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From Operations to Strategy: The Potential of RFID for the Automotive Industry

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Abstract

For the automotive industry RFID (Radio Frequency Identification) is more than just a barcode replacement. Major companies regard RFID as strategic relevant for supply chain management. This report analyzes the business need for RFID in the automotive Industry and evaluates possible applications that address strategic challenges.

The automotive industry has been using RFID technology for many years to improve local processes like production control and asset management. Potentials for improving the supply chains are recognized, but there are only few activities that could support the deployment. Unclear business cases, technological drawbacks and missing standards are challenges for the adoption. Nevertheless, companies from the automotive industry can achieve quick benefits through increased handling efficiency and higher data granularity for their local processes. Building on those applications they can step by step develop an infrastructure that facilitates global supply chain applications.

Our recommendations show how companies from the automotive industry can achieve more benefits from RFID technology and avoid taking the risk to invest without clear idea about their return on investment. The results presented in this report are based on a survey Booz Allen Hamilton and the Auto-ID Lab at University of St. Gallen carried out jointly between November 2003 and January 2004.

Table of Contents

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1. Introduction

1.1 RFID – The Next Big Thing in Auto-ID?

Radio Frequency Identification (RFID), a technology for tracking physical objects from tires to entire vehicles by using small electronic tags, is becoming an increasingly hot technology. Industry analysts are forecasting this market leaping to billion dollar levels in the next 3 to 4 years. Technology providers like IBM, SAP, Intel and Philips are announcing product rollouts for the RFID market (tags, reader infrastructure, software solutions and supply chain services) at an ever increasing pace.

The adoption of RFID for supply chain applications is currently driven by the retail and FMCG sector. Recent announcements from retail giants Wal-Mart, Tesco and Metro to make pallet and case level tagging mandatory for their suppliers by 2005 has pushed a whole industry into implementing RFID-compliant logistics and supply chain processes. However, proven business cases for those applications that promise a sustainable success beyond marketing effects are still missing.

In order to analyze the strategic implications of RFID technology for the automotive industry, Booz Allen Hamilton together with the Auto-ID Lab at the University of St. Gallen have conducted a survey with 25 senior executives from 16 companies including 11 VMs (Vehicle Manufacturers) and suppliers, 4 technology providers and one industrial organization.

Key questions raised as part of this survey are:

- How can RFID technology address strategic challenges for the automotive supply chain?
- What are the key challenges for the deployment of this technology for a single company and for the entire value chain?
- How are RFID roll-out programs orchestrated and governed?
- To what extent does it make sense to invest into RFID technology already today?

We believe that the vision for RFID must be seen from two directions – from the perspective of the individual company that seeks to improve their own processes, new products and services, and from the perspective of the entire value chain where the focus is on improving global supply chain efficiency and collaboration.

In the following, this study describes the main strategic challenges for the automotive industry and proofs that the RFID technology can contribute to meet these challenges (chapter 2). Then, by contrasting the automotive industry's strategic claim towards RFID with the real status of RFID activities found in the interviews, this survey shows evidence for a strategy gap towards RFID within the automotive industry (chapter 3).

Based on on the results from the interviews and the expertise of the authors, the report identifies drivers and risks for the adoption of RFID technology. As a result it provides a set of recommendations that show under what conditions and to what extent the automotive industry should invest into RFID technology already today. The last chapter summarizes the key messages of this report.

1.2 RFID – An Overview

Like the barcode 25 years ago, RFID is expected to have a large impact on supply chains, assembly processes, products and after sales services in various industries. RFID technology can virtually connect physical objects and data within a network, e.g. via the Internet. Data about every product, for example its history or other product related information can be made available through a standardized infrastructure anywhere and anytime1. Such a RFID system uses several components:

- The **Smart Tag** is a low cost RFID based label that turns ordinary physical objects into “smart objects”.
- A **Reader Infrastructure** communicates with the smart objects without the need for line of sight.
- A **RFID Middleware** manages the data as it is collected and provides it in real-time to business software systems, e.g. ERP systems, or to the Internet.

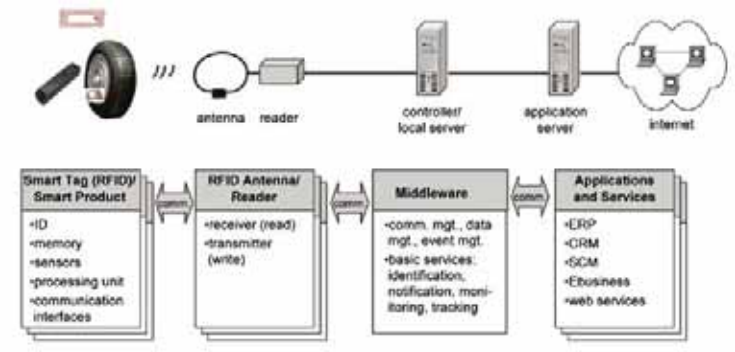

Fig. 1: RFID System Architecture

In the last years RFID technology has gained more and more attention in various industries. The miniaturization of the technology and increased demands lead to decreasing costs and extended the scope of application from niche applications like tracking of high value goods or production automation to high volume supply chain applications. Today the price for a typical simple RFID label is still between 20 and 70 US-cent, for an active RFID tag around 10$, but leading research institutes predict a further drop in price when the RFID market evolves. This effect could drive prices for passive labels significantly below 10 cent and for active RFID tags below 1$ in the mid term, which will facilitate applications that are still showing a negative business case today.

The emergence of standards is another driver for RFID applications. Examples for recently released standards are ISO 1596X, ISO 18000-X, B-11 and EPC (Electronic Product Code). The concept of EPC goes beyond standardization of the data structure on smart tag and air interface of tag and the reader infrastructure. Moreover it provides middleware software that enables the integration of the technology with backend systems.

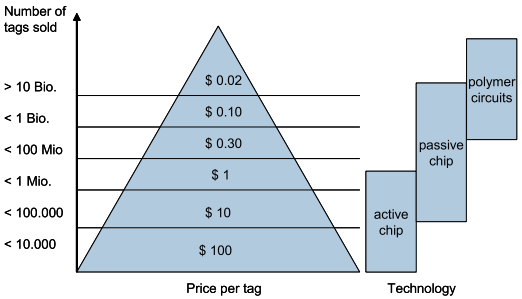

Fig. 2: High Volume Mean Low Cost (Source: IDTechEx)

The Advantages of RFID against other Auto-ID technologies that impact the business case are increased handling efficiency and support for higher data granularity (see Table 1). The reasons for improved handling efficiency are automatic identification without line of sight, the capability for bulk reading and the possibility for rewriting that helps to avoid relabeling. Higher data granularity is achieved by unique identification, additional product related data and real-time availability of accurate data. For this reason major potentials of RFID technology exist where accurate and granular data is necessary, e.g. for customization, quality and security checks and tracking&tracing. The direct attachment of these data to the objects supports the concept of decentralization in data management.

Schottky Diode Name	Junction Area	Junction Peri	Finger Number	W*L
SBD1	0.23p	1.92u	1	0.48um*0.48um
SBD2	0.23p	1.92u	1	0.48um*0.48umi
SBD3	1.4976p	7.2u	1	0.48um*3.12um
SBD4	16.128p	72.9u	6	0.48um*5.6um
SBD5	14.4p	60.96u	1	0.48um*30umii

Table 1: Benefits of RFID

First movers that released roadmaps to adopt RFID to their supply chains based on the EPC concept come from the retail sector:

- *Wal*Mart* directs their top 100 suppliers to use RFID on all pallets and cases by January 2006. Analysis indicated that the world's largest retailer alone could save as much as $8.35 billion per annum.
- *Metro* will begin using RFID throughout its entire process chain. Beginning in November 2004, approximately 100 suppliers initially will affix RFID tags to their pallets and transport packages. According to IBM that is involved in this project, Metro could save up to 20% of their warehousing cost by the use of RFID.
- The *US Department of Defense (DoD)* requires its suppliers to put passive RFID tags on the lowest possible piece part, case or pallet packaging by January of 2005. RFID will help DoD improve the management of inventory with hands-off processing.

2. The Strategic View on RFID

As indicated above for the retail sector, we also regard RFID for the automotive industry as technology with strategic relevance. The following sections describe six major challenges for the automotive supply chain, and show how RFID could contribute to master these challenges.

2.1 Strategic Challenges of the Automotive Industry

In an environment of strong global competition the automotive industry faces six main strategic challenges to their supply chains:

Fig. 3: Strategic Trends in Supply Chain Management

- *Demand chain (shift from push to pull)*. Manufacturers are shifting from long term production planning to flexible short term planning based on customer orders. This principle changes the whole supply chain. Each member places orders to its supplier based on the current demand. Increased collaboration and information exchange between supply chain players is necessary to achieve efficiency in this process.
- *Customer focus*. Companies in the automotive industry are looking for ways to offer more and improved services to their customers to maximize their value creation. For example, VMs seek to offer more value added services, e.g. telematics, entertainment, vehicle financing services, or improved and faster after sales services, i.e. better maintenance & repair services as well as improved availability of spare parts availability.
- *Outsourcing/Decentralization*. At the same time, VMs outsource more and more upstream activities to suppliers and logistics service providers. The result is a downward shift along the automotive value chain. Examples of these outsourced activities

are: production of entire systems or even vehicles, vehicle customization, in-house logistics, asset management, information services, tracking & tracing services and direct delivery to the line. This means that suppliers and LSPs provide larger parts of the value generation and thus need to achieve higher system and vehicle knowledge. The integration along the supply chain adds to the requirements with regard to information exchange along the supply chain and for VMs capabilities to maintain visibility and control.

- Mass customization. Each car is built individually according to the customer's order. For example, at VW in Wolfsburg, statistically only two equally configured vehicles of the Golf series are manufactured per year. The number of different variants and the related complexity of in-house logistics and assembly processes are increasing from model to model. Achieving high process flexibility on the one hand and maintaining an efficient supply chain that supports just-in-time (JIT) and just-in-sequence (JIS) manufacturing on the other hand, is a major challenge.
- *Total Quality Management (TQM)*. High quality is required not only by customers but it is also increasingly enforced by law. To ensure the safety of vehicles, new laws require documentation of certain assembly processes and traceability. Deficits in quality lead to costly claims and recall actions.
- Lifecycle Compression. The product lifecycle of vehicle models is decreasing. For the production of a new model production layout and logistic processes have to be changed. These changes are a source of potential errors during ramp up and can increase the time-to-market leading to lost sales. For example, Volkswagen stated that it missed their production plans for the Golf V model in 2003 because of assembly problems during ramp up. The decreasing time of product lifecycle is also critical for an increasing number of parts, especially electronics. Assuring the availability of such spare parts for cars is a major challenge.

To accomplish the goals described above, automotive manufacturers increasingly rely on information technology to help manage their processes. Many projects in this area focus on improving supply chain collaboration, e.g. CPFR (Collaborative Planning Forecasting and Replenishment), VMI (Vendor Managed Inventory), and SCEM (Supply Chain Event Management).

2.2 The Strategic Importance of RFID for the Automotive Industry

The strategic challenges mentioned in the section above are the starting point to show the strategic relevance of RFID technology for the automotive value chain. RFID technology enables significant improvements along the critical processes that are key to address these challenges: improved handling efficiency through reliable automatic identification without human intervention, bulk reading and higher data granularity due to of real-time and accurate product related data (see Table 2 and the following paragraphs).

Strategic Challenge	Critical Processes	Used features of RFID	Contribution of RFID
• Customer focus	• Production control • Distribution • Maintenance	• Unique identification • Real-time information about product	***Supportive,*** improvements in after-sales services, but no main driver for value generation
• Demand chain	• Planning • Inventory management • Production control • Distribution • Tracking & tracing	• Handling efficiency • Accurate data • Real-time information	***High,*** RFID enables a new dimension in process efficiency, reliability and flexibility

• Outsourcing	• Asset management • Tracking & tracing	• Accurate data • Real-time information	***Supportive,*** improved process reliability but no major driver for outsourcing
• Mass customization	• Production control • Quality control	• Unique identification • No manual handling	***High,*** management of complexity, reliable and efficient
• Total quality management	• Production control • Quality control	• Handling efficiency • Accurate data	***High,*** efficient error avoidance
• Lifecycle compression	• Planning • Production control (warm up) • Tracking & tracing	• Accurate data • Handling efficiency	***Supportive,*** improvements in operations, but not for planning or product development

Table 2: Support of RFID for Critical Processes and Strategic Challenges

Demand Chain

The main challenge of the demand chain is coping with shorter planning cycles. Sizes of orders are dependent on master plans that are made short -term based on customer needs. This requires flexibility from the supplier to adapt to changes in demand also in the short-term and continues from the 1st tier supplier to the 2nd tier supplier and so on along the whole value chain. A better solution than costly excess stocks would be a flexible or so called "agile" supply chain. Such supply chains require efficient and reliable planning, inventory management, production, and distribution processes.

Based on accurate inventory data more reliable production plans can be made, which avoid the risk of running out of parts. With its ability to automatically track check-ins and check-outs at warehouses, RFID can help making data on inventory levels more reliable. A requirement for flexible production processes is the ability to produce several variants of a product on the same production machine without long setup time. The procedure creates additional complexity for replenishment and assembly. RFID facilitates the identification of parts and helps preventing mix-ups of parts by mistake. Another risk that can be reduced using RFID technology is the possibility of distribution errors. Misrouted or wrong packed deliveries jeopardize material replenishment at the customer's site. RFID can be used in picking and packing for completeness checks and control of consignment.

Customer Focus

Increasing value generation with the customer requires better identification of customer needs as well as offering improved or new services. The implementation of the demand chain with a reliable delivery process is a first step towards improving customer service, e.g. if a VM is able to arrange a fixed delivery date for the vehicle with the customer. A next step to better get to know the needs of the customer after the sale, is detailed knowledge about the product that was bought. For example, a VM at least should store configuration data about the vehicles he has sold. It would be even better, if the VMs later can maintain this information for the whole product lifetime. Based on this information VMs can better support maintenance for the car. For example, many electronic parts need to be programmed individually for a specific configuration. Parts that are tagged with RFID offer the possibility of being recorded automatically with their serial number during assembly. Later during maintenance, the configuration information needs to be updated by the garage that could use the same procedure.

Outsourcing

Outsourcing increases the risk of quality deficits in the outsourced process. Exact service level agreements can minimize the risk.

For this reason manufacturers are interested in monitoring the performance of their service providers. With its ability to track processes automatically, RFID as an extension to a common IT infrastructure helps the manufacturer to maintain visibility and also supports controlling outsourced processes. In this way RFID reduces the risks of outsourcing. The higher the degree of automation and independence from human interaction, the easier it is to outsource a process to service providers. The degree of automation and process reliability can be leveraged before outsourcing as described for the demand chain. Asset management is an example of a process that can potentially be outsourced. Service providers can provide the same assets to several customers and use RFID technology to improve the efficiency of this process.

Mass Customization

The challenge of mass customization is the efficient assembly of different product variants, on the same production line according to customer orders. The more variants are assembled on the same line, the higher is the risk that parts are mixed up. The risk is even higher if for any reason a necessary part is missing and as a result the sequence of those parts that are delivered JIS, is mixed up. This requires additional efforts for accurate parts identification, careful comparing with the variant part list and quality checks. Wrong configured cars either need to be repaired or scrapped. RFID can ease the identification of parts that are at risk for being mixed up. Cable trees are an example where some VMs are already using RFID for automatic identification.

Total Quality Management

The goal of TQM is “zero error production”. High quality levels are necessary to meet today’s customer requirements. Quality is expected as a basic service and is also required by law. Consequently, manufacturers may face lawsuits if their products fail. Today manufacturers implement quality checks to prevent wrong assemblies. As a result, there are very few cases where a customer gets a wrongly assembled car. But there are still cases where errors are discovered and have to be fixed. The costs for quality checks and errors have a significant impact on the total production costs. As described for mass customization, the automatic identification of parts during assembly can be used to better integrate quality control into the assembly process to prevent errors. Examples on how RFID can help support production processes are the commonly used WIP (Work in Progress) tracking systems. They use an RFID tag, which either directly stores information on the part, its quality and assembly status or contains an ID which is linked to a central database where this information is stored. This way, information about necessary assembly steps is available in real-time and executed assembly steps as well as quality checks are recorded automatically.

Some errors in the production process are discovered only after the product has already been delivered. In this case the respective products need to be recalled. Mostly, reasons for recalls are errors in the design of the product or quality defects of single components. In case of a recall it is important to act as fast and precise as possible. Data on where the affected products and parts are helps to limit those costly recalls by addressing only the affected customers. Configuration data recorded with RFID during production can be used to address such recalls.

Lifecycle Compression

Shorter product lifecycles increase the need for a flexible supply chain and production processes as described for the demand chain. The ramp up for new models always is a challenge for the management of supply chains and production processes. At this

stage, it is important to establish reliable processes as soon as possible. Under the condition that planning of the new processes was done carefully, RFID technology can support the process execution as described above for the demand chain.

Another challenge applies to spare parts distribution. As parts need to be on stock for at least ten years after a model has been sold, the number of parts that need to be managed is increasing. Lifecycle compression also applies to the parts themselves and especially to electronics that today already make up approximately 30 % of a typical car. If such parts are not manufactured anymore, the VM is required to store them in case of later need. Knowledge about the configurations of the cars that have been sold can be used for better forecasting of quantities of parts needed. As described above, RFID can help to record the configuration of cars.

Beside the fact that RFID will be a key supporting technology to address these challenges, RFID used for supply chain tracking bears a high potential for the automotive value chain, encompassing all tasks associated with moving goods from raw-materials through to the consumer. This includes tasks such as sourcing and procurement, inventory management, assembly, order processing, distribution, transportation and warehousing. Although the automotive supply chain has the reputation of being quite efficient compared to other industries, supply chain visibility and information accuracy are still far from perfect. The VMs are dependent on their suppliers for a large number of parts, components or modules. Due to this dependency, supply chain visibility is more crucial.

In addition to supply chain applications like inventory management, check-in/check-out at the warehouse and order management, other beneficial applications are found in the area of after sales services. Examples are maintenance support, recalls and recycling. While RFID today is used only in combination with valuable goods (e.g. special racks) and in local applications it will soon serve for all kinds of containers that are used for parts transportation.

RFID can help to improve visibility over the whole supply chain and beyond as soon as there are standards for data management and middleware that integrate RFID systems with business software like ERP systems.

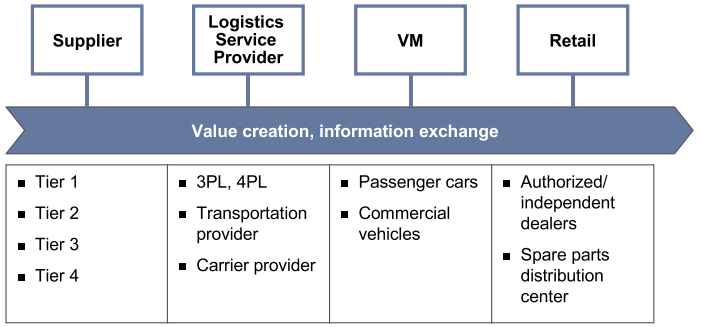

Fig. 4: Automotive Value Chain

The potential benefits for adopting RFID are similar for suppliers and VMs. Both will profit from higher efficiency and reliability in the supply chain, production, and distribution processes. Through the improvement of efficiency and reliability, in those processes RFID can also help the industry to address their strategic challenges. Especially LSPs see a chance to offer value added services based on RFID technology. This report focuses on VMs and their suppliers. The potential of RFID for LSPs is analyzed in Booz Allen Hamiltons viewpoint “RFID-The Opportunity for Logistics Service Providers”.

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3 . The RFID Strategy Gap in the Automotive Industry

Although 50% of the interviewed companies stated that for them RFID has a strategic relevance, supply chain applications as described above, still seem far from being realized in the automotive industry. Current RFID activities focus on improving local processes instead of having the entire value chain in mind. Nevertheless half of the companies see themselves as innovators in adoption (see Figure 6), which supports the importance of this technology.

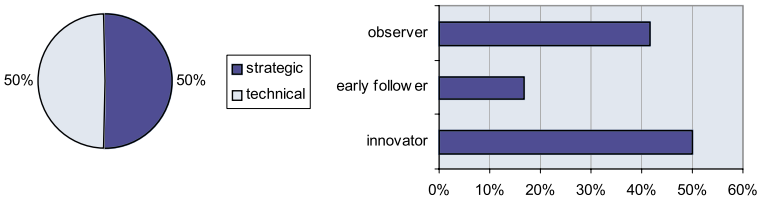

Fig. 6: Attitude towards RFID

The RFID teams in the automotive industry are in most cases not positioned on corporate level, often staffed with only 1 FTE, and in no case a clear RFID roadmap was mentioned. Benefits are only envisioned on the operational level of individual production plants/ sub-processes. This leads to the clear conclusion that most players along the automotive supply chain are acting from an operational perspective only, not capturing the strategic opportunity of RFID yet.

3.1 The Current Status of RFID Adoption

Today, RFID technology does not play an important role in order to support the applications related to the strategic perspective, but RFID has been used for more than a decade for production control, e.g. for work-in-progress tracking, and recently for asset management, e.g. for bin tracking. Improving local process efficiency is the main goal for these applications.

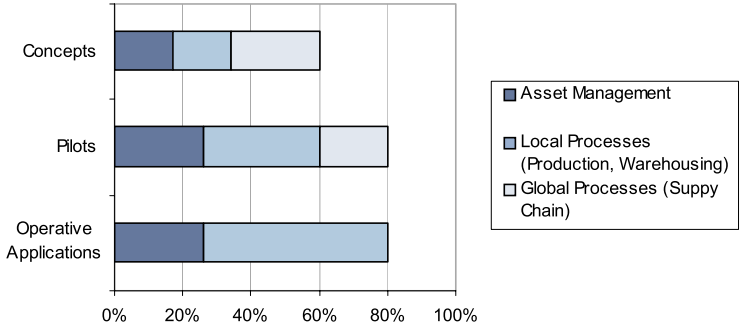

Fig. 7: Concepts, Pilots and Operative Applications

Overall, the evaluation of the interviews indicates that the automotive industry already seems to be advanced in the adoption of RFID. 80% of the interviewed companies have at least one operative application. 80% have started not less than one pilot project and 60% have applications in the concept phase (see Figure 7).

However, the total number of RFID applications is low (only ten in the concept phase, 12 pilot projects and 13 operative applications). This indicates that RFID solutions still have an exceptional character and are not used as a companywide standard solution. The majority of applications are linked to asset management or local processes in production or supply chain management, e.g. check-in at the warehouse, quality control in production, and in-house material replenishment. Most of those applications are of a closed loop type. Open loop applications play a minor role. There are few companies that have concrete plans to build such

applications. However, many named tracking&tracing as main motivation for looking into RFID.

Current project organizations could be a reason for the low number of applications. At the moment, projects are mainly driven by operational management and IT management (see Figure 7) on the production plant level. Only some interviews also indicate a high involvement of strategic management, which however assumes to have a more supervisory than a driving role.

In the past each manufacturer's factory decided independently on the implementation of RFID technology to improve local processes, which according to the interviewees is about to change. A first result is the setup of umbrella programs (see Figure 8). But this does not mean that now companywide roadmaps or roll-out plans are being developed, nor is there any intention to increase the amount of resources that are provided for RFID activities. Today the majority of the interviewed companies do not provide R&D funding for this topic.

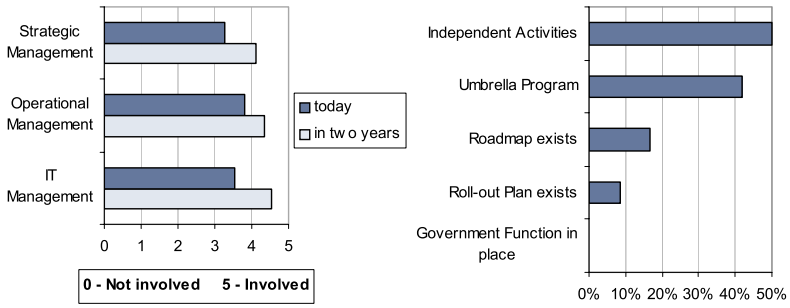

Fig. 8: Project Organization

In summary these findings are opposed to the opinion that the automotive industry already has a strategic approach to the introduction of RFID. In combination with our insight from other industries we position the automotive industry in the leading position for process automation applications but lacking behind other industries like retail in the more advanced applications that help to improve supply chain management.

3.2 The Motivation for the Use of RFID

The interviewed companies stated that improving process efficiency is their main motivation for looking at RFID (see Figure 9). They expect that RFID can help them improve operative processes like inventory management, production and distribution. Only few say that offering new products or services is a goal for them. Some suppliers see the attachment of product related information like version, manufacturing date, and quality status to their products as a value added service. A need for upgrading existing technology or external drivers like customer demands, laws or insurances are not seen as a driver for RFID at the moment. Requirements from laws like the TREAD (Transportation, Recall, Enhancements, Accountability, and Documentation) act in the USA, that demand documentation of several assembled parts like tires can be met by the use of barcodes. The relevance of a potential EU traceability law like EU 178 for food can only be seen in the future.

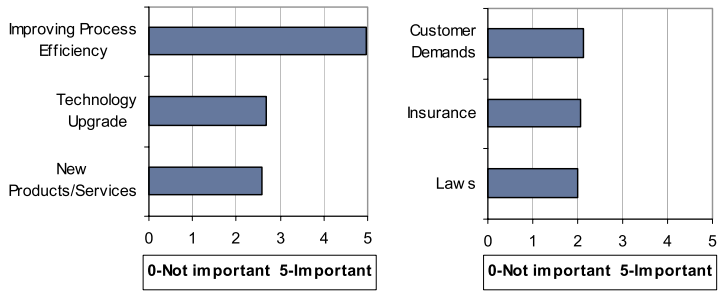

Fig. 9: Internal vs. External Motivation for RFID

The interviewees see the largest potential to improve process efficiency and quality in supply chain tracking&tracing. The availability of accurate tracking&tracing data could be used to identify critical situations on the supply side earlier, in order to avoid time for information acquisition and manual exception handling, e.g. if an order status is unclear, to document the proof of delivery, and, to trigger billing as soon as the delivery has arrived at the customer.

The improvement of local supply chain processes like check-in/check-out at the warehouse, inventory management, and distribution is mainly driven by improved handling efficiency and avoidance of errors. Today check-ins at the warehouse are done manually based on paper based shipping labels that are attached to the packing units. Exhaustive completeness checks are only done randomly. Typical errors that occur are exchanged labels on the packing units and missing electronic availability of shipping labels.

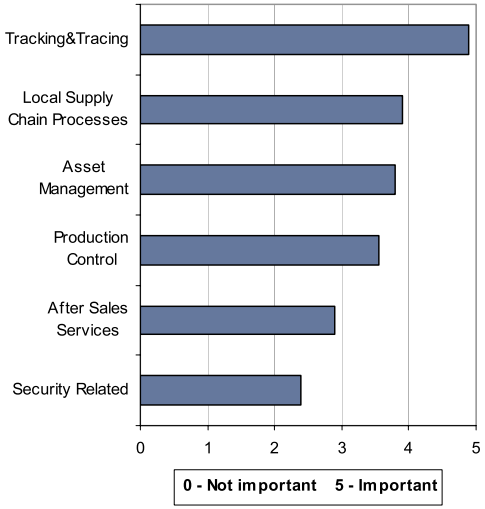

Fig. 10: Priority of RFID Applications

Inventory levels have to be checked manually to identify discrepancies from defined minimum and maximum levels. Such discrepancies should not occur if planning, ordering, and receiving were reliable. The challenge in distribution is to assort daily shipments according to the customer's sequence. Interviewees stated manual handling costs of more than 20 $ per part in their distribution center for several complex parts as a consequence.

The motivations for improving asset management are improving asset utilization, avoiding search times and as consequence a reduction of purchases of containers by 5-8%. They are also planning to use the tracking of containers to monitor and improve the related logistics processes and to support tracking&tracing of parts that are delivered with these containers.

As further important processes the interviewees see production control and related to that mass customization. The avoidance of errors and the efficient management of the increasing complexity are major goals for those processes. One VM stated that only 50% the manufactured vehicles pass through the assembly process without any disruption like missing parts or assembly errors. Findings from pilot projects at a VM show that RFID can reduce the total process costs in production by 10-30% (dependent on the degree of automation).

The reliability of the processes mentioned above has also a major influence on whether a manufacturer can adhere to its planned delivery dates. Recalls could cause costs of more than 1 billion dollars per year. Reliable data on vehicle configurations could help limit the number of cars to be recalled. Configuration data is also seen as a source for improved maintenance service.

For most interviewees the business case will largely determine whether they will implement RFID technology for any process or service. Companies in the automotive industry can profit from increased sales, cost reduction, working capital reduction and

fixed capital reduction. What the major benefit is depends on the specific application. For example, a new service aims at increasing sales and customer retention. Improved inventory management aims at cost reduction due to less manual handling and to get a working capital reduction due to less unused inventory. The goal of improved asset management is divestment of capital assets. An overview of potential benefits and selected business needs stated in the interviews are shown in Figure 10.

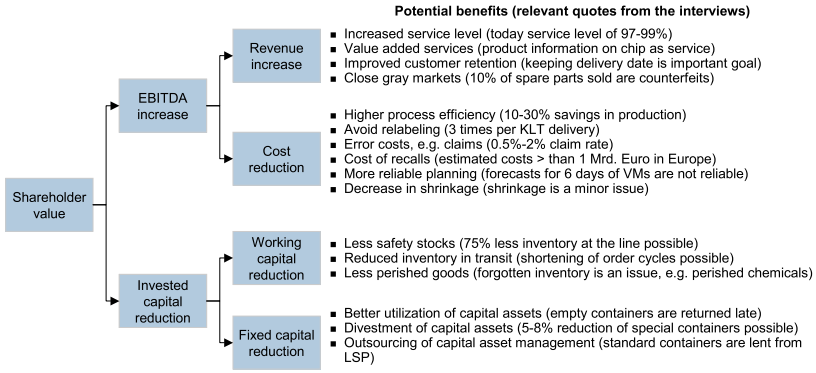

Fig. 11: Potential Benefits of RFID Applications (Quotes from the Interviews)

4. The Adoption Path to RFID in the Automotive Industry

The automotive industry is already experienced in the use of RFID technology for the support of local processes, especially production control and asset management. But large-scale roll-outs have not taken place yet, and industry wide or even companywide approaches are missing in most of the interviewed companies. The following sections analyze drivers and risks of RFID adoption based on the interviews and provide practical recommendations on the way forward.

4.1 Drivers and Risks, Accelerators and Roadblocks

As mentioned before the automotive industry sees improving operational efficiency as the most important driver for RFID adoption. RFID is also seen to have a strategic relevance for the industry. This can be justified by showing that RFID could help meet strategic challenges in the industry. Processes that are critical for those challenges can be improved with the technical capabilities of RFID like automatic identification without line of sight, bulk reading and rewritable memory. Last but not least, the automotive industry is a technically advanced industry that has the capability to integrate innovative IT for improving the supply chain and has already gained some experience in using RFID technology. This applies especially to VMs and tier 1 suppliers. Due to collaborative organization of the automotive supply chain, the decision for RFID adoption by major players will also enforce other players in the value chain to adopt the technology.

However, such a decision is still far from becoming realistic in the midterm. The interviewees see a number of challenges and risks that need to be addressed before. Business cases are stated as the most important decision driver for the implementation of RFID solutions (see Figure 12). Costs for hardware do not justify the rollout of existing concepts or pilot projects. However, business cases are also largely dependent on the type of application. For certain applications, mainly where tags can be reused, like WIP-tracking or asset management, RFID already pays off or approaches a critical price for large scale rollouts, like for the management of special containers. For supply chain applications,

a collaborative approach that does not only focus on local benefits but uses cost/benefit sharing models to calculate the business case is missing.

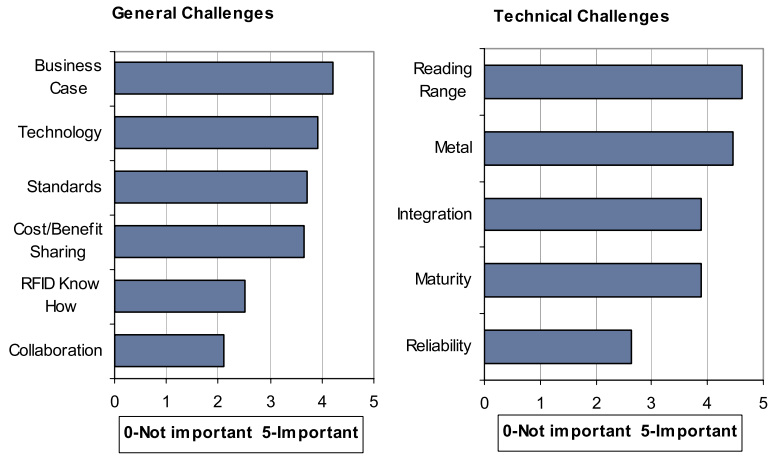

Fig. 12: Challenges and Risks

Technology is seen as the second major roadblock. Interviewees complain about missing maturity, reliability, plug&play readiness, capability for bulk reading, compatibility with metallic surfaces and too short reading ranges. These observations are based on experiences gained in several pilots, especially with passive RFID technology. Experts fear they could even lose process efficiency or reliability due to potential technology failures. Especially from an operative perspective, the potential for improving a local process that is already on an acceptable level, which is true for many highly automated processes in automotive assembly, does not justify the risks of losing performance.

The interviewees named standards and integration as further challenges. The readiness to invest into large-scale roll outs is not there before there are at least companywide standards. In addition, the existence of industry-wide or global standards is expected to lead to a drop in hardware costs, which would drive the emergence of standard software for integration, which is seen as a further but less challenging roadblock.

An important roadblock, which however was not widely seen by the interviewees, is the organizational setup. As described in section 3.1, missing coordination of RFID activities and lack of resources for such activities are major constraints. Not considering this as a major roadblock (besides cost of hardware, technological matters, standards and integration) is opposed to a strategic view on RFID. Table 3 summarizes the drivers and risks on the adoption path.

Drivers	Risks
• Operational efficiency • Strategic need • Collaboration • Advantages over barcodes: handling efficiency and data granularity • Technology leader: e.g. experiences with RFID technology	• Business case: cost/benefit sharing, cost of hardware • Organization • Technology: maturity, reliability, metal, plug&play readiness, reading range, dependency • Standards • Integration • High level of process reliability

Table 3: Drivers and Risks for the Adoption of RFID

The reflection of the representatives on roadblocks again shows that the adoption is not as advanced as it should be in the light of the benefits and strategic opportunities. From the outside perspective, the most important roadblock for a broad application of RFID in this industry beyond current operational local installations is the lack of central management and roadmap definition for RFID on corporate level. Like in the retail industry, the installation of a strategic RFID team that drives a corporate wide RFID strategy

definition process could initiate a broader RFID penetration across the automotive supply chain.

Nonetheless, the automotive industry is in a good starting position to change their point of view towards RFID to a more strategic one. Current applications are a starting point to work towards meeting the strategic challenges described before. For example, the applications in production control are important for mass customization and TQM. But for achieving the demand chain and for significantly improving customer service, these applications are not sufficient. To meet those challenges, a stronger focus on global supply chain applications is necessary.

A key strength of the automotive industry is the existing knowledge about the technology that could be leveraged to build further know-how by the implementation of supply chain applications. As such initial knowledge is missing in other industries, the risk to back away from pursuing RFID plans due to implementation challenges is higher in those industries than in the automotive industry.

4.2 Our Recommendations

The findings demonstrate that the way the industry addresses RFID gives a different impression from a strategic approach. Most activities focus on local processes like production, automation and asset management. The adoption is driven by independent organizational units, mainly by operational management. Only few resources are allocated to RFID projects and it is not decided whether R&D budgets will be made available in the future. Roll-out plans or corporate governance do not exist. The analysis of challenges focuses on technical deficits, missing standards, and cost of hardware instead of potentials on the level of supply chain management. This indicates that indeed there is a mere technical view on RFID. The following recommendations consider this as a starting point and show how the automotive industry can achieve the full range of benefits that were presented in chapter 2. We distinguish between recommendations for different stages of RFID adoption: planning, doing and keeping benefits (see Figure 12). We will conclude with a recommendation on appropriate actions for the current situation.

Planning

- *Use a coordinated approach for RFID technology.* In a first step, the automotive industry should coordinate existing RFID activities within their companies. In a second step, they should coordinate themselves with other members of the automotive value chain, to push standardization. The retail sector is an example for an industry that used a coordinated approach from the beginning, which made it possible to come up with a concept much faster than other industries.
- *Use strategic challenges and technical potentials as a starting point* when looking for RFID applications. It has to be sorted out where RFID through improved handling efficiency and more data granularity really can improve the supply chain and how the contribution to meeting strategic challenges looks like. Figuring out the business case should be done before thinking about standards and technology. This helps to concentrate investments to the most important business needs.
- *Use collaboration for gathering knowledge and pushing standards.* Workgroups of industrial organizations like AIAG, JAMA/JAPIA, VDA and from standardization bodies like ISO and EPCglobal are good platforms for knowledge exchange and the establishment of standards. Also consultants and

technology providers that are able to merge experiences from different industries are useful to prevent users from wasting money on own experiments.

↓

Doing

- ➜ *Start with pilot projects or island solutions but do have the big picture in mind.* For meeting strategic challenges like mass customization and TQM it is not necessary to start with global supply chain applications. Starting with local applications is important to gain experience with RFID. A step by step diffusion of RFID technology and infrastructure will facilitate collaborative applications.
- ➜ *Use standardized solutions whenever possible.* Using standardized solutions supports the adoption strategy to start with island solutions that can be interconnected later for global applications. Standardized software and hardware will also save costs for upgrades and maintenance in the future. And it helps avoid dependencies from special technical components or their suppliers.
- ➜ *Use the help of experienced technology providers.* Technology providers that already have been involved in several RFID projects can help avoid problems during the implementation and later. Guarantees and full service support agreements should be negotiated to reduce the risk of loosing money because of technical failures. Technology provider might be interested to use innovative projects as showcases and willing to participate in the costs.

↓

Keeping Benefits

- ➜ *Think carefully how improved data granularity should be used.* Collecting data with RFID is not enough, the question is how the integration is done and for what processes can be supported with more granular data. Users should use RFID as an extension of their existing business information systems.
- ➜ *Monitor new technologies to keep your application's state of the art.* RFID is still an evolving technology. RFID labels will become smaller and will integrate more and more features, e.g. sensors and positioning systems. The evaluation of those technologies is important to maintain the competitive advantage.
- ➜ *Expand your solutions.* Once local applications are in place and RFID infrastructure has been rolled out within the company it should be figured out how other independent applications could be better integrated. This comprises the integration between single RFID systems (e.g. control at the check-in and production control) but also the integration of local RFID systems with the collaborative IT infrastructure, e.g. to provide information about own inventory levels in real-time to suppliers. The goal is that RFID is not viewed as a stand alone application, but as an extension of existing business information systems.

Fig. 13: Recommendations

Last but not least, the question of timing is important. *Early adopters* will achieve benefits earlier than their competitors and can use this for competitive advantage. They will also benefit from broad

support of technology providers that are aiming at implementing showcases. As a consequence, the costs for implementing RFID technology can be significantly lower than for the followers. But early adopters also face the risk to lose money on immature technology or missing standards that will force them to upgrade their systems in the near future. Companies that are now waiting and watching might sometimes be forced to introduce RFID, at least when it becomes a quasi standard for supply chain tracking. They face the risk to be unprepared and forced to adopt technology when everyone is adopting it for a high price.

For the moment, we recommend to carry out carefully the planning phase. This can be supported by joining industrial workgroups for gathering knowledge about RFID applications and to push the development of standards. We also recommend to start gaining experience with implementations in the own company. This can be achieved by quick benefits that RFID offers in production control and asset management to be prepared for *the most substantial challenge to supply chain management systems that is expected for the next decade:* The introduction of RFID on a global basis.

5. Conclusion

An increasing number of companies from the automotive industry have a strategic view on the adoption of RFID. They regard improving process efficiency of their supply chains as the most important benefit of RFID technology. Operative applications already exist for production control and asset management, typically closed loop applications that provide quick benefits. This report shows how a strategic approach to RFID could look like that derives a need for this technology from major challenges in supply chain management. These challenges are implementing the demand chain, improving customer focus, mass customization, TQM, life-cycle compression and outsourcing. The contribution of RFID is the support of processes that are critical for meeting these challenges through improved handling efficiency and more granular data.

However, RFID is not a stand-alone-application. If it is integrated with existing applications, it will add additional performance and reliability by closing the avoidable media break between IT systems and physical processes. There will always be some physical limits of RFID technology and it will be more expensive than a barcode for the foreseeable future.

Thus, it needs to be figured out carefully where the use of RFID pays off. For the automotive industry there is no need for taking the risk of deploying RFID for the whole supply chain immediately. In the light of current prices for RFID and the maturity level of the technology applications for production control and asset management are good starting points that offer quick benefits but also address the strategic challenges with regard to mass customization and TQM. A coordinated approach and detailed planning are necessary to facilitate the adoption of RFID on the supply chain level as soon as technology further matures and prices drop.

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Appendix I
Interview Guide and Evaluation
Interview Guide Potentials of RFID Technology

Background
Booz Allen Hamilton and the Auto-ID Center Lab at University of St. Gallen are jointly conducting a study on Radio Frequency Identification (RFID) technology. The study will generate deep insights on the nature and trends in RFID usage in several industries for the both interviewees and interviewers. On top, it will increase knowledge of emerging technologies and standardization issues. The results of the study will be shared with participants and will enable future development of RFID technologies.

To understand your point of view on RFID, your current experience and usage, as well as your RFID strategy and action plan for the next years, we kindly ask you to invest 60 minutes of your time. The study covers the current and planned application of RFID technologies in your company, the reasons for implementation and your assessment on the technology and its standardization. We would also like to discuss your approach for developing your RFID solution and to understand your RFID partnering.

We believe that the included quantitative questions add enormous value to the results of this study and yourself as one of the interviewees. It would therefore be very helpful if you would provide us with rough numbers where requested. Booz Allen Hamilton and the Auto-ID Center Lab at University of St. Gallen will adhere to the strictest non-disclosure rules regarding the information gained form specific interviews. The information will be used for the study and for further research at the University of St. Gallen. We will take the survey anonymously and make results public in an aggregated form only. But, subject to your agreement, we would like to include your company's name in our study as one of 30 interview partners. Please let us know prior to the interview if you don't want to be mentioned on this list.

Instructions
The following questionnaire contains the following issues: motivation for usage of RFID, expected business value, current status of your RFID activities, standardization and technology, and challenges/risks in adoption and usage. Please feel free to answer the questions ahead of the interview. But please note that some of the issues require a more detailed discussion in person. Usually we do conduct personal interviews, but eventually we might decide to proceed with telephone interviews. Thank you in advance for your time and effort.

Interview Background

Date of Interviev	
Interviewer	
Industry Segment	
Company	
Interviewee(s)	
Title of Interviewee	
Area of Responsibility	
Contact Information	
Confidentiality Statement	

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	Questions	
1	Motivation for Usage of RFID Technology	
1.1	What is your attitude towards RFID?	☐ strategic ☐ technical ☐ innovator ☐ early follower ☐ observer
1.2	How important are the following items for your internal motivation to use RFID?	Important Not important improving process efficiency: ☐ ☐ ☐ ☐ ☐ new products/services: ☐ ☐ ☐ ☐ ☐ technology upgrade: ☐ ☐ ☐ ☐ ☐ _____ ☐ ☐ ☐ ☐ ☐
1.3	How important are the following items for your external motivation to use RFID?	Important Not important customer demands: ☐ ☐ ☐ ☐ ☐ laws: ☐ ☐ ☐ ☐ ☐ insurance: ☐ ☐ ☐ ☐ ☐ _____ ☐ ☐ ☐ ☐ ☐
1.4	Do you consider RFID as an enabling technology to any of the following trends?	☐ ECR (Efficient Consumer Response) ☐ JIT/JIS ☐ Mass Customization ☐ Outsourcing ☐ TQM ☐ Supply Chain Visibility ☐ Traceability Other:_____

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2	Expected Business Value	
2.1	How important is improving the efficiency of the following processes for you?	Important / Not important tracking & tracing: ☐☐☐☐☐ check-in/out at warehouse: ☐☐☐☐☐ inventory management: ☐☐☐☐☐ theft control: ☐☐☐☐☐ production control: ☐☐☐☐☐ mass customization: ☐☐☐☐☐ picking and packing: ☐☐☐☐☐ distribution/order management: ☐☐☐☐☐ customs: ☐☐☐☐☐ counterfeit protection: ☐☐☐☐☐ recall: ☐☐☐☐☐ maintenance: ☐☐☐☐☐ recycling: ☐☐☐☐☐ asset management: ☐☐☐☐☐ _____ ☐☐☐☐☐
2.2	What are the specific error cost/handling cost you have today in those processes? (If possible please quantify)	error-ratio: delivery reliability: reduction of claims: transit time per item: handling cost per item: _____
2.3	How large are the (expected) efficiency gains for those processes? (If possible please quantify with baseline)	error-ratio: delivery reliability: reduction of claims: reduction of transit time per item: reduction of manual labor per item: flexibility: _____ _____

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2.4	How important are the following new products, product features or services to you?	tracking & tracing: cool chain management: pay per use: pay per risk: _____	Important Not important ☐
2.5	What are the benefits that are expected from those services?	competitive advantage: new customers: improved services: cross selling: _____ _____	
3	Status of own RFID Activities/Organization		
3.1	What RFID projects exist within your company and what is their status?	concepts: pilots: operative applications:	
3.2	To what processes or products/services are those RFID projects related? (short description of project goal)		
3.3	What are the specific benefits that are expected/were achieved for each project? (please quantify if possible)		
3.4	What are the RFID plans for the next 1,2,5 years? Amount of resources involved with RFID today and in 1,2,5 years. Does a Roadmap exist?	1 years: 2 years: 5 years:	

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3.5	What organizational units are today and will be involved in RFID activities in 2 years?	Involved / Not involved **Today** strategic management: ☐ ☐ operational management: ☐ ☐ IT management: ☐ ☐ In house consulting: ☐ ☐ _____ ☐ ☐ **In 2 Years** strategic management: ☐ ☐ operational management: ☐ ☐ IT management: ☐ ☐ In house consulting: ☐ ☐ _____ ☐ ☐
3.6	How does your project organization look like:	Yes / No Only local independent activities: ☐ ☐ Umbrella program exists: ☐ ☐ RFID roadmap (>1year) exists: ☐ ☐ Roll-Out plan exists: ☐ ☐ Government function in place ☐ ☐
3.7	What is the role of external players in your RFID projects?	Involved / Not involved suppliers: ☐ ☐ customers: ☐ ☐ industrial organizations: ☐ ☐ standardization bodies: ☐ ☐ technology providers: ☐ ☐ consultants: ☐ ☐ _____ ☐ ☐
3.8	What percentage of the R&D budget are today used for RFID and will be used in 2 years?	today: 1 year: 2 years:
4	Standardization	
4.1	What role do standards play for your RFID activities/plans?	☐ not important ☐ additional benefits ☐ necessary

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4.2	What standardization bodies are you watching for RFID?	Watching / Not watching ANSI: ☐ ☐ Auto-ID Center/EPC: ☐ ☐ ISO: ☐ ☐ Industrial organizations: ☐ ☐ _____ ☐ ☐
4.3	What standards for automatic identification are important to you?	Important / Not important EAN: ☐ ☐ EPC ☐ ☐ GTAG/ISO 18000: ☐ ☐ ISO 15459: ☐ ☐ _____ ☐ ☐
4.4	Are you involved in the creation of standards?	Industrial organizations: Standardization bodies: others:
5	Technological Matters	
5.1	Which Auto-ID technologies are currently used in your company?	Used / Not used Barcode: ☐ ☐ 2D-Code: ☐ ☐ Alphanumeric Codes/OCR: ☐ ☐ RFID: ☐ ☐ _____ ☐ ☐
5.2	What kind of RFID technology do you (plan to) use?	☐ active ☐ passive ☐ rewritable memory ☐ sensors ☐ positioning frequency: ☐ 130kHz ☐ 13,56MHz ☐ UHF ☐ ____
5.3	What problems do you have with RFID technology?	Problem / No problem maturity: ☐ ☐ plug & play readiness: ☐ ☐ reliability: ☐ ☐ metal: ☐ ☐ _____ ☐ ☐ ☐ ☐

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5.4	How important is integration of RFID technology into existing IT systems and how do you plan to do the integration?	Important / Not important integration: ☐☐☐☐☐ replaces previous Auto-ID tech: ☐☐☐☐☐ self developed interface: ☐☐☐☐☐ standard software interface: ☐☐☐☐☐ _____ ☐☐☐☐☐
5.5	What requirements must be achieved in order to use RFID technology within your company?	
6	Challenges and Risks in Adoption and Usage	
6.1	What are the major challenges/pitfalls/risks/roadblocks for the adoption of RFID in your company?	Problem / No problem standards: ☐☐☐☐☐ technology: ☐☐☐☐☐ knowledge: ☐☐☐☐☐ cost/benefit sharing: ☐☐☐☐☐ collaboration: ☐☐☐☐☐ costs of hardware/software ☐☐☐☐☐ _____ ☐☐☐☐☐
6.2	When (2, 5, 10 years) and how do you expect could theses problems be solved?	standards: technology: knowledge: cost/benefit sharing: collaboration: costs of hardware/software: _____
6.3	Which migration effort (cost) is linked to RFID implementation? (If possible please quantify)	RFID equipment/readers: Adoptions of the backend systems: Ongoing expenses for RFID tags (in 1, 2, 5 years): _____ How many tags will be necessary/year (in 1, 2, 5 years): _____
6.4	How do you take into account security/ privacy issues into your RFID strategy?	

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How we did the evaluation:

This survey was carried out jointly by Booz Allen Hamilton and the Auto-ID Lab at University of St. Gallen between November 2003 and January 2004. In total we personally interviewed 39 representatives from 27 companies and organizations (see the table below). Our interview guide asked for the motivation for looking at RFID, expected business value, own activities, technology, standards, challenges and risks. We sent a written protocol for approval to each interviewee.

Technology Providers	Automotive Suppliers	Logistics Service Providers	Automotives VMs	Organizations
Identec, Infineon, SAP, Sokymat	Bosch, Continental, Siemens VDO, ZF Friedrichshafen	BLG, Chep, DHL, Fedex, Kühne&Nagel, Panalpina, Rail Cargo Austria, Schenker, Stinnes, TPG, Wincanton	BMW, DaimlerChrysler, Ford, Opel, Renault, Volkswagen	BVL, VDA

We separated the protocols according to the industries automotive, logistics service providers, and technology providers and did a separate evaluation for each of these groups. This document aggregates data from 11 interviewed companies from the automotive industry.and one industrial organization. The following data is anonymized and presented in the following form:

- For ”yes/no” questions we counted the number of “yes” and divided it by the number of total answers to this questions to get the percentage of interviewees that agreed to an given item. See the following example:

Number of interviewed companies

Number of answers to this question

General comments to this question

1.1 What is your attitude towards RFID?			
12/ 12	innovator	early follower	observer
number of 'yes'	6	2	5
% of total answers	50%	16.7%	41.7%
competitive advantage		potential of technology is recognized	idea generation

Given items from the interview guide and items that were named from the interviewees

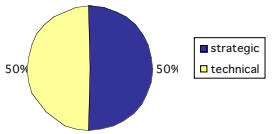
Comments to this item

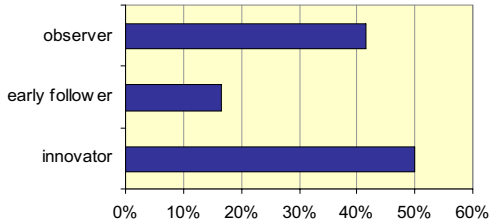
- For questions where the interviewees should rate items we used a scale from 5 (very important/high relevance) to 1 (not important/no relevance) and 0 if the interviewee did not rate an item. As aggregated results we calculated the median and the standard deviation. See the following example:

1.2 How important are the following items for your internal motivation to use RFID?			
11/ 11	improving process efficiency	new products/services	technology upgrade
median	4.5	3.2	3.2
% of votes >0	100%	100%	90.9%
std. dev.	1.2	1.1	1.5
	customer's SCM process	consulting	barcode

- For all other questions we aggregated the different statements in a list.

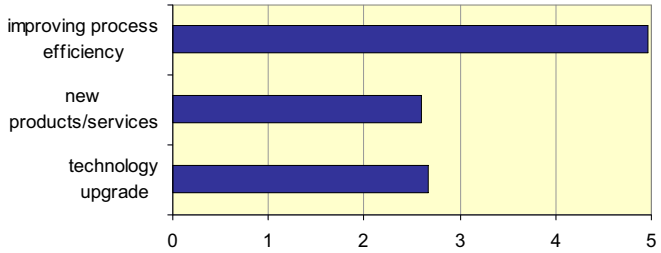
1.1	What is your attitude towards RFID?						
12/ 12	strategic	technical	innovator	early follower	observer		
number of 'yes'	6	6	6	2	5		
% of total answers	50%	50%	50%	16.7%	41.7%		
competitive advantage	there is also a technical view on RFID	strategic view is goal for the next years (SCM-applications)		potential of technology is recognized by OEMs, diversification, first-to-market	idea generation		
strategic vision is needed							



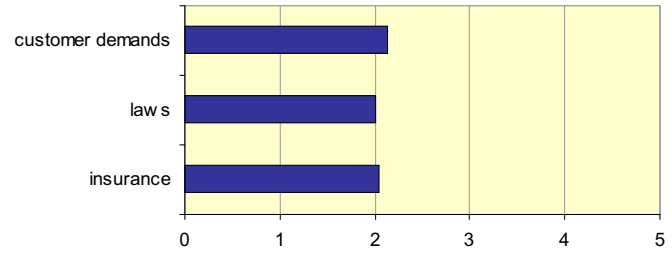


1.2	How important are the following items for your internal motivation to use RFID?						
12/ 12	improving process efficiency	new products/services	technology upgrade	improving asset utilization	quality of data	data stored at container	quality
median	5.0	2.6	2.7	5.0	5.0	5.0	5.0
% of votes >0	100%	91.7%	100%	8.3%	8.3%	8.3%	8.3%
std. dev.	0.1	1.5	1.6				
	cost reduction	product related information, eg. for production or maintenance	manufacturer driven				effectiveness
	quality improvement	drilling machines	depends on closed or open loop				
	production control	enhance service, provide customer with data	barcode is cheap but not robust, maintenance of printers etc.				
	reliable processes	provide data					
		enhanced safety of products					
		security, tire pressure monitoring					

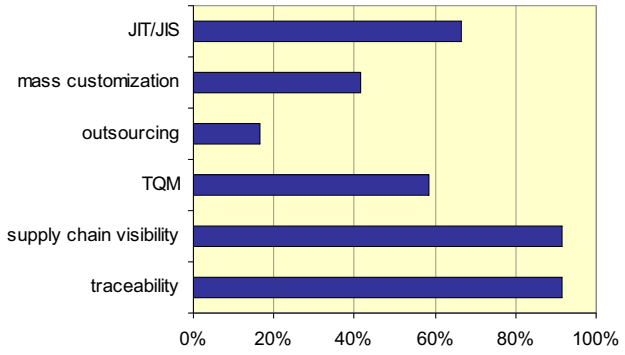
1.2	How important are the following items for your internal motivation to use RFID? (cont.)						
12/ 12	customer relationship management	process reliability					
median	3.0	5.0					
% of votes >0	8.3%	8.3%					
std. dev.							



1.3	How important are the following items for your external motivation to use RFID?						
12/ 12	customer demands	laws	insurance	standardization/interoperability	supplier demands	technology provider push	
median	2.1	2.0	2.1	5.0	5.0	3.0	
% of votes >0	100%	100%	83.3%	8.3%	8.3%	8.3%	
std. dev.	1.4	1.1	1.3				
	customer would have to pay for the additional service but is not willing to pay so far (this won't change for the next 2 years).	traceability (EU)	possibly in the future		today there is no stable forecast for six days		
	some customers in USA	TREAD act (US)	potential for the future				
	internal customer production	TRAD Act USA, but 2D barcode is sufficient					
		for critical operations documentation is required, but no need for RFID is seen					
		documentation, end-of-life					
		currently					
		TREAD act (USA), traceability on batch level (D)					



1.4	Do you consider RFID as an enabling technology to any of the following trends?						
12/ 12	ECR	JIT/JIS	mass customization	outsourcing	TQM	supply chain visibility	traceability
number of 'yes'	1	8	5	2	7	11	11
% of total answers	8.3%	66.7%	41.7%	16.7%	58.3%	91.7%	91.7%
		30-40% JIT/ thereof 70% JIS					



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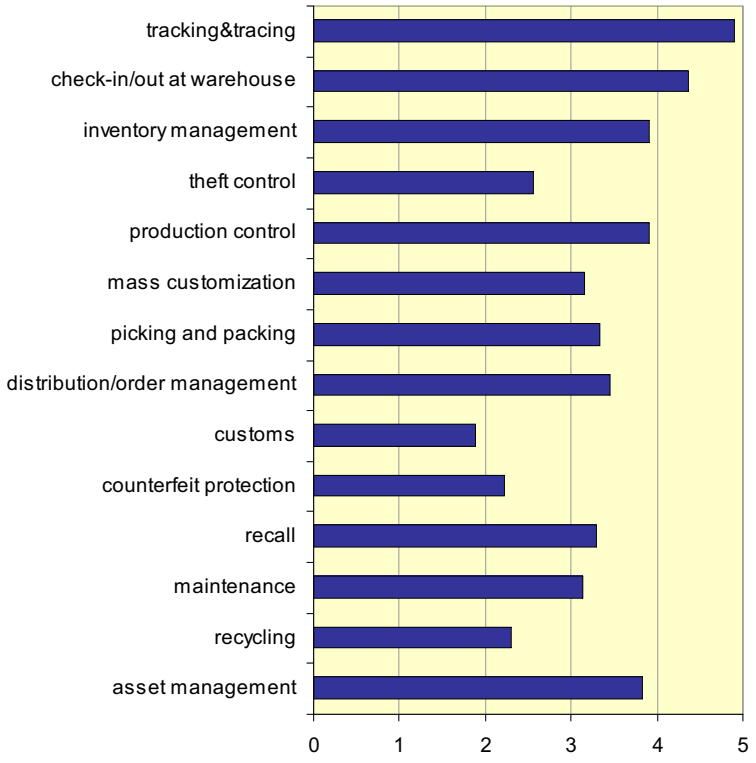
2.1 How important is improving the efficiency of the following processes for you?							
12/ 12	tracking&tracing	check-in/out at warehouse	inventory management	theft control	production control	mass customization	picking and packing
median	4.9	4.4	3.9	2.6	3.9	3.2	3.3
% of votes >0	91.7%	91.7%	91.7%	83.3%	91.7%	83.3%	75%
std. dev.	0.3	0.9	1.6	1.4	1.2	1.6	1.5
	tracking of full containers, today full containers carry an Odette label	check-out for distribution	min/max-control has to be done manually, difficult to separate from general control	no information	already implemented	sequencing	pilot project V2
	overseas (CKD)	today no exact controls at check-in, plain writing is used	not with today's technology	is solved by other systems, LSP	pick-to-light applications possible	eg. seat frames	
		goal is 100% reliability, most important		only total shrinkage is measured	few cases where direct scanning makes sense	could be supportive	
				shrinkage is an issue	maximize "Durchläuferquote"	There are very few cases where a customer gets a wrong vehicle, but there are high efforts for quality control.	

2.1 How important is improving the efficiency of the following processes for you? (cont.)							
12/ 12	distribution/order management	customs	counterfeit protection	recall	maintenance	recycling	asset management
median	3.4	1.9	2.2	3.3	3.1	2.3	3.8
% of votes >0	75%	66.7%	75%	83.3%	58.3%	83.3%	100%
std. dev.	1.9	1.4	1.6	1.8	2.0	1.3	1.4
		LSP	not from today's perspective	collaborative approach	parts are already equipped with microchips that could be used for Auto-ID	eg. for plastic parts	focus of interview
		only if there is a global infratsructure	GVO, original spare parts, registered design	not from today's perspective	may be solved by other technologies	maybe in the future	future application
						not from today's perspective	tests carried out
						recycling systems already work well	shrinkage is extremely high, problem if container costs more than 500 Euro.
						some mixtures are confidential	

2.1	How important is improving the efficiency of the following processes for you? (cont.)						
12/ 12	support E-business	launch of new product					
median	5.0	5.0					
% of votes >0	8.3%	8.3%					
std. dev.							
	integration necessary	processes change, this is a source for errors and delays					



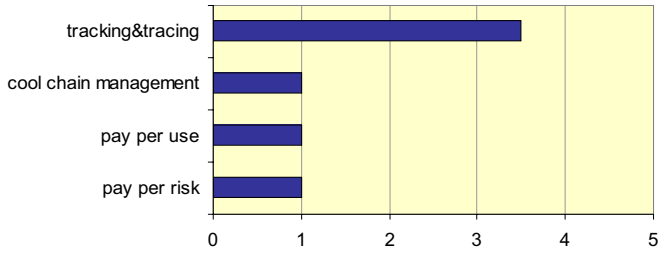
2.2/2.3	What are the specific error cost/handling cost you have today in those processes and how large are the (expected) efficiency gains?
error costs	traceability allows to identify errors during production earlier, today errors are discovered too late and product must be destroyed
	wrong delivered products are only claimed if the value is less than the products that were ordered
	0.4% internal wrong replenishment
	2 times a week:labels on the left side are exchanged with the right side at check-in
	daily express deliveries, but mostly by the fault of suppliers --> event monitoring
	if cars parts are not in time, cars have to be finished later, additional costs of ca 100 Euro x typical lot of 200-400 cars (supplier pays)
	50.0% approx."Direktläuferquote"
	no exact statistics about costs per recall, most recalls are done without knowledge of the customer during routine service checks.
service level	99% material replenishment
	100 000 wrong delivered products per year, each wrong delivery causes costs of 4 Euro
	99.5% internal to production
	potential waiting time for customer because of bad distribution management
	96.5% order positions
	insufficient planning leads to daily express tours, suppliers pay 90% of the expenses
	adherence to completion date is very important (reliability)
claims	minor
	100 000 claims per year
	time for handling claims
	2 internal claims per day
	container that has been delivered from supplier has been overseen at check-in
	0.8%
transit time	measuring of time goals
	1 day per item
	no need for action
	warm-up of production for new vehicle is 6 hours.
process efficiency	high efforts for management and control of processes, especially replenishment and related to the increasing number of variants/versions

AUTO-ID LABS

	replenishment of foreign fabs is more critical because timewise some of those parts might need to be send by air
	search times afeter change of shift because nobody knows where semiproducts have been stored
	high manual effort for picking and packing in distribution
	high manual effort to do 2D labeling that is required by several OEMs
	30 person days:manual inventory
	50 000$ per year (20-30 express deliveries per day)
	60$ total costs per m2
	there is a potential to reduce manual labour in exception handling and quality control
	today 1% of exact controls at check-in
	manual scanning or manual dara entry of shipping labels at check-in
	10% improvement in total process costs in highly automated plants
asset management	excess stocks
	to much circulation time
	1 Mio Euro/year:: management of special containers (price > 500 Euo), demand/stock of containers, searching for containers, critical for start of new model, network is getting more and more complex (today 1300 suppliers), shrinkage of special containers equals loss of ca. 1 Mio Euro per year
	40% improvement in total process costs in not automated plants (checked in four plants)
	5.0% pear shrinkage in special containers
	8.0% shrinkage of KLTs per year (5 Mio).
flexibility	missing parts lead immediately to problems

2.4 How important are the following new products, product features or services to you?

12/ 12	tracking&tracing	cool chain management	pay per use	pay per risk	VMI	automatic billing	safety features
median	3.5	1.0	1.0	1.0	5.0	5.0	5.0
% of votes >0	16.7%	8.3%	8.3%	8.3%	8.3%	8.3%	8.3%
std. dev.	0.7						
not relevant	customer, dealer						tire pressure monitoring, type of tires, sensor applications
not relevant							
not answered							
cannot be answered							



2.5	What are the benefits that are expected from those services?						
12/ 6	competitive advantage	new customers	improved services	cross selling			
No. of comments	2	1	2	1			
% of interviewees	33.3%	16.7%	33.3%	16.7%			
not relevant							
not relevant							
	important	important	customer retention is most important				
				mobility, tickets, etc.			
	very important and more efficient than acquiring new customers		very important				

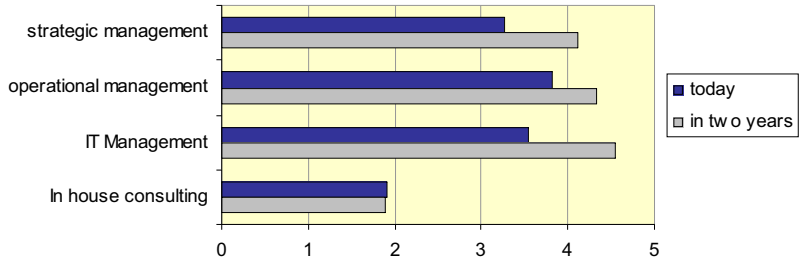
AUTO-ID LABS

3.1/3.2/3.3 What RFID projects exist within your company , to what processes are those projects related and what are the benefits?		
	Application	Processes
concepts	container tracking	asset management, tracking&tracing
	distribution of vehicles	order management
	management of transport vehicles (internal)	fleet management, transport control
	container tracking	asset management, tracking&tracing
	RFID in production	production control
	full concept from goods receipt to distribution	supply chain tracking
	cross company program to develop a gloabl concept for identification of cars and parts	customer relationship management, supply chain tracking, distribution
	check-in at warehouse	
	tire identification	
pilots	assembly of safety related components (documentation required by law)	quality control, required by law
	container tracking between supplier and OEM	tracing&tracing, asset management
	extentension of parts replenishment solution	tracking&tracing, replenishment, asset management
	container management	asset management
	car identification	customer relationshop management, product lifecycle management
	parts&packaging	tracking&tracing
	container tracking	asset management
	container tracking between several fabs	asset management, process tracking
	CKD at LSP	distribution, quality control
	power train	asset management, transport control
	container tracking between OEM and supplier	asset management, tracking&tracing
	KLT-tracking between LSP and OEM	check-in, check-out, tracking&tracing, transport control
operative applications	WIP-tracking of car body through the whole production process	production control, wip-tracking
	identification of customer specific harness	tracking&tracing, identification, quality control
	asset logistics in small plants	
	wip-tracking in all plants (RFID on assemblies, propietary system ID80 to get information into central database)	production control, quality control, control or recursions (eg. performance measurements and fine tuning of production parameters)
	RFID on pallets in one factory (id and quality data is stored on the tag)	tracking&tracing, check-in and check-out at warehouse, quality control
	control of KLTs in spare parts center (closed-loop)	distribution, order management, transport control
	tracking of car body during production	production control, mass customization
	FTS (driverless transport vehicle control)	transport control
	materials replenishment	tracking&tracing, inventory management, replenishment
	QAS help system	support
	wip-tracking of subassemblies	production control, wip-tracking
	tracking of special containers	asset management
	vehicle delivery	distribution, order management
	container tracking (special containers for pressed parts)	asset management
	WIP-tracking at vehicle finish center	production control
	container tracking at OEM	asset management

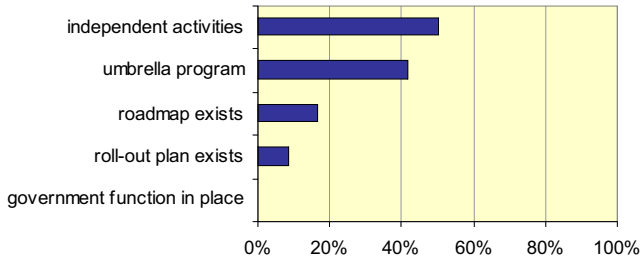
AUTO-ID LABS

3.4	What are the RFID plans for the next 1,2,5 years?						
12/ 11	1 years	2 years	5 years				
no. of comments	5	3	3				
% of interviewees	45.5%	27.3%	27.3%				
no specific program, driven by applications, observing, idea generation and gathering of knowledge							
depends on business case	0,2FTE:interns, diploma thesis, participation in workgroup, observe Wal*Mart						
only observing		not planned yet	not planned yet				
currently evaluating potentials							
not yet decided, depends on concept.	depends on benefits of technology						
depends on benefits of applications		depends on benefits of technology	depends on benefits of technology				
	support further roll-outs of RFID solution						
			apply RFID to further assets				
	goal is proof of concept						
		next technology tests					
	observer						

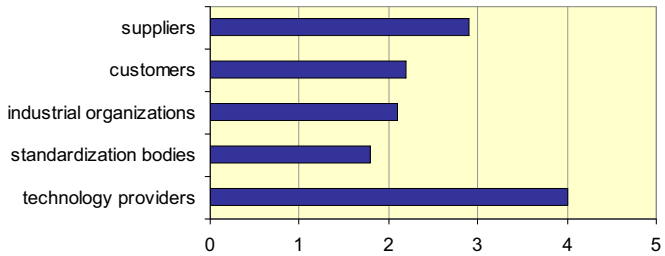
3.5	What organizational units are today and will be involved in RFID activities in 2 years?							
12/ 12	strategic management	operational management	IT Management	In house consulting	strategic management_2	operational management_2	IT management_2	In house consulting_2
median	3.3	3.8	3.5	1.9	4.1	4.3	4.6	1.9
% of votes >0	91.7%	91.7%	91.7%	91.7%	75%	75%	75%	75%
std. dev.	1.7	1.8	1.8	1.4	1.8	1.3	1.3	1.5
	brand manager	logistics management						further distribution of the solution



3.6	How does your project organization look like:						
12/ 12	independent activities	umbrella program	roadmap exists	roll-out plan exists	government function in place		
number of 'yes'	6	5	2	1	0		
% of total answers	50%	41.7%	16.7%	8.3%			
		Administrative department					
		all RFID activities are controlled by procurement					

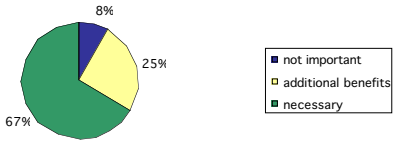


3.7	What is the role of external players in your RFID projects?						
12/ 12	suppliers	customers	industrial organizations	standardization bodies	technology providers	consultants	
median	2.9	2.2	2.1	1.8	4.0	1.9	
% of votes >0	83.3%	83.3%	83.3%	83.3%	75.0%	66.7%	
std. dev.	2.0	1.9	1.8	1.7	1.5	1.6	
	a few of the suppliers are not able for barcoding	requirements	regarding RFID		planned	planned	
	eg. BASF		VDA, AIAG				
			VDA				

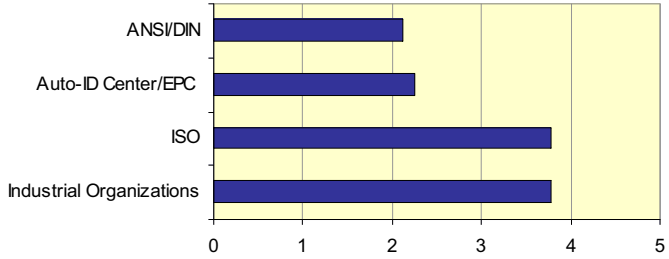


3.8	What percentage of the R&D budget are today used for RFID and will be used in 2 years?						
12/ 10	today	1 year	2 years				
no. of comments	6	3	2				
% of interviewees	60%	30%	20%				
decistion will be made for roll-outs							
R&D mainly is used for product development	0%						
depends on potential of technology		not planned yet	not planned yet				
very small	small budget						
no R&D funding planned							
in general: R&D budget is only used for product development	operational budget	possibly	possibly				
	0%	1 infrastructure of antennas					
	0%						
	small budget						

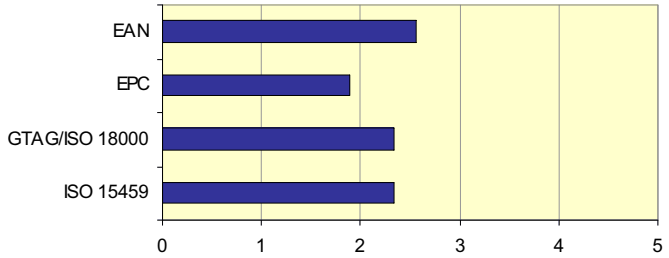
4.1	What role do standards play for your RFID activities/plans?						
12/ 12	not important	additional benefits	necessary				
number of 'yes'	1	3	8				
% of total answers	8.3%	25%	66.7%				
		internal applications	supply-chain applications				
		standards help to achieve cheaper hardware	at least company wide				
		quasi-standards	island solutions less interesting				



4.2	What standardization bodies are you watching for RFID?						
12/ 12	ANSI/DIN	Auto-ID Center/EPC	ISO	Industrial Organizations			
median	2.1	2.3	3.8	3.8			
% of votes >0	66.7%	66.7%	75%	75%			
std. dev.	1.4	1.8	1.7	1.6			
	container standardization			VDA, ITA			
				VDA			
				VDA, Odette			
				VDA			
				believe that retail sets standard for RFID			
				VDA			

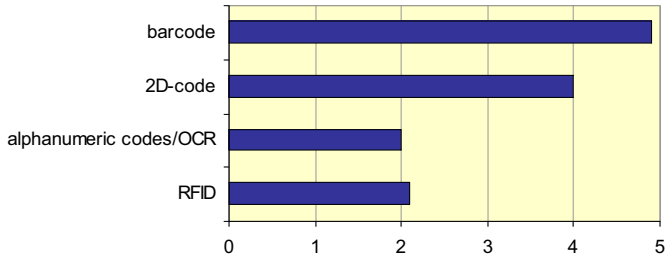


4.3	What standards for automatic identification are important to you?							
12/ 12	EAN	EPC	GTAG/ISO 18000	ISO 15459	Odette Label			
median	2.6	1.9	2.3	2.3	5.0			
% of votes >0	75%	75%	75%	75%	8.3%			
std. dev.	1.9	1.1	1.7	1.7				

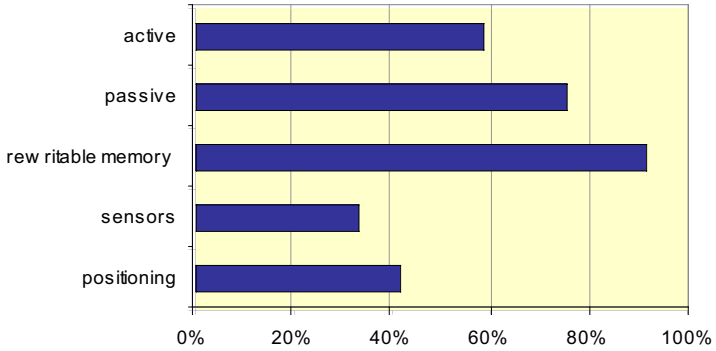


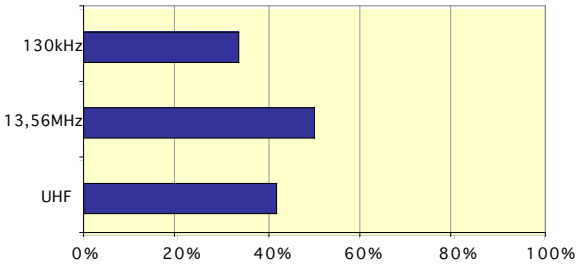
4.4	Are you involved in the creation of standards?						
12/ 12	industrial organizations	standardization bodies	others				
number of 'yes'	6	0	1				
% of total answers	50%		8.3%				
	VDA		discuss with competitors				
	VDA						
	VDA, AIAG						
	VDA						
	VDA						

5.1	Which Auto-ID technologies are currently used in your company?						
12/ 12	barcode	2D-code	alphanumeric codes/OCR	RFID	PVS	old technology similar to RFID	
median	4.9	4.0	2.0	2.1	5.0	5.0	
% of votes >0	83.3%	83.3%	83.3%	91.7%	8.3%	8.3%	
std. dev.	0.3	1.6	1.2	1.4			
	traceability	Kanban					



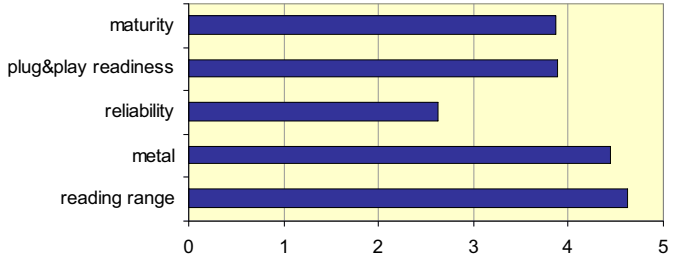
5.2	What kind of RFID technology do you (plan to) use?								
12/ 12	active	passive	rewritable memory	sensors	positioning	130kHz	13,56MHz	UHF	2,45GHz
number of 'yes'	7	9	11	4	5	4	6	5	2
% of total answers	58.3%	75.0%	91.7%	33.3%	41.7%	33.3%	50%	41.7%	16.7%
frequency is not relevant, but functionality and standards									



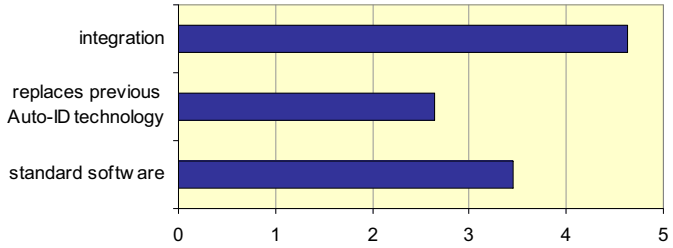


5.3	What problems do you have with RFID technology?						
12/ 12	maturity	plug&play readiness	reliability	metal	reading range	data capacity	bulk reading
median	3.9	3.9	2.6	4.4	4.6	3.5	4.0
% of votes >0	66.7%	75%	66.7%	75%	33.3%	16.7%	16.7%
std. dev.	1.8	1.8	2.0	1.3	0.8	0.7	1.4
depends on application	active	active	active	has been a problem in the pilot		size	today additional handling costs
				active			

5.3	What problems do you have with RFID technology?						
12/ 12	software	user and maintenance friendliness	life time/battery	raeding range	heat	size	data security
median	5.0	3.0	5.0	5.0	5.0	5.0	5.0
% of votes >0	8.3%	8.3%	25%	8.3%	8.3%	8.3%	8.3%
std. dev.							



5.4	How important is integration of RFID technology into existing IT systems and how do you plan to do the integration?						
12/ 12	integration	replaces previous Auto-ID technology	standard software				
median	4.6	2.6	3.4				
% of votes >0	91.7%	91.7%	75.0%				
std. dev.	1.2	1.8	1.4				
		smart product	Asset Management System				
			nice to have				

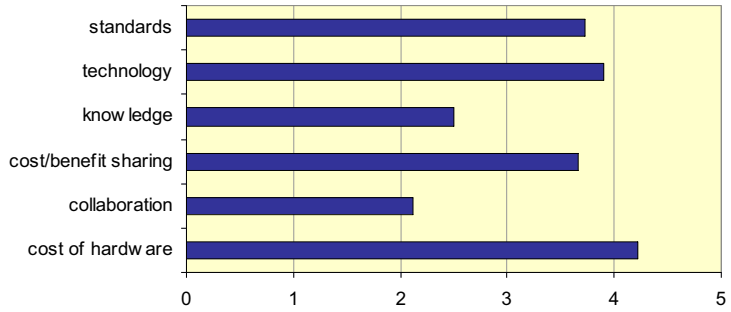


AUTO-ID LABS

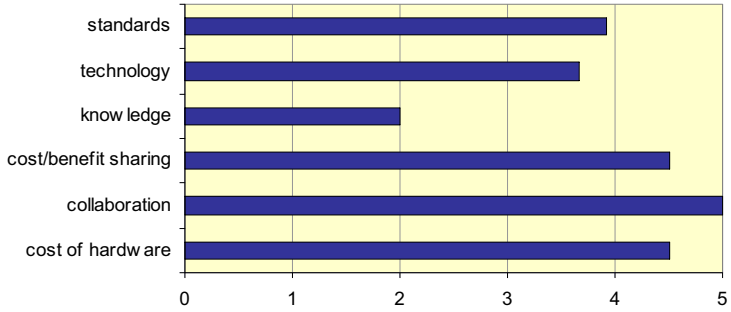
5.5	What requirements must be achieved in order to use RFID technology within your company?						
12/ 9	requirements						
no.of comments	9						
% of interviewees	100%						
	reading range in metallic environment						
	reading range of 2m						
	bulk reading						
	plug and play solution						
	costs too high						
	combination of technologies (ID, GPS, etc), hybrid solutions						
	100% reliability						
	robust system						
	resists harsh environment in production						
	maturity						
	standards						
	technical integration on circuit board						
	Positioning						
	business case, 100% reliability, standard software						
	technical reliability						
	implementation guide						

6.1	What are the major challenges/pitfalls/risks/roadblocks for the adoption of RFID in your company?						
12/ 12	standards	technology	knowledge	cost/benefit sharing	collaboration	cost of hardware	integration
median	3.7	3.9	2.5	3.7	2.1	4.2	5.0
% of votes >0	91.7%	91.7%	91.7%	75%	75%	75%	8.3%
std. dev.	1.6	1.4	0.9	1.7	1.5	1.2	
	has impact on costs	battery	local experts		many internal customers don't know RFID technology	business case	open to other technologies
	related to processes	active	application map			depends on application, boarder case is reached	
			responsibility is typical problem				
			user's point of view				

6.1	What are the major challenges/pitfalls/risks/roadblocks for the adoption of RFID in your company? (cont.)						
12/ 12	organization	quality of data	business need				
median	5.0	5.0	5.0				
% of votes >0	8.3%	8.3%	8.3%				
std. dev.							
	convince own organization		high level regarding process reliability				



6.2	When (2, 5, 10 years) and how do you expect could theses problems be solved?						
12/ 12	standards	technology	knowledge	cost/benefit sharing	collaboration	cost of hardware	
median	3.9	3.7	2.0	4.5	5.0	4.5	
% of votes >0	50%	50%	8.3%	25%	8.3%	25.0%	
std. dev.	2.4	1.2		0.9		0.9	
	driven by organizations and single players		more events, eg. roadshows				
	ISO 2.4						



6.3	Which migration effort (cost) is linked to RFID implementation?						
12/ 7	RFID equipment/readers	integration with backend systems	ongoing expenses for RFID tags	how many tags will be necessary			
No. of comments	2	3	2	2			
% of interviewees	28.6%	42.9%	28.6%	28.6%			
depends on application							
5 years depreciation period	20%	80%					
Decision for rollout is made in 2004, if positive then:			1,5-2 Euro per product				
if electronic spare parts department would use RFID...		little compared to hardware costs		600 000			
if concept would be realized			90 000 000 chips per year				
personal opinion				150 000 tags per year			
	90% today's cost driver						
		10% little					

6.4	How do you take into account security/privacy issues into your RFID strategy?
12/ 12	privacy
number of 'yes'	8
% of total answers	66.7%
	basic requirement that has to be considered for each application
	relevant for retail products only
	data security is part of all IT projects and of high importance
	basic requirement
	not important
	not relevant for observer
	serious security/privacy issues with integration of personal information, especially when RFID is used in a vehicle
	ensure deletion of data on product before shipping
	data security on tags plays an important role
	not relevant, more important are influences on health
	system must be safe against external attacks (data security, sabotage), same problems as with WLAN, bluetooth
	important, especially tracking of employees