to an expected actual inventory level of 25.27 units. With compensation for both mean and standard deviation of inventory inaccuracy, the service level reaches 97.5% again. This requires, however, increasing the safety stock by another 0.46 units, which means that the expected actual reorder point increases to 25.73 from 25.27. The reorder point according to the inventory management system increases to 30.73.

Using the static worst case estimate yields a safety stock of 6.17 units for n=25, 5.90 units higher than without inventory inaccuracy and 5.44 units higher than with dynamic compensation of mean and standard deviation. The reorder point increases to 36.17 units, and the expected actual reorder point to 31.17 units. Due to the additional safety stock, the service level increases to close to 100%. If the reorder point is chosen so that Pavg=P, the safety stock at n=25 is 1.8 units, the reorder point 26.8 units, and the service factor 98.3%. This reduction in safety stock, however, would be compromised by a fall in the service level at n=50 to 92.9%.

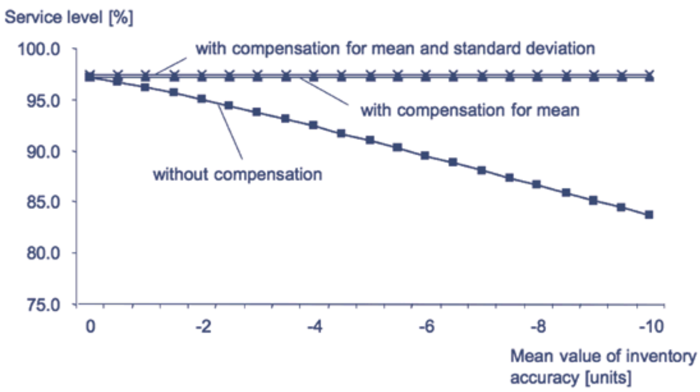

Figure V-2: Service level vs. mean value of inventory inaccuracy under different strategies

1 *In order to calculate the values for Gu(k), the approximation formula provided in Silver et al. (1998), appendix C.1, p. 735 ff. has been used*

2 *Due to non-linearities in the model, the results calculated in the following are not the average expected values over the entire time between two inventory counts*

3 *It is difficult to choose an appropriate value for the standard deviation of inventory inaccuracy. One can, for example, simulate the impact of delivery inaccuracy. If one assumes a picking error of 0.3%, with an equal chance of 0.15% each for a missing and additional case, 10 products per case and weekly delivery, and then calculates the average standard deviation of inventory inaccuracy after 25 periods, one gets a value of slightly above 2.5.*

4 *The safety stock would be much higher (1.96√0.5_=6.93) if the company would require that with a probability of 97.5% no stock-out should occur during the replenishment period. In the current model, stock-outs frequently occur at the end of each replenishment period. At the current level of safety stock, the probability of a stock-out is 1-_(0.08)=0.468, i.e. close to 47%.*

Sensitivity analysis

Figure V 2 shows the service level for different mean values of inventory inaccuracy per period for three policies: no compensation for inventory inaccuracy, compensation for the mean inventory inaccuracy, and compensation for the mean and standard deviation of inventory inaccuracy. All other parameters are kept constant.

If the mean inventory record inaccuracy increases, stock-out levels increase in case there is no compensation. For a deviation between inventory record and physical inventory system of 10 units, the service level drops to 83.7% compared to the targeted 97.5%. (Assuming that this figure is reached 25 periods after the last inventory count, it corresponds to a shrinkage level of 10/25*50=0.8%.) Compensation for mean and standard deviation of inventory inaccuracy ensures that the service level stays at the desired level of 97.5%. Compensation of the mean can already eliminate most of the adverse effect of inaccurate inventory records. In this case, the service level is 97.1%, only 0.4%-points below target.

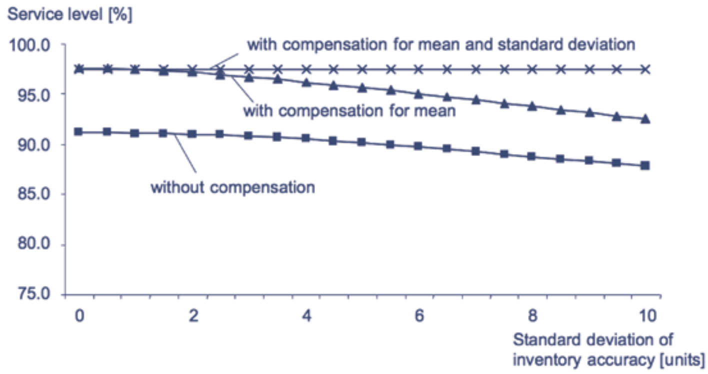

Figure V-3: Service level vs. standard deviation of inventory inaccuracy under different strategies

Figure V 3 depicts the service level for different standard deviations of inventory inaccuracy. This example clearly shows the limitations of the compensation of the mean strategy. At higher levels of standard deviation, the chances increase that the difference between inventory records and physical inventory deviates from its expected value by a substantial amount. Due to the non-symmetrical impact of inventory record inaccuracy (the positive impact of lower than expected inventory record inaccuracy on service levels is smaller than the negative impact of higher than expected inventory record inaccuracy), service levels fall when the standard deviation of inventory record inaccuracy increases. Again, compensation for both mean and standard deviation keeps service levels constant at the desired level.

Figure V 4 shows the service level for different order quantities. For smaller order quantities, inventory record inaccuracy has a higher impact on service levels. Smaller order quantities lead to more frequent orders and deliveries, and average inventory decreases. The frequency with which the company relies on safety stock increases. Without inventory inaccuracy, this is compensated for by a higher level of safety stock so that service levels stay constant. With inaccurate inventory records and no compensation, however, this adjustment is too small, and service levels deteriorate. Compensating for the mean inventory inaccuracy can increase service levels. However, at smaller order quantities the strategy does not perform as well as with higher order quantities. For Q=5, for example, the service level for the compensation of the mean strategy is 95.8%, compared to 97.1% for Q=50.

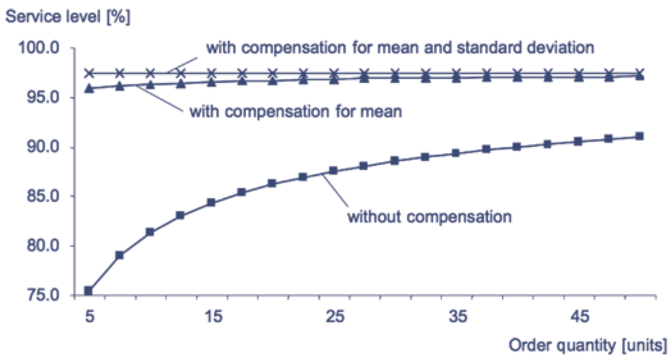

Figure V-4: Service level vs. order quantity under different strategies

Figure V 5 illustrates the relationship between service levels and the replenishment lead time L. The shape of the curves is very similar to the shape of the previous curves for variations in the order quantity. For short lead times, service levels decrease. This is because safety stock decreases when lead times become shorter. With inventory inaccuracy, this means that there is less buffer to compensate for inaccurate inventory records which leads to worse performance.

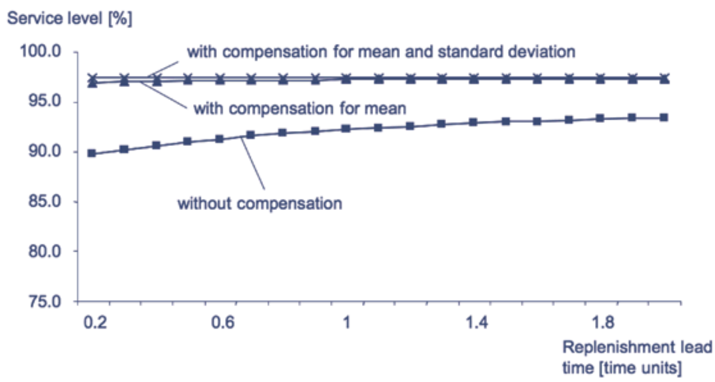

Figure V-5: Service level vs. replenishment lead time under different strategies

So far, the sensitivity analysis has only considered how variations in certain parameters affect the service level. There is also an alternative way to look at the problem, assuming that companies are aware of inventory record accuracy and, depending on the strategy, keep additional inventory in order to achieve the desired service level. Figure V 6 compares approximate average inventory levels under different strategies, given a specific service level. The following formula is used to approximate[1] the average actual inventory per period I_{avg}:

$$I_{avg} = \frac{Q}{2} + SS$$

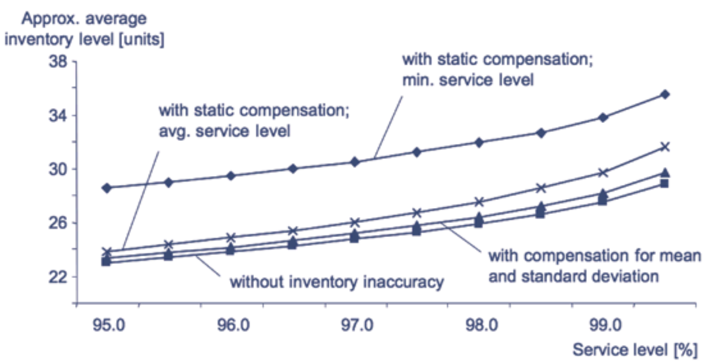

Figure V-6: Approximate average inventory vs. service level under different strategies

1 *The formula is just an approximation of actual average inventory as it ignores stock-outs, i.e. assumes that products are always available*

Figure V 6 depicts the approximate inventory levels for n=25, i.e. for a period halfway between two inventory counts. Apart from the two dynamic strategies, the figure also includes the two static compensation strategies for n=25. As already discussed, both strategies provide service levels above the indicated target levels right after an inventory count has been conducted. For the minimum service level strategy, the service level is in fact above the target level for all periods except for the period right before an inventory count. For the average service level strategy, it is above the target level when n is small and falls below that level for larger n.[1]

Average inventory levels are lowest if inventory records are accurate. The strategy to compensate for mean and standard deviation leads to slightly higher average inventory levels. This is because companies need to increase safety stock in order to compensate for the standard deviation of inventory inaccuracy.

The difference between inventory levels for the different strategies increases at higher service levels. At a service level of 97.5%, the approximate average inventory level is 26.7 units for the average service level strategy and 31.2 units for the minimum service level strategy. Compared to the case with accurate inventory records, the approximate inventory levels are 6% and 23%, respectively, higher than without inventory inaccuracy. This indicates that accurate inventory levels are more important for companies that want to achieve high product availability as it decreases their need to keep excess inventory.

V.3.9 Discussion

The results presented in this chapter show that inventory inaccuracy can have a significant effect on product availability. The findings indicate that the importance of inventory accuracy increases in lean environments with short lead times and small order quantities and for companies that want to achieve high service levels. This confirms observations from a simulation study made by Kang and Gershwin.[2] The results also show that not only the non-zero mean of inventory inaccuracy causes stock-outs, but also the variance in these errors. In other words: Even when inventory records are accurate “on average”, inventory inaccuracy affects product availability. This observation is contradictory to Kang and Gershwin’s conclusion that “the randomness in the model behavior is not what causes the inventory inaccuracy problem.”

The model is still relatively simplistic. Further researchers may use this model as a basis to build more sophisticated models. Applied researchers may also use the ideas presented in this chapter and, based on empirical data from retailers, determine the actual impact of inventory record inaccuracy on product availability.

Retailers may directly apply the model to estimate the impact of inventory inaccuracy on service levels. Furthermore, and of high relevance in the context of this thesis, the model can help to assess how increased delivery accuracy due to RFID can affect product availability. While any number that companies derive from the model is certainly only a rough estimate, it will at least provide some guidance on the magnitude of benefit they can expect.

In order to apply the model in practical settings, companies need to provide a number of inputs, including estimates of the mean and standard deviation of inventory inaccuracy. Retailers can obtain these figures by recording the difference between physical inventory and inventory record for individual SKUs. The parameters can vary between products and stores. Companies should therefore strive to use products from the same category and store that are similar in terms of demand and shrinkage levels. As inventory inaccuracy is likely to build up over time, it is important to take the time since the last cycle count into consideration when calculating the figures.

1 *In the example, the service level for this strategy at n=25 is still above the target level of 97.5%. This is because the product availability curve is concave for small values for the mean and standard deviations as considered here. At higher values for both mean and standard deviation, the curve turns convex. Therefore, the fall in service levels in the periods directly after an inventory is initially slow.*

2 *Kang, Gershwin (2004), p. 13*

RFID at the case and pallet level will not eliminate all causes of inventory inaccuracy. Rather, as chapter IV.3 has argued, it is likely to primarily affect delivery accuracy and the detection of inaccurate deliveries from the DC. In order to adequately account for the potential of RFID at the case and pallet level, retailers need to estimate the contribution of delivery errors from the DC to inventory record inaccuracy. This data can be derived from statistics on the distribution of picking errors. The remaining parameters (mean and standard deviation of demand, order lead time, order quantity, and order point) should be easily available from the store inventory management system.

The research also indicates how retailers can effectively deal with inventory inaccuracy even if they cannot eliminate it. This assumes that the companies first recognize the problem and try to measure it. Currently, retailers – either explicitly or implicitly – seem to follow a strategy of keeping a fixed amount of additional safety stock at their stores in order to compensate for inaccuracies. Even if this approach is right "on average" for the period between two cycle counts, it results in excess inventory right after an inventory count (when inventory records are relatively accurate) and deteriorating product availability levels over time (as inventory record inaccuracy increases) that eventually fall below the desired value. Retailers that implement policies which dynamically adjust inventory records over time can increase product availability with little additional inventory. Up to now, I am not aware of any retailer that uses such a model to dynamically adjust inventory records for shrinkage and other causes of inaccuracy.

V.4 Transformational effect: RFID and the replenishment-from-the-backroom process

V.4.1 Introduction

Delays in the replenishment-from-the-backroom process can cause stock-outs at the retail shelf (see chapter IV.3). Although a large number of retailers try to move products onto the shop floor as quickly as possible, they still tend to store certain products in the backroom. RFID readers at the interface between store backroom and shop floor allow retailers to distinguish between backroom and shop floor inventory. This provides a fairly accurate picture of the actual number of products available to the consumer. The store inventory management system can derive an estimate of the number of products available on the shop floor by combining the data on the flow of products from the backroom with POS data. Based on this information, it can automatically generate alerts to replenish products from the backroom before an OOS situation occurs.
This chapter examines the potential impact of RFID at the case level to improve the timeliness of shelf replenishing from the backroom.

V.4.2 Related work

Few researchers have dealt with the problem of time delays in shelf replenishment from the backroom. Part of the reason is probably that before the advent of RFID, retailers had no cost-effective means for keeping track of product movement from the backroom onto the shop floor. Among the research available so far, the work by Wong and McFarlane and by Gaukler et al. is the only work of which I am aware that deals with this process. Their research is described briefly below.

Gaukler et al.[1] assume RFID at the item level. They examine how the quality of the in-store backroom-to-shelf replenishment process affects profits. Quality problems during shelf restocking not only cause stock-outs and lost sales as shelves are replenished too late, but also lead to too low forecasts of demand. This is because the retailer uses its actual sales to estimate demand, which is lower than actual demand due to the out-of-stock situations caused by the restocking process. In an extension of their base model, the authors consider the decentralized case in which manufacturer and retailer are individual profit optimizers and examine how to share the RFID tag cost in order to maximize supply chain profits. Wong and McFarlane[2] study the impact of different time delays on profitability and product availability for products that are replenished from the store backroom. So far, the results of their work have not been published.[3]

1 *Gaukler et al. (2004)*
2 *Wong, McFarlane (2003)*
3 *For an overview of results presented so far, see Wong, McFarlane (2004)*

V.4.3 Model formulation

The following deterministic analytical model illustrates the impact of time delays in the backroom-to-store replenishment process on product availability. The model assumes that the retailer keeps the products in the backroom of the store and replenishes the shelf from the backroom. The retailer employs an order-point, order-up-to-level (s, S) replenishment policy[1] for the shelf with s as the replenishment point and S[2] the replenishment-up-to level.[3] For the sake of simplicity, the replenishment lead time is assumed to be zero.

Smaller lot sizes and shorter lead times have lead to a reduction in inventory at retail stores. Larson and DeMarais[4] argue that this requires retailers to consider what they call psychic stock when determining inventory levels and reorder points. They define psychic stock as "*retail display inventory carried to stimulate demand*."

The model assumes that the demand function D is a known deterministic function that depends on the inventory shelf level I. The maximum demand D_{max} is reached when the shelf is fully stocked, i.e. when inventory I is equal to S. Demand decreases linear in I by a parameter a, which constitutes the elasticity of demand in I:[5]

$$D(I) = D_{\max} - a \cdot (S - I)$$

This linear relationship is a simplification. Usually, researchers assume that the marginal increase in sales decreases for higher levels of inventory.[6] For high inventory levels, up to a certain point, inventory may not affect sales at all.[7] The assumption of linearity, however, does not affect the general point and has the advantage that it reduces the mathematical complexity of the model.

Average inventory Iavg during a replenishment period is

$$I_{avg} = \frac{S+s}{2},$$

and average demand D_{avg} during a replenishment period is given by the following formula:

$$D_{avg} = D_{\max} - a \cdot (S - I_{avg}) = D_{\max} - a \cdot \left(S - \frac{S+s}{2} \right) = D_{\max} - \frac{1}{2} a \cdot (S - s)$$

1 *Silver et al. (1998), p. 237 ff*

2 *The order-up-to level S is assumed to be exogenous to the model. It might e.g. have been determined using shelf space allocation models (see Dreze et al. (1994) for an overview).*

3 *An alternative approach could be to use a periodic-review, order-up-to level (R, S) system*

4 *Larson, DeMarais (1999), p. 499; emphases in original*

5 *The following formulas assume that the shelf is replenished before an out-of-stock situation occurs. The definition of the profit function defined below and the fact that demand is deterministic ensure that, in the optimum, I is always larger than or at least equal to zero. In this model, out-of-stock situations can only occur if the shelf is replenished too late, which is going to be discussed at a later stage.*

6 *see e.g. Larson, DeMarais (1999)*

7 *see e.g. Urban (2002)*

The retailer tries to maximize its average profit P per period which takes into account the margin p-c, the average demand D_{avg} and the replenishment cost k per period from the backroom:

$$\max_s P = \max_s (p-c)\cdot D_{avg} - k$$ [1]

with

$$k = K \cdot \frac{D_{avg}}{S-s},$$

where K is the replenishment cost per replenishment.

V.4.4 Profit maximization

Calculating the first derivative for P in s provides

$$\frac{\partial P}{\partial s} = \frac{1}{2}(p-c)\cdot a - K \cdot D_{\max} \cdot (S-s)^{-2}.$$

Setting the first derivative equal to zero and solving the equation for s yields

$$s_1 = S - \sqrt{\frac{K \cdot D_{\max}}{\frac{1}{2}(p-c)\cdot a}} \quad \text{and} \quad s_2 = S + \sqrt{\frac{K \cdot D_{\max}}{\frac{1}{2}(p-c)\cdot a}}.$$ [2]

The second derivative is

$$\frac{\partial^2 P}{\partial s^2} = 2 \cdot K \cdot D_{\max} \cdot (S-s)^{-3},$$

which is less than zero for s_1 and greater than zero for s_2. This means that s_1 is a local maximum of p. Plausibility considerations for the upper and lower limit of P for variations in s show that s_1 is the global maximum of p. In the following, the notation s* for the optimal replenishment point, s_1, is used.

The optimal restocking interval t* can be calculated by the following formula:

$$t^* = \frac{S-s^*}{D^*_{avg}} = \frac{S-s^*}{D_{\max} - \frac{1}{2}a\cdot(S-s^*)}$$

1 *The profit function does not include any inventory holding cost. This is due to the initial assumption that the shelf is replenished from the backroom. This means that the total inventory position is not affected by s. Implicitly, the model assumes that inventory holding costs are the same whether the product is stored on the shelf or in the backroom which might not be exactly true in reality. Interestingly, the formula is very similar to the well-known economic order quantity formula if one interprets (p-c)a as inventory holding cost vr (see Silver et al. (1998), p. 154 ff.).*

2 *The formula is correct for a→0. If a=0, i.e. demand does not depend on available shelf inventory I, the profit function p reaches its maximum for s*=S. This means that the shelf is replenished at the very moment when I reaches zero.*

V.4.5 Suboptimal replenishment intervals

In practice, it is difficult and time-consuming for an employee to replenish the shelf exactly at t*. Without separation of backroom and shop floor inventory, the employee needs to manually count the number of products on the shelf. The associated effort can be significant, especially when the optimal restocking point is relatively high. The situation is further complicated by the fact that the products in a category are likely to have different restocking points (or might not be restocked from the backroom at all). Relying on employees' memories for making restocking decisions is potentially error-prone, and the use of technical means (e.g. handhelds with barcode scanners) that allow employees to look up restocking points can be time-consuming. Furthermore, employees might not always recognize that there is still stock in the backroom when checking shelf availability (or recognize that a shelf needs to be refilled when checking backroom inventory).

Any restocking interval, whether shorter or longer, that deviates from t* leads to suboptimal profits. As long as the inventory I is greater than zero, the profit function introduced above can be used to determine the profit for the optimal as well as for any other restocking interval. As long as I is positive, product availability PA is 100% (i.e. there are no stock-outs), although the retailer already loses some sales due to the sensitivity of demand to shelf inventory levels.

The time t_{oos} at which an out-of-stock situation occurs, can be calculated as follows:

$$t_{oos} = \frac{S-0}{D_{\max} - \frac{1}{2}a \cdot (S-0)} = \frac{S}{D_{\max} - \frac{1}{2}a \cdot S}$$

For $t \leq t_{oos}$, the loss of sales LS per period can be calculated using the following formula:

$$LS = D^*_{avg} - D_{avg}$$

If an out of-stock situation occurs, the formulas to calculate profit, product availability PA, and loss of sales LS need to be adjusted. For $t > t_{oos}$, assuming that no product substitution takes place, the subsequent formulas are

$$P = \frac{(p-c) \cdot S + (t - t_{oos}) \cdot 0}{t} - \frac{K}{t} = \frac{(p-c) \cdot S - K}{t}$$

$$PA = \frac{t_{oos}}{t}$$, and

$$LS = D^*_{avg} - \frac{\left(D_{\max} - \frac{1}{2}a \cdot S\right) \cdot t_{oos} + (t - t_{oos}) \cdot 0}{t} = D^*_{avg} - \frac{\frac{S}{t_{oos}} \cdot t_{oos} + (t - t_{oos}) \cdot 0}{t} = D^*_{avg} - \frac{S}{t}$$

V.4.6 Product substitution

Allowing for product substitution in case of an out-of-stock situation, the profit function P can be formulated as

$$P = \frac{(p-c)\cdot S + (t - t_{oos})\cdot b \cdot (p' - c' - \Delta k')}{t},$$

where b is the substitution parameter, p'-c' the margin for the substitute, and _k'[1] the additional replenishment cost for the substitute per period due to shorter replenishment intervals because of higher demand. The formulas for product availability PA and loss of sales LS are product-specific and therefore do not change.

V.4.7 Numerical example

The following numerical example illustrates the impact of suboptimal replenishment policies. The following parameter values are assumed: D_{max}=10, p-c=0.5, S=50, K=4, a=0.1, b=0.3, p'-c'-_k'=0.4. This provides s*=30, t*=2.1 and t_{oos}=20/3. Figure V 7 shows the profit, Figure V 8 the product availability, and Figure V 9 the loss of sales per period for different restocking intervals t.

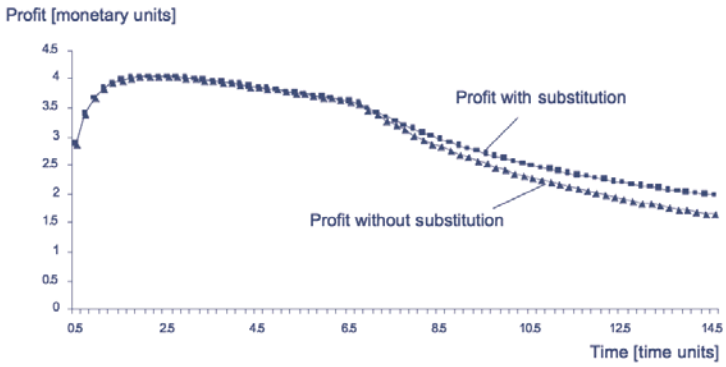

Figure V-7: Profit for different restocking intervals

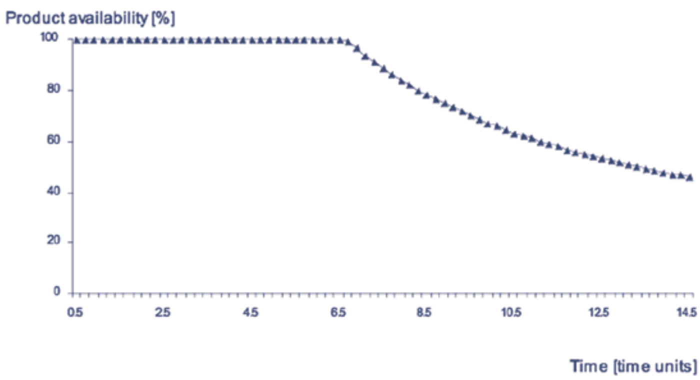

Figure V-8: Product availability for different restocking intervals

Although late restocking does not lead to any out-of-stock situations as long as $t \le t_{oos}$ (see Figure V 8), Figure V 7 shows that profits per period P already start to decline for t › t* due to lost sales (because of low psychic stock). This is only partly compensated by a decrease in the restocking cost k per period. Profits per period also decline for short restocking intervals as k increases, which is only partly compensated by additional sales due to high psychic stock.[1]

1 *Additional sales show in Figure V 9 as negative values for lost sales*

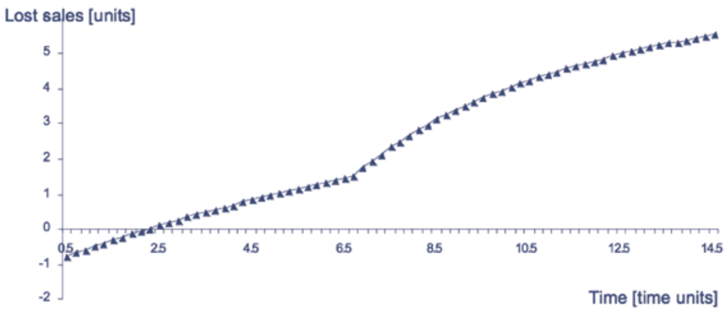

Figure V-9:
Sales loss for different restocking intervals

Product availability per period PA starts to decline for t › t_{oos}. This leads to a non-continuous increase in the marginal level of lost sales (see Figure V 9) and the marginal profit loss P*-P. The decline in profit is slower when there is a substitute available. The absolute and relative gap in profits between the case with and without substitution widens the longer the product is out-of-stock.

The marginal profit loss is initially increasing for t › t*: Restocking one unit of time later than the optimum (t=t*+1) leads to a decrease in P of 0.04 or 1.0% compared to the optimum; at t=T*+2, the figure is 0.14 or 3.5%. For t ‹ t*, the marginal loss is decreasing. This means that the closer a company is to the optimal restocking point, the less it gains.

As described above, it is difficult for store employees to replenish the shelf exactly at t*. In order to reduce the monitoring effort, retailers could instruct their employees to frequently "move the aisles" and restock only those products that are not available on the shelf. If demand were inelastic in the inventory level, this policy would be optimal (assuming that employees replenish the shelf at t=t_{oos}). However, with a › 0, the resulting profit will be lower than at the optimum. In the current example, the profit per period P declines by 0.45 or 11.8% lower. If the shelf stays empty for one unit of time (t=t_{oos}+1), the figures are 0.93 or 23.0% without substitution, and 0.85 or 21.0% with substitution.

V.4.8 Discussion

If sales is positively influenced by the number of products on the shelf, simply replenishing shelves once they become empty leads to suboptimal profits, despite high levels of product availability. The model presented in this chapter can help companies to determine optimal restocking points for products stored in the backroom.

Due to a lack of data on shelf inventory, however, it is currently difficult to ensure optimal shelf replenishment. RFID at the case level enables retailers to infer shelf inventory levels from POS data and data on product movements between backroom and shop floor. Based on this information, the inventory management system can generate timely replenishment orders.
Researchers may use the model as a basis for more sophisticated quantitative models. For example, a more realistic – but computationally also more demanding – model could incorporate that store employees conduct regular availability checks. With such a model, it becomes possible to simultaneously determine the profit-maximizing values for the frequency with which to check shelves, the order point, and the order-up-to level that maximize profit.[1]

1 *see eg. Silver et al. (1998), p. 240 ff*

Companies can use the model to estimate the impact of delays in the replenishment-from-the-backroom process. It may, however, be difficult to determine the relevant parameters. One obvious challenge is to calculate a value for the elasticity of demand in the inventory level. In principle, it is possible to estimate the parameter using linear regression. However, retailers are unlikely to possess the data to actually carry out the analysis.[1] Another challenge is to determine the actual cost for the product replenishment from the backroom. The current model considers only one SKU and does not take into account that employees are likely to replenish more than one SKU at a time. Furthermore, retailers need to estimate the current delays in the process.

In the end, companies may decide to rely on managerial judgment to estimate the parameters. Even if the estimates are likely to be inaccurate, the model provides at least some indication of the potential benefit of RFID in the replenishment-from-the-backroom process. Such an approach might be superior to simple guesses or to not attaching any value at all.

V.5 Summary

This chapter dealt with the challenge of quantifying the impact of RFID. Quantification of automational effects seems relatively easy. This is due to the highly tangible nature of the resulting benefits. However, as the example shows, even here companies can come to different conclusions, depending on their approach towards dealing with benefits that result from the potential role of RFID as catalyst.

The main challenge lies in estimating the benefits that result from the informational and transformational effects of RFID. If companies cannot quantify the potential benefits of a new technology, there is a risk that they will not invest.

Higher product availability at the retail shelf is one of the most-frequently mentioned benefits of RFID on which companies currently focus. The models that deal with the informational and transformational effect therefore focused on the potential impact of RFID on product availability. The models provide an initial attempt to determine the impact of inventory inaccuracy on stock-outs and the impact of delays in the replenishment-from-the-backroom process on lost sales and profits.

1 *see Urban (2002)*

VI.1 Key findings

This thesis dealt with the following research question:

How can RFID technology improve supply chain performance in the FMCG industry?

It addresses the question by considering five sub-questions:

How do Auto-ID technologies in general affect process performance?

The introduction of RFID in the FMCG industry is a specific example of the application of an Auto-ID technology in business processes. As a first step, the thesis therefore looked at Auto-ID technologies in general and derived a framework from complementarity theory and research on the business value of IT that conceptualizes the impact of Auto-ID technologies on process performance. Starting points are the capabilities of a specific Auto-ID technology in relation to the capabilities of alternative technologies.

According to the framework, Auto-ID technologies can have three different effects which influence process performance:

- Automational effect: This effect occurs when companies substitute one identification technology for another in order to lower the cost of data capturing.
- Informational effect: This effect occurs when companies use the new identification technology to improve data quality dimensions such as accuracy, timeliness, objectivity, or completeness of data within existing processes and control systems.
- Transformational effect: This effect occurs when companies use higher data quality to realize new processes by making changes to process control systems.

The degree to which companies can realize these effects and the extent to which the effects impact process performance is moderated by two types of variables:

- Complementarities: Auto-ID technology can be considered as a detector that provides input into task and management control systems. A control system consists of several other components that can all constrain the system's performance. This includes a slow or non-existing communication network, decision rules that cannot take advantage of the data, missing auxiliary information, and lack of execution capabilities. If the appropriate means to use the data are not available, the potential of the Auto-ID technology to create value is limited.
- Contextual factors: Environmental and organizational circumstances influence the need for and value of Auto-ID data. In a highly-automated environment with well-defined processes, for example, there is less need for frequent identification of objects than in an environment where a large number of tasks are conducted manually, and employees need to ensure that they have the right object in hand before they can proceed.

Auto-ID technologies act as an implementer of existing processes (in the case of automational and informational effects) and an enabler of new processes (in the case of transformational effects). The field research identified an additional role of Auto-ID technologies, the role as a catalyst that can lead to transformational effects, which researchers have not described previously. When an Auto-ID technology acts as a catalyst, it drives changes in the supply chain that do not rely on the capabilities of the technology. Metro, for example, sees RFID as a catalyst for ECR initiatives.[1] These changes might not have been pursued up-to then due to, for example, a lack of management attention or differing interests between trading partners.

1 *Metro (2005b)*

What benefits does RFID offer in the FMCG industry?

Based on a review of existing publications and company material that deal with the benefits of RFID at the case and pallet level, the thesis has identified a number of benefits that companies intend to reap from RFID at the case and pallet level. The five most-frequently mentioned benefits are:

- Handling efficiency: RFID allows the automatic identification of objects without line-of-sight. This reduces the manual data capturing effort, for example, in the receiving and shipping process.

- Out-of-stock: Despite the importance of high levels of product availability for retailers and manufacturers, stock-outs are still common at the store level.[1] RFID at the case and pallet level can help to improve product availability by reducing the number of delivery errors, by increasing inventory accuracy, and by ensuring the timely replenishment of products from the store backroom.

- Inventory reduction: Advocates of RFID claim that the technology will lower inventory levels in the FMCG supply chain. RFID, for example, can help to avoid excess stock in the store due to situations in which store employees reorder products they cannot immediately locate in the backroom.

- Order reconciliation: RFID at the case level can avoid delivery errors and reduce the effort companies expend checking deliveries. The technology may potentially also simplify the dispute resolution process by acting as proof of delivery.

- Theft: Even if RFID at the case and pallet level may not prevent theft, it can help companies to detect weak points in the supply chain. In the future, it may also make it more difficult for thieves to reintroduce stolen products into the legitimate supply chain.

The results from the field research indicated that the relevance of these benefits to companies can vary, depending on contextual factors and the presence or absence of complementary technologies and practices. So far, it seems that companies in the FMCG industry focus on only a few of the potential benefits. This includes out-of-stock, order reconciliation, and handling efficiency. In other areas (e.g. theft), the companies involved in the field research could see the potential for some minor improvements, whereas other potential benefits (e.g. inventory reduction) were not regarded as relevant. There are two reasons why some companies disregarded certain benefits despite the fact that these frequently occur in reports and white papers:

- Some companies can already realize the benefits that the reports and white papers advocate or, even if they cannot realize the benefits, this is not due to limitations concerning data capturing. Rather, companies feel that the constraints lie elsewhere. One example is data sharing in the supply chain. The retailers in the research sample already capture rather detailed data on the movement of products in the supply chain in a timely fashion, but may choose not share it or only provide aggregated data with time delays. The introduction of a new Auto-ID technology, which deals with data capturing, does not directly influence current data sharing practices.

- Some companies tend to exclude benefits that require investments in complementary systems and practices in addition to RFID, that will only be available in the long term, or that assume changes in the entire industry. For these companies, the possibilities are too remote, and the realization beyond their planning horizon. For example, in order to prevent the re-introduction of stolen cases in the supply chain, companies may have to share data on unique case identifiers with all potential trading partners.

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1 *see e.g. Gruen et al. (2002)*

In which areas will RFID transform the FMCG supply chain?

The empirical investigations based on a number of projects indicate that companies currently focus primarily on the automational and informational effects of RFID. There are a number of areas in which RFID can lead to transformational effects, but – with the exception of the replenishment-from-the-backroom process – few are likely to be implemented in the short to medium term.

In the medium to long term, RFID may enable companies to transform processes and realize automatic order reconciliation based on RFID data as proof of delivery and the traceability of unique cases (which can improve stock rotation at the store and reduce the amount of products removed from the supply chain in case of recalls). RFID may also enable companies to prevent stolen products re-entering the legitimate supply chain, as mentioned above, or that companies engage in product diversion.

The transformational effects differ in the extent of change, in addition to the introduction of RFID technology, that is required in order to realize the potential benefits. There are three levels of change:

- *Intra-company* (e.g. replenishment-from-the-backroom process);
- *Inter-company* (e.g. automated proof of delivery);
- *Intra-industry* (e.g. product diversion).

As the examples from field research suggest, companies are most likely to adopt intra-company processes and practices first, while it may still take some time before we see changes at the inter-company or even industry-wide level in the FMCG industry.

RFID may also drive the further proliferation of dispatch advices and increase the amount of data sharing in the FMCG industry, among others. In these instances, however, RFID acts more as a catalyst then as an enabler. In fact, according to a recent survey by Gartner Research[1], 50% of retailers mentioned that driving process change in the supply chain will be a large or very large benefit of adopting RFID, ahead of benefits such as improved product availability (48%).

Which factors influence the value of RFID in the FMCG supply chain?

Consistent with the predictions from the conceptual framework, the evidence from the field research indicates that companies need to have certain complementary technologies and practices in place before they can fully benefit from RFID. The specific complementarities, of course, depend on the application. In general, however, they are similar to the technologies and practices in current state-of-the-art barcode solutions. Much of the investment will be the same, including the introduction of

- dispatch advices;
- warehouse and store inventory management systems;
- automatic store ordering systems;
- wireless networks in DCs and stores.

1 *Gartner Research (2005b)*

As a report by A.T. Kearney[1] puts it: “For companies [referring to CPG manufacturers] that have not invested in WMS [warehouse management systems] and other supply chain technologies, the effort is not any easier. Although the potential improvements through RFID/EPC case tagging is more significant, they must first upgrade their supply chain systems to exploit the data, thereby substantially increasing their investment.”

Companies may also have to invest in certain technologies and practices that are not yet common in the FMCG industry in order to realize the new processes enabled by RFID. Examples are

- ability to store and process unique case identifiers;
- expiry dates and lot numbers by cases;
- separation between backroom and store inventory in store inventory management systems.

Also consistent with the conceptual framework, contextual factors can affect the value of RFID. This includes

- country-related factors such as labor cost, geography, and regulation;
- strategy-related factors such as the number of SKUs and the impact of stock-outs on customer loyalty;
- process-related factors such as the current data capturing effort, the level of slack in the supply chain, and process quality;
- product-related factors such as product value, theft rates, and perishability.

How can the impact of RFID in the FMCG supply chain be quantified?

Quantification of the potential benefits from RFID is relatively straightforward for automational effects. It is more difficult for companies to assess the value of higher data quality in existing and new processes (informational and transformational effects). If companies cannot quantify the expected benefits, they might not invest in the technology. The experience from the field research showed that estimating the impact of RFID on, for example, product availability can be difficult.

Mathematical-analytical models offer an alternative approach to estimating the impact of RFID if gathering the necessary real-world evidence via interviews, site visits, surveys or other forms of data collection is not possible. One example of research of this kind that has helped to drive the proliferation of new practices is that on the value of sharing POS data and the bullwhip effect.

This thesis suggests two mathematical-analytical models. The first model offers a way to estimate the impact of increased inventory accuracy on product availability, which is an example of a potential informational effect of RFID. The second allows companies to calculate the impact of current delays in the replenishment-from-the-backroom process on product availability and sales. RFID-based information can help to establish a new process (i.e. RFID leads to a transformational effect) that reduces these delays.

[1] *A.T. Kearney (2004), p. 2*

VI.2 Discussion of research findings

Early snapshot likely to underestimate impact

Even though some retailers have started to roll out RFID at the case and pallet level, the adoption of RFID is still at an early stage. This thesis found few examples of companies that implement new RIFD-enabled processes. There are a number of reasons for this:

- First, several attributes of an innovation influence its rate of adoption besides relative advantage. These include observability, compatibility, trialability, and complexity.[1] Automational effects (e.g. the elimination of manual barcode scans) are, in general, highly observable (i.e. the benefits are highly tangible), compatible with, for instance, existing processes and systems, trialable and of low complexity. This increases the chances of adoption. The benefits of informational and transformational effects can be difficult to observe and may be hard to trial[2], and this can have a negative effect on adoption. However, in contrast to transformational effects, informational effects are likely to show a high degree of com patibility and a low degree of complexity, as the underlying processes and control systems do not change.
- Second, companies may require some time before they become proficient users of an innovation and have implemented complementary technologies and practices.
- Third, companies may initially not be aware of all possible applications of a technology. Speaking about the barcode, Little[3] remarks that "whenever a new, much-more detailed look at the world is possible, there will follow a great flowering of measurement, theory, and practical applications."

Delays in the realization of benefits, missing complementarities and the need to learn about how to best use a technology are among the reasons for negative findings on the potential value of new information technology (see chapter III.1.2). It is likely that the number of reports that claim disappointing results from introducing RFID will rise in the not-too-distant future. The initial results, however, may not adequately capture the ultimate value of the technology.

Uneven distribution of costs and benefits between retailers and manufacturers constitutes a risk for RFID adoption

This thesis has looked at RFID from a supply chain perspective. However, despite the focus on supply chain management, companies still strive to maximize their own performance. There is a risk that an uneven distribution of costs and benefits between trading partners hinders adoption, although the technology increases the overall performance of the FMCG supply chain.[4]

Many of the application areas mentioned in this thesis apply at the case level or affect store processes. The affect of RFID on the processes within the domain of manufacturers seems limited. In some areas, e.g. the handling of full pallets, companies claim to have already reached high levels of data quality. The capabilities of RFID compared to the barcode, especially non-line-of-sight reads and bulk reading, seem to result in few advantages except for the elimination of barcode scans. This limits the potential of manufacturers to realize operational savings from RFID. Manufacturers are at a further disadvantage as they need to carry the tag costs (see chapter I.1).

Manufacturers, however, may gain indirectly from RFID. First, they can expect to gain from higher levels of product availability at the retail shelf when retailers improve their store operations. Second, retailers might be willing to provide access to data in exchange for manufacturers applying RFID tags at the case and pallet levels.

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1 *Rogers (1995), p. 207*
2 *Despite tests with RFID at the case and pallet level since 2001, Wal-Mart, for example, was not able yet to estimate the impact of RFID on product availability (see RFID Journal 2005l)*
3 *Little (1991), p. 537*
4 *In fact, even if new technologies or practices have a positive effect on performance, companies seem to complain if they perceive the distribution of benefits and cost to be uneven (Corsten, Kumar 2003)*

Early adoption phase creates challenges and opportunities

This thesis implicitly assumes that a critical mass of retailers and manufacturers has adopted RFID. It does not explicitly consider the strategic options of companies in the early phase of adoption. In this phase, companies need to determine how to approach RFID. Manufacturers, for example, have to determine whether they want to actively drive adoption, how best to comply with retailer mandates, and when to start using RFID internally.[1] Retailers have to decide, for example, whether to issue RFID mandates and how to implement RFID so that they can quickly start to see benefits from RFID.

Innovators and early adopters of RFID technology may realize a number of first-mover advantages, including the following:[2]

- Early adoption allows companies to quickly move down the learning curve and discover and implement new RFID-enabled processes ahead of competition. These companies may be able to gain a temporary competitive advantage from RFID and increase company performance. With more and more companies adopting, the benefits from RFID may be competed away (see chapter III.8). In this respect, RFID is likely to follow the life cycle of many other technologies. Some benefits might diminish when more and more companies adopt. One example is product availability: While the first companies may see an increase in sales if they achieve higher levels of product availability with RFID, the overall impact on sales is likely to be small once product availability levels have risen in the industry as a whole.

- Early adoption of RFID can help to market the company against customers, competitors, investors, and suppliers.[3] One example of a company that actively pursues this strategy is Metro: “Interestingly, a primary motivation for METRO’s FSI [Future Store Initiative] is to differentiate itself as an innovator in the industry”, as Rice[4] observes. The activities have won the company the Supermarket News “Technology Excellence Award 2003” for international companies and the RSI News “Fusion Award 2004 for Retail Management Excellence”.[5]

- Manufacturers that adopt early may also see this as an investment in the relationship with key customers. Christine Overby[6] from Forrester Research states that “[y]ou become more strategically aligned with Wal-Mart if you adopt RFID before your competitors, and it is very safe to say that you will get some kind of ‘support’ from Wal-Mart.” Citing technological challenges and problems finding a business case, Mark Engle[7], IT Director Supply Chain at Campbell USA, mentions as good news from early RFID compliance: “We continue to maintain a positive collaborative relationship with top customers.” According to Thonemann et al.[8], especially large manufacturers take on a leadership role in a large number of initiatives with retailers in order to secure a preferred relationship with them in the long term. The number of preferred relationships is likely to be limited to five to ten companies, and manufacturers do not want to risk their position. Small companies need to be more selective and may expect more direct rewards for adopting RFID. As Karl Paepke[9], vice president of operations for Jack Link’s, a company that sells meat products to Wal-Mart and voluntarily complied with the January 2005 deadline, states: “We are certainly hopeful that RFID compliance will mean we sell more product to Wal-Mart.” In contrast, companies that cannot convince their customers that they are ready to comply with RFID mandates might see an erosion of market share.[10]

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1 *see e.g. Deloitte (2004a)*
2 *see Gilbert, Birnbaum-More (1996) for a general discussion of first-mover and second-mover advantages*
3 *Kaapke, Bald (2005)*
4 *Rice (2005), p. 7*
5 *see www.future-store.org*
6 *cited in Intelligent Enterprise (2004), p. 9*
7 *Engle (2004), slide 17*
8 *Thonemann et al. (2003), p. 43 ff*
9 *cited in Intelligent Enterprise (2003)*
10 *Shutzberg (2004)*

Other companies may choose to take a more cautious approach to the RFID technology. These companies may realize some second-mover advantages which include the following:

- Second movers may free-ride on the investments of first movers, assuming that the innovation is easily and inexpensively imitated. This strategy can be tempting as companies such as Metro share their learning relatively open in order to drive adoption in the industry.[1]

- Increases in volume and technological developments lower the cost of adoption. For RFID technology, this concerns, among others, the cost of RFID tags and readers. Philips, for example, projects that the cost for Generation 2 UHF chips (not the entire tag) would drop from 0.047 Euro per piece to 0.024 Euro if production volume increased from 10 million pieces to 1 billion.[2]

- Adoption for second movers can become easier because market, technology, or regulatory uncertainty is resolved. Second movers may wait with their investment, for example, until it becomes clear whether the technology will finally be adopted. Specifically for RFID, technology uncertainty includes standardization issues surrounding the Generation 2 UHF protocol. For Europe, one risk concerning regulation involves the new ETSI specification and its adoption in Europe.

Management attitude towards technology can influence judgment of RFID

This thesis did not try to assess general attitudes towards innovation in the companies that took part in the research. There are several factors that can influence a company's attitude towards new technologies such as RFID:

- Any investment in new technology carries risks. Companies that see the risks inherent in new technologies more as an opportunity than a threat are likely to hold a more positive view of RFID. Investments in RFID pilots may be justified by thinking about RFID in terms of real options. Conducting the pilot may offer the chance to reap significant benefits in the future with a limited initial commitment of resources.

- RFID may drive change in the supply chain by acting as a catalyst. Companies that include these considerations in their assessment are likely to attach a higher value to RFID.

- Some benefits of RFID may only materialize in the longer run when companies learn how to extract value from the technology. Companies with a longer planning horizon may have a more favorable attitude towards RFID.

- Companies that see new technologies as a way to increase competitive advantage rather than focus solely on operational efficiency are more likely to be among the industry leaders in adopting RFID. Second movers may realize higher benefits from RFID at lower cost once they decide to adopt than the first movers were initially able to reap, as the technology has become more mature and there is more knowledge on how to derive value from RFID data. However, once the technology and associated practices are well-understood, the potential to achieve a performance advantage relative to competition might have vanished. On example is product availability. Those retailers that are able to reduce stock-out levels ahead of competition are likely to see an increase in sales, whereas those that only match the levels competitors have already achieved might not gain much.

1 *see e.g. Metro, KSA (2004)*
2 *Philips (2004)*

RFID likely to extend the lead of most efficient players

The research findings confirm the view that, from what is known today, RFID is a sustaining innovation for those retailers that compete on supply chain efficiency which offers incremental improvements.[1] Or, as Tony Puckett[2] from Wal-Mart is quoted as saying: "RFID is not the silver bullet but the next stage in improving the supply chain."

This perspective is supported by looking at three of the most prominent retailers that have decided to adopt RFID: Wal-Mart is generally considered the world leader in retail supply chain management; Metro won the 2002 German Logistics Award for its logistics system[3]; and Tesco was recognized as the industry leader in logistics in the UK as long ago as the 1990s[4] and has since massively invested in its distribution network[5]. It may now be the retailer which has most consequentially implemented lean management principles.[6]

So far, it is content retailers such as Tesco and channel retailers such as Wal-Mart and Metro[7] that are engaging in RFID roll-outs. Global discounters[8] such as Aldi and Lidl are absent. A look at the contextual factors might explain this effect: Due to the low number of SKUs, it is easier for employees to oversee operations. Furthermore, due to the shipment of larger quantities of each product to the store[9], there is less handling at the case level. This reduces the potential benefit of RFID. On the manufacturer side, the picture is less clear. Currently, it is primarily brand manufacturers[10] that engage in initiatives such as EPCglobal and are known to participate in retail roll-outs and pilots. One reason for this may be that these companies potentially suffer the most from the negative effect on brand loyalty of repeated OOS situations (see chapter IV.3). However, the engagement might also partly result from the fact that these companies have to be active in a lot of initiatives in order not to risk their preferred relationship to customers (see chapter II.2). Furthermore, their activities might simply receive the most attention, while many channel manufacturers or private label suppliers may start RFID tagging with key customers without making this public.

1 *Raynor (2004)*
2 *cited in CIES (2004b), p. 10*
3 *MGL (2002)*
4 *Fernie (1994)*
5 *see e.g. Clarke (2002). The latter example contrasts with another leading UK retailer, Sainsbury's, which is struggling to adapt its supply chain despite heavy investments (Sainsbury 2004).*
6 *Womack, Jones (2005)*
7 *see Rudolph (2000). Tesco, for example, offers more than 4 500 products as private labels in the UK, and more than 80% of its customers regularly buy these products (www.tescocorporate.com). Rudolph mentions only Metro Cash&Carry, not Metro in general, as an example of a channel retailer, but the classification also fits for other Metro distribution lines such as Real and Extra.*
8 *In the US literature, Wal-Mart is often classified as a discounter (see Ghemawat et al. 2004), despite the wide range of products that the company offers. In Europe, typical discounters such as Aldi and Lidl offer only a few hundred to a few thousand different SKUs (see IGD 2004).*
9 *For specific products, Aldi, for example, places full pallets onto the shop floor*
10 *See Schmickler, Rudolph (2002), p. 36*

As Raynor[1] states: "Sustaining innovations are what enable organizations to appeal to increasingly more demanding customer segments, and hence grow. Sustaining innovations can be incremental, year-by-year improvements, or breakthrough, leapfrog-beyond-the-competition offerings. [...] Disruptive innovations are inferior to the currently available products, as measured by traditional performance metrics, but they offer other benefits. Typically, disruptive innovations are simpler, more convenient and often less expensive, too." The use of RFID technology in advanced retail supply chains hardly matches these criteria when compared to the barcode: RFID offers superior functionality compared to the barcode (non-line-of-sight, bulk readings)[2], is technically more demanding (e.g. antenna design) and more expensive than barcode technology. So, despite the fact that RFID may transform some processes, it may nevertheless sustain the lead of established players such as Wal-Mart which actively drive the development of RFID technology. To quote Raynor again: "For Wal-Mart, as for other retailers who compete based on their supply chain efficiencies, RFID is simply another turn of the crank. The changes required to adopt RFID might be wrenching at times, but they pose no fundamental challenges to the organization's underlying business model." In the retail industry, RFID is, however, another disruptive technology for department stores and other retailers that compete on service and selection.

VI.3 Theoretical implications

This thesis contributes to theory in three areas:

- First, the thesis proposes a theoretical framework that conceptualizes the impact of Auto-ID technologies on process performance. So far, the research on RFID lacks a theoretical foundation. The framework links the research on RFID to existing research in the area of complementarity theory and the business value of RFID.

- Second, the research findings draw attention to an additional role of RFID apart from the role as implementer and enabler: In some instances, RFID can act as a catalyst, i.e. as a vehicle for companies to implement changes in the supply chain that were not possible before but do not rest on the capabilities of RFID. Examples include the industry-wide adoption of SSCCs and dispatch advices as well as the sharing of additional data on product location and movement.

- Third, this thesis develops two mathematical-analytical models that can be used to estimate the benefits from informational and transformational effects of RFID on product availability.

In each of the areas, there is a need for further research:

- Researchers may use the theoretical framework as a basis for an empirical-quantitative survey of RFID benefits at the case and pallet level. Even those companies that have already decided to adopt RFID at the case and pallet level are at a very early stage of adoption.

- Further research may examine in more detail why a catalyst such as RFID is needed to drive change. The research may also examine to what extent companies are aware of this role of RFID and include them in their evaluations.

- There is a need for more research that seeks to quantify the impact of RFID data. The two models suggested here may provide a starting point to the development of more sophisticated models on how RFID will increase product availability. Researchers may also develop models that deal with the effect of unique item identification (which is a complementary innovation to RFID as RFID reduces the cost of capturing unique item data).

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1 *Raynor (2004)*

2 *It can be argued that RFID technology is currently still technically inferior to barcode technology due to lower read rates. However, as for example Wal-Mart has made clear, they intend to use RFID in applications where read rates of close to 100% are achievable (as they do not intend to read cases when on a pallet, but rather when on a conveyor) and expect their suppliers to deliver products that can be read 100%.*

Once adoption has taken place, researchers may, for example, examine the following hypotheses with respect to RFID and product availability (see Figure VI 1):

H1: *RFID at the case level increases inventory accuracy at the retail store.*
H2: *The impact of RFID at the case level on inventory accuracy at the retail store is moderated by the origin of the delivery (retail DC versus direct store delivery). The impact is higher for products delivered from the retail DC compared to direct store deliveries.*
H3: *Increased inventory accuracy leads to higher product availability at the retail store.*
H4: *The impact of inventory accuracy on product availability is moderated by the availability of complementary technologies and practices such as automatic store ordering systems.*
H5: *RFID at the case level increases product availability at the retail store.*
H6: *The effect of RFID at the case level on product availability is moderated by in-store processes and increases with the use of backroom inventory.*

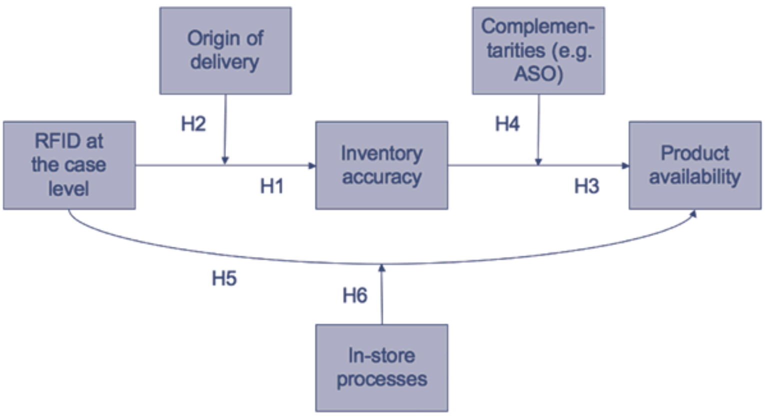

Figure VI-1: Example of research model for empirical-quantitative research

VI.4 Managerial implications

This thesis has sought to improve the practical understanding of the potential benefits of RFID at the case and pallet level:

- First, it has identified potential benefits of RFID in the FMCG industry and discussed how companies intend to realize them. The goal has been to look for RFID applications that allowed companies to transform business processes.
- Second, it has discovered a number of contextual factors and complementary technologies and practices that affect the potential value from RFID.

No company in the FMCG industry can simply ignore RFID, and each company should define an RFID strategy. Not every company, however, may come to the conclusion that it needs to adopt RFID immediately. This thesis offers six recommendations to companies that want to determine their approach to RFID (see Figure VI 3).

1. Build a company-specific business case for RFID

The conceptual framework and the experience from the field research suggest that there is no generic business case for RFID at the case and pallet level. Environmental and company-specific factors influence the potential benefits from RFID.

Companies therefore need to conduct their own analysis and should not rely on the experience of other companies. The business case should not only deal with internal operations, but also how RFID technology affects processes with trading partners. Manufacturers in particular should also evaluate whether the benefits that their customers can realize from RFID translate into benefits (e.g. higher sales) for their organizations.

Companies may use the following questions in order to get a better understanding for the potential of RFID technology in their supply chain:

- How much effort do we and our trading partners expend on product identification?
- In which areas do we and our trading partners lack accurate, timely, complete or objective data on the flow of products? Which of these problems are caused by problems or high cost associated with data capturing?
- How would the availability of data affect current processes? How could we and our trading partners use RFID data to realize new processes?
- Can the adoption of RFID be combined with other initiatives which we have found difficult to implement with trading partners?
- Do we and our trading partners have the necessary systems and practices in place so that we can actually use RFID data?
- How do our supply chain and our products compare to the industry? Do there exist some favorable conditions that allow us to extract a higher value from RFID than our competitors?

2. Look for informational and transformational effects

There seems to be not one benefit that justifies the adoption of RFID across the FMCG industry. RFID offers a variety of potential benefits to companies in the FMCG industry, with each of the benefits in itself relatively small and potentially difficult to estimate.

Industry sources suggest that increased sales and margin due to fewer stock-outs at the retail shelf may be the single most important benefit. For some companies, this benefit alone may drive the business case. In a lot of instances, however, companies may have to consider that multiple benefits are likely to add up to a business case.

An investment in RFID at the case and pallet level may not pay off if companies regard RFID as a mere substitute for the barcode and focus on automational effects. The replenishment-from-the-backroom process is one example where RFID may enable new processes. There are other areas, for instance in shrinkage prevention, where RFID data can improve decision making processes or lead to transformational change.

Companies should strive to develop innovative ways to use the capabilities of RFID. Those that succeed may be able to realize a competitive advantage that is hard for competitors to imitate.

3. Take a long-term perspective and evaluate alternatives

Companies should take a long-term perspective when determining their RFID strategy. They might define a number of strategic alternatives and compare the outcome of each alternative for different scenarios. The alternative strategies may, for example, consider different dates for an investment in RFID. The scenarios could capture different developments concerning business benefits, technology maturity and cost, and industry activities. One scenario could, for example, incorporate that the benefits of RFID increase over time as the company finds new ways to use RFID data. Adoption of RFID would allow a company to take advantage of these additional opportunities

A long-term perspective can ensure that a company does not start to invest too late or too early. For example, although the company might not expect to invest in RFID before 2007, it might discover that it needs to implement complementary technologies and practices now. It can also ensure that a company does not fail to invest in RFID simply because the payback period is longer than one or two years.

4. Include industry activities in your considerations

Companies should take into account how their trading partners and competitors approach RFID. For example, non-compliance with retailer mandates may not be an option if competitors comply or even volunteer. When more and more companies in the industry adopt RFID, a non-adopter risks falling behind. For a manufacturer, adoption of RFID may become a strategic necessity in such a situation, as non-adoption could seriously affect the relationship to retailers that drive RFID. A company may also find that it is the first in its market and actively exploit its RFID activities for marketing purposes.

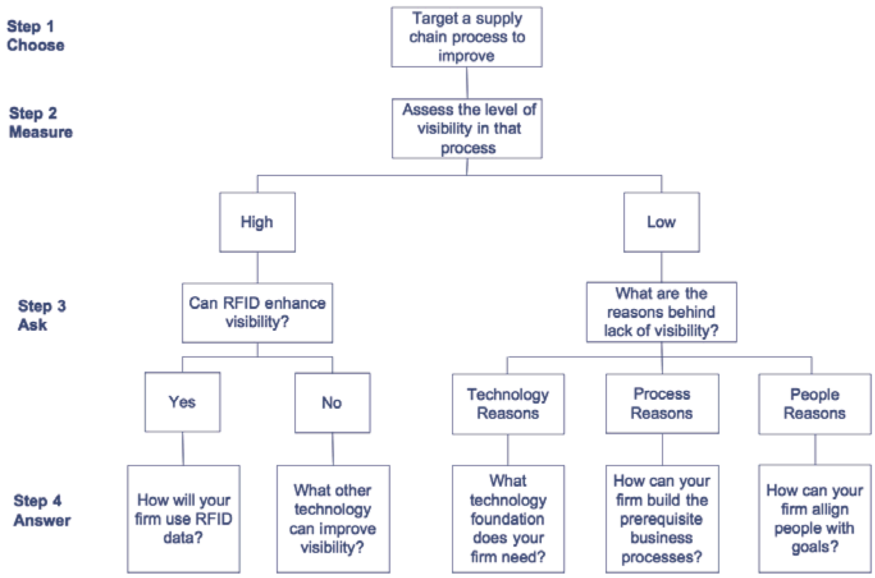

Figure VI-2: RFID and supply chain visibility[1]

5. Be clear about the reasons for adopting RFID technology

Companies should closely examine whether the potential benefits that they expect to derive from RFID actually rely on the capabilities of RFID. They, for example, should evaluate whether a new process is actually enabled by RFID or whether there is a cheaper way to realize the process based on existing data capturing technology.

There may be good reasons to invest in RFID, even when the capabilities of RFID are not intrinsic in order to achieve the envisioned change. Companies, however, should be aware when they use RFID as a catalyst to drive, for example, the adoption of other technologies and practices or to deepen the relationship with trading partners. One example where RFID at the case and pallet level may act as a catalyst is information sharing across the supply chain. If visibility into the status and movement of products is low, it is often not the data capturing that is the constraint (see Figure VI 2). The discussions about RFID between trading partners, however, may help to overcome the hurdles.

1 *adapted from Tohamy (2004)*

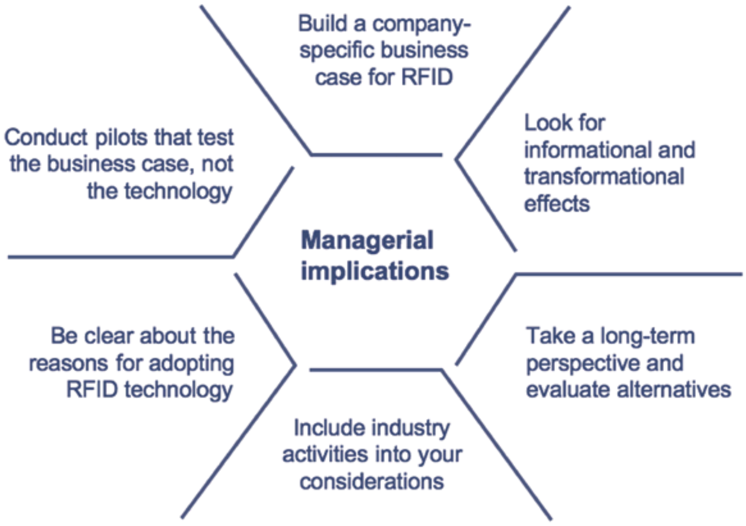

Figure VI-3: Managerial implications

6. Conduct pilots that test the business case, not the technology

Pilots can be an effective way for companies to learn about the technology and to find out where RFID can improve decision-making and enable new processes. The pilots should focus on testing the business case rather than technology. These tests are likely to involve more than just a few readers and tags, but also include process changes and some form of system integration. Before the pilot starts, the companies involved need to define the metrics against which to evaluate the technology. They might define a controlled experiment in which they observe process performance with RFID and compare the performance with that of a control group without RFID.

Companies can regard RFID trials as learning options.[1] They offer new insights and allow companies to figure out how the technology can be applied. After the results of the pilot are available, companies can make better informed decisions, for example, whether or not to start a roll-out.

1 *Amram, Kulatilaka (1999), p. 11*

VI.5 Future prospects

Transformational effects are likely to increase over time

The current research provides only a snapshot of what companies may be able to achieve with RFID technology. Evidence from the introduction of the barcode suggests that indirect effects, which mainly result from transformational effects, can be much greater than initially anticipated.

Taking the apparel industry as an example, Hwang Smith and Weil[1] describe the adoption of barcode technology, EDI and other technologies and practices as a ratchet-up process: With each adoption of a technology or practice by retailers and their suppliers, there was an incentive to adopt additional technologies or practices. The result was a "revolutionary change in evolutionary steps."[2]

Practitioners confirm this view specifically for RFID: John Clarke[3] of Tesco remarks that "RFID may be a revolutionary concept which must be deployed in an evolutionary manner over the next 5 to 25 years." Simon Langford[4] of Wal-Mart mentions that Wal-Mart is "taking the stance that if we start it at a point where we integrate the EPC and take that as though we're reading a bar code [...]. So, it's one byte at a time, and [...] we will just have iterations through each year and continue to improve."

EPCglobal Network becomes available

Many EPCglobal standards that deal with the actual networking components of the EPCglobal Network are not yet defined.[5] Wal-Mart, Tesco and Metro have made it clear that they will initially exchange data via existing EDI linkages. Once the full EPCglobal Network becomes available, retailers and manufacturers may gradually shift from data exchange via EDI to the EPC-global Network. In the long term, this may be a cheaper way to exchange data, especially when companies want to distribute and provide access to instance-level data.

Technical developments will drive adoption of RFID

Standardization, mass production and new production technologies are likely to drive down technology cost for both RFID readers and hardware. There is a lot of research going on in areas such as printing antennas and chips. Additionally, solution providers are likely to provide RFID solution packages which reduces the implementation cost.

These developments may eventually lead to the industry-wide adoption of RFID at the case and pallet level and to the introduction of item level tagging, at least for specific categories.

A new coherent pattern for managing the FMCG supply chain?

The term revolution, as mentioned by representatives from Wal-Mart and Tesco, implies some form of fundamental shift in existing practices. Complementarity theory offers some insights into what constitutes a fundamental change. The theory talks about coherent patterns of practice. One example of a new coherent pattern in managing supply chains is the emergence of lean retailing as an alternative to mass merchandizing in the apparel industry.

It can be argued that the barcode has at least partly contributed towards the development of a new paradigm for how FMCG companies manage their supply chain (see chapter III.8), characterized by a centralization of distribution and decision-making, by an increase in store size and the number of SKUs, and by practices such as automatic store ordering and vendor-managed inventory. Probably the best-known example of a company that has strived to follow this approach is Wal-Mart.

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1 *Hwang Smith, Weil (2004)*
2 *ibid, p. 8*
3 *cited in Rice (2005), p. 7*
4 *cited in FTC (2004), p. 122*
5 *see EPCglobal (2005) for an overview*

Some researchers and analysts have suggested that RFID might lead to changes that reverse some of these developments. However, as Sheffi[1] remarks: "At this point, while the technology is still nascent, it is difficult to imagine the structural changes that might unfold. By definition, these changes are not part of the current vision. Some will come into being because RFID will provide some unknown value in conjunction with other, yet-to-be invented technologies." One example Sheffi mentions is that RFID enables continuous monitoring of product availability and more frequent deliveries which allow companies to reduce shelf space per product. This may lead to a reversal of the trend towards ever larger suburban supermarkets and a revival of smaller stores, located closer to the customer, with a product assortment adjusted to fit local tastes.[2] Kevin Mitchell from Accenture expects that RFID will lead to an increase in direct store deliveries.[3] Other analysts have suggested that RFID will lead to a proliferation of practices such as VMI at the store level, vendor-managed store operations, and scan-based trading.[4]

Ultimately, new ways of doing retail, enabled by RFID, may prove a disruptive technology that challenges the business model of current FMCG industry leaders. The activities of visionary and innovative companies will determine the future of RFID. The results of these companies will reveal the true potentials of the technology.

1 *Sheffi (2004), p. 8*
2 *see also Progressive Grocer (2005b)*
3 *according to RFID Journal (2005b)*
4 *Gartner Research (2005a)*

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