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RFID Applications, Impacts and Country Initiatives

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Working Party on the Information Economy

RFID APPLICATIONS, IMPACTS AND COUNTRY INITIATIVES

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FOREWORD

This report was presented to the Working Party on the Information Economy at its meeting in December 2007 as part of its work for the 2008 Seoul Ministerial on *The Future of the Internet Economy*. It was recommended to be made public by the Committee for Information, Computer and Communications Policy in March 2008.

The report was prepared by Verena Weber, consultant, in conjunction with Graham Vickery, OECD Secretariat, as part of work on the economic and social impacts of ICTs and new technologies. It is published under the responsibility of the Secretary-General of the OECD.

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SUMMARY

Radio frequency identification (RFID) technology is currently one of the most promising and discussed auto-identification and data capture (AIDC) technologies. Although it is not a new technology, the range of applications is broadening rapidly and new applications which integrate other technologies such as sensors are developing. Eight major fields of application are analysed in this study, comprising: *i*) asset utilisation, where mobile assets are tagged for their use along the supply chain; *ii*) asset monitoring and maintenance, where mostly fixed and high value assets are tagged to store information, *e.g.* for maintenance purposes; *iii*) item flow control in processes, where RFID tags are attached to items which are moving along the supply chain; *iv*) inventory audit, for example in warehouses where pallets are tagged to improve the speed and efficiency of stock taking; *v*) theft control; *vi*) authentication to provide secure identification mechanisms for persons and objects; *vii*) payment systems to secure transactions; *viii*) automatic display of information where items are tagged to provide additional information on products and services when read.

It is difficult to quantify the impact of the technology, in part because most RFID applications are recent. Market analysis shows rapidly growing markets for RFID systems and, apart from very detailed mainly qualitative evaluations of particular applications, there are few aggregate impact studies. Available aggregate studies show large impacts in terms of benefit/cost ratios and productivity gains; however calculations are based largely on current good practice case studies, leading to a potential overestimation of aggregate benefits.

Country initiatives are divided into three main categories: *i)* the use of RFID by the public sector; *ii)* information, awareness and education programmes; and *iii)* incentives for business R&D and public funding of projects. The review of initiatives draws largely on replies to the *Information Technology Outlook 2008* policy questionnaire. This review suggests that government support for RFID technologies is focused on government applications for own use, often with a large demonstration component, and supporting multi-stakeholder projects to meet technological and industry needs, often to develop new technologies or applications. There are potentially large gains in innovation and efficiency from more widespread applications. Due to technological and business uncertainties education and awareness activities could be further emphasised, particularly for small businesses and more advanced applications where potential impacts are high, for example, those involving sensors.

INTRODUCTION

Radio frequency identification (RFID) technology is currently one of the most promising and discussed auto-identification and data capture (AIDC) technologies. It uses electromagnetic waves to transmit real-time data to identify specific objects (Garfinkel and Rosenberg 2005, p. xxvii). The technology is already in broad use in different fields of application such as toll collect systems, car keys and applications along the supply chain of companies.

There is high business and policy interest in this promising technology and the OECD has published a series of studies dedicated to RFID. The 2004 and 2006 editions of the *OECD Information Technology Outlook* as well as the Background report and Proceedings from the Foresight Forum on "Radio Frequency Identification (RFID) Applications and Public Policy Considerations" held in October 2005, give an introduction to the technology and its impacts. The Working Party on the Information Economy country study for Germany analyses in detail how companies use newer RFID applications along their supply chains [see "RFID implementation in Germany: Challenges and benefits", DSTI/ICCP/IE(2007)6/FINAL]. Studies by the Working Party on Information Security and Privacy summarised in "Radio Frequency Identification (RFID): A Focus on Security and Privacy" [DSTI/ICCP/REG(2007)9/FINAL] focus on trust-related challenges when deploying RFID systems.

Some of these studies briefly discuss possible roles of the public sector as well as touch on the economic impacts of the technology. As technological development has occurred at a rapid pace, estimates on the economic impact of the technology have varied and public sector projects have become more concrete. This document aims at addressing the following three questions:

What is the historical development of RFID technology and which fields of application in the public and private sector can be identified?

- What is the economic impact of RFID technology according to selected studies?
- What government RFID initiatives are there in OECD countries?

Section 3 on country initiatives is based in particular on 27 replies to the Information Technology Outlook Policy Questionnaire 2008.

1. DEVELOPMENT AND APPLICATIONS OF RFID

The first part of this section summarises the historical development of RFID, the second part gives an overview of different RFID fields of application in the public and private sector.

1.1 Historical development of RFID

RFID is not a new technology despite rapidly growing interest in RFID technology in recent years. The concept of the technology dates to "the mid to late 1940s, following on from technological developments in the 1930s and the development of radar during World War II" (Hodges and McFarlane, 2005). In the 1950s, several technologies related to RFID technology were developed. One prominent example is the "identification friend or foe (IFF)" system for aircraft which is a long-range transponder system. An active IFF system was first developed for British aircraft whereby each aircraft was equipped with a transponder. When radar stations emitted signals from the ground, the aircraft transmitted a signal back to identify itself as friendly (*RFID journal*, 2007).

The first commercial applications emerged in the 1960s and 1970s. The electronic article surveillance (EAS) equipment was developed by new companies such as Sensormatic and Checkpoints (Landt and Catlin, 2001) to prevent theft of goods at the point of sale. This system is currently in widespread use. With generally a 1-bit transponder, it is the most basic use. The data is sufficient to tell the reader whether a transponder is located in a certain area or not (Finkenzeller, 2006). Overall, this period was characterised by important further development of RFID technology. Research focused on applications for animal tracking, vehicle tracking, car keys, as well as process automation in production facilities (Landt and Catlin, 2001, *RFID Journal*, 2005).

Besides the development of these commercial applications, governments also began the development of RFID systems in the 1970s. For example, the US Department of Agriculture spurred the development of animal tracking and the US Department of Energy promoted the development of a system to track nuclear materials (*RFID Journal,* 2007) which was put in place in the mid-1980s.

In the 1980s, the "commercial exploitation of RFID started to increase, led initially by small companies" (Hodges and McFarlane, 2005). An important aspect for the expansion of the technology was the development of the Personal Computer (PC) facilitating data management.

Whereas the exploitation of RFID was a common point in different countries, the interest in special fields of application diverged. The main interests in the US were for applications including access control of persons and transportation. European countries were mainly interested in toll collection systems and industrial applications as well as short-range systems for the tracking of animals (Landt and Catlin, 2001). Overall, from a technological point of view, applications developed to this point were mainly operating at low-frequency and high–frequency ranges.[1]

In the early 1990s, applications operating at ultra high frequency (UHF) emerged (*RFID journal*, 2007). These systems attained a higher read range and faster data transmission than systems operating at lower frequency ranges. The very first pilot projects started in the retail sector for the tracking of consumer goods along the supply chain. However, due to low volumes, these RFID systems were expensive (*RFID Journal*, 2007). A further obstacle to widespread use was that applications to this date were niche

applications. As a consequence, a large number of proprietary systems were developed which were incompatible with each other (Landt and Catlin, 2001). The development of standards was thus crucial both for price decline and the use of RFID technology beyond niche applications.

Standardisation activities emerged in the late 1990s. The International Organisation for Standardisation (ISO) developed several standards in the field of RFID. One example is the ISO 18000 series which defines the air interface for different frequencies, *i.e.* how readers and tags of an RFID system communicate with each other. Furthermore, in 1999, the Auto-ID Center at the Massachusetts Institute of Technology (MIT) was established "to develop an open standard architecture for creating a seamless global network of physical objects" (Auto-ID Labs, 2006). It was initially funded by the Uniform Code Council, European Article Numbering (EAN) International and industry. By the year 2003, the Center was supported by over 100 user companies, key RFID suppliers and the US Department of Defense and a federation of Auto-ID research institutes was created. Specifications developed by the Auto-ID Center focused on low cost tags for goods with the aim of tracking them along the supply chain. The results of the standardisation activities include two air interface specifications, the Electronic Product Code (EPC) numbering scheme as well as a network architecture (*RFID Journal*, 2007). These specifications were passed to EPCglobal for commercialisation purposes.[2]

Besides standardisation activities, the 1990s were furthermore characterised by an increased commercialisation of RFID systems. According to Landt and Catlin (2001), electronic toll collection systems were widely deployed both in the United States and Europe. For example, different regional toll agencies in the Northeast of the United States developed a regionally compatible toll system. Further important implementation projects included applications such as the tagging of over 3 million rail cars in the United States, access control applications (*e.g.* company badges and ski passes) as well as applications along the supply chains of companies. For example, in the late 1990s, European car manufacturers started RFID projects for asset tracking and tracking of parts along their internal supply chains. In addition, an RFID–based immobiliser system for cars was commercialised in the mid-1990s which authenticate car keys and is in wide use. With the broader deployment of these applications, multiple use tags arose *e.g.* for toll collection, access control and gated community access (Landt and Catlin, 2001).

The beginning of the 21st century is marked by *i*) a growing interest of industry, government and the media in RFID technology, *ii*) further technical development, *iii*) a first round of standards harmonisation, and *iv*) an increasing number of applications.

The impact of RFID is repeatedly discussed in mainstream media, and journals specifically devoted to RFID have been launched such as the *RFID Journal* in 2002. Technological development contributes to smaller tags, a reduction of costs and increased functionality. Concerning standardisation, a first harmonisation was implemented in 2006 when an ISO standard (ISO 18000-6) included the EPC Generation 2 UHF Air Interface Protocol and thus provided a broader technological basis for further RFID implementation in the field of passive, low cost RFID systems. There is a growing interest in RFID applications in different sectors, especially for applications along the supply chain. Important retailers such as Wal-Mart, Metro and Tesco conducted pilot projects and began to implement the technology in 2003 and 2004. Further sectors such as the aviation sector, the logistic sector and the pharmaceutical sector are also moving to wider implementation of RFID technology (*RFID Journal*, 2007). In addition, the public sector has important RFID implementation projects *e.g.* in the areas of defence, health, e-passports and identity cards. Overall, the range of different applications is broadening at a rapid pace and new applications which also integrate other technologies such as sensor technology are emerging. The following section provides an overview of different fields of application.

1.2 Overview of RFID applications

As discussed in the previous section, there is a large number of different RFID applications and the number is growing at a fast pace. To structure this range of applications, eight fields of application are described below.

- **Asset utilisation:**
  Mobile assets are tagged for their use along the supply chain. Typical examples are RFID–tagged containers which are used at different production stages. Companies rely on RFID technology in order to locate these assets and to monitor which departments use the assets how many times. The aim is to optimise processes and attain a more efficient use of capacity.

- **Asset monitoring and maintenance:**
  Mostly fixed and high–value assets are tagged to store information, *e.g.* for maintenance purposes. Examples include tagged machines where the maintenance history and information on replaced parts are stored on the tag. When data is stored directly on the tag and not on the companies' network, tags with high data capacity are needed.

- **Item flow control in processes:**
  For item flow control, RFID tags are attached to items which are moving along the supply chain. Often information going beyond a simple ID number is stored on the tag to control production processes. This is, for example, the case in the automotive industry where production information is stored on the tag which can be attached to car bodies or smaller parts. This mainly aims to avoid costly errors during the production process.

- **Inventory audit:**
  A prominent application is the use of RFID for inventory audit. Examples include retailers' warehouses where pallets and sometimes cases are tagged to improve the speed and efficiency of stock taking. In most cases, only an ID number is stored on the tag to minimise the cost of the tag.

- **Theft control:**
  Item level RFID tags are used to prevent theft along the supply chain or at the point of sale. A simple form is electronic article surveillance (EAS) which can be RFID-based. In this case, low-end RFID systems (*e.g.* 1-bit tags) are used which communicate when consumers leave the shop if they have not been deactivated (Finkenzeller, 2006, pp. 25, 32). Applications for theft control in mail order for high-value products such as mobile phones use more sophisticated tags.

- **Authentication:**
  For authentication purposes, RFID is used to provide secure identification mechanisms for persons and objects. Prominent examples of personal authentication are company entry badges, transportation system cards, electronic passports and identity cards. Current fields of application for object authentication include the tagging of drugs in the pharmaceutical sector and high-value goods in the luxury sector to prevent counterfeiting.

- **Payment systems:**
  RFID technology is used for payment systems to secure transactions. Safety requirements for tags are very high. The systems are further characterised by very low read ranges to avoid mixing different payment cards.

- **Automatic display of information:**
  In the emerging field of automatic display of information, items are tagged to provide additional information on products and services when read. Early applications can be found at the point of sale or in the public sector, for example, in museums.

Table 1 shows the first seven fields of application and gives application examples for the private and the public sector. However, as new applications are developed on a daily basis, the list of examples is non-exhaustive. Further application examples organised by different industry sectors are listed in Table 2 where fields of application and industry sectors are cross-tabulated.

Table 1: Overview of RFID applications in the private and public sectors

	Application examples in the **Private sector**	Application examples in the **Public sector**
Asset utilisation	• Container management (*e.g.* small load carriers in the automotive sector) • Loading equipment management (*e.g.* for gears in the automotive supplier sector) • Management of dollies at airports • Fleet management	• Waste management: Container management • Health: Location of medical equipment at hospitals
Asset monitoring and maintenance	• Machine maintenance • Tool box maintenance (*e.g.* for the maintenance of aircraft) • Maintenance of parts built in aircraft • Smart home applications	
Item flow control in processes	• Tagging of parts along the supply chain to correlate information on the tagged item to process steps • Goods movement control • Quality control of goods • Tracing drugs in the pharmaceutical value chain • Tracking finished goods for the purpose of diversion control	• Health: Tracking of medication from the pharmacy to the hospitalised patient • Health: Tracing blood bottles • Administration: Document management
Inventory audit	• Real-time location systems for finished vehicles in the automotive sector • Automation of warehouse management • Automated sorting and counting of inventory • Checking of ingoing and outgoing goods • Baggage handling at airports • Livestock tagging	• Defence: Ammunition management • Education: Lending system in libraries • Exhibition in museums • Science: Tagging animals and plants for research purposes
Theft control	• Car keys (immobilisers) • Electronic Article Surveillance (EAS) systems • Tracking products along the supply chain to minimise theft	

Authentication	• Persons:
	  ○ Company badges
	  ○ Ski passes
	  ○ Event ticketing
	  ○ Sports: recording time during a competition
	• Objects (counterfeiting control):
	  ○ Proof of authenticity of spare parts (*e.g.* in the aviation sector)
	  ○ Proof of authenticity of drugs
	  ○ Proof of authenticity of luxury goods
		• E-Passports, identity cards
		• Health: Patient authentication for the monitoring of medication in hospitals
		• Leisure/sports: recording time during a competition
		• Traffic: Tolling systems
		• Traffic: Speed control
		• Transport: Access control cards for public transport

Payment systems	• Tolling systems • Contactless cards for financial transactions	• Transport: Payment cards for public transport

Source: Authors' compilation.

Table 2: Overview of RFID applications by sector [Note: Includes government applications]

	Asset utilisation	Asset monitoring and maintenance	Item flow control	Inventory audit	Authenti-cation	Theft control	Payment systems
Automotive	• Container management • Loading equipment management • Truck control	• Machine maintenance	• Tagging body parts on the assembly production line • Tagging built-in parts	• Finished vehicles real-time location system		• Car keys combining automobile immobiliser systems and access control	
Automotive suppliers	• Container management • Loading equipment management			• Finished products identification • Automation of warehouse management			
Wholesale and retail trade			• Goods movement control from store warehouses to the sales area • Freshness control of goods	• Goods receipt checking and database entry in the warehouse • Automated sorting and counting of inventory • Checking shipments of outgoing goods		• Checking deliveries (in trucks) for theft prevention • Anti-theft systems at the point of sale (EAS)	• Contactless payment cards
Consumer goods			• Goods tracking along supply chain • Freshness control	• Checking outgoing shipments			
Aviation	• Container management	• Tool box maintenance • Aircraft main-tenance • Tagging built-in parts to avoid errors (wiring harnesses)			• Proof of authenticity (*e.g.* for spare parts)		
Airports	• Management of dollies	• Maintenance of fire shutters	• Baggage handling	• Equipment check	• Border control (e-passport)		
Pharma-ceutical industry			• Tracing drugs		• Proof of authenticity of drugs		

	Asset utilisation	Asset monitoring and maintenance	Item flow control	Inventory audit	Authenti-cation	Theft control	Payment systems
Agriculture and forestry			• Tracing of goods (*e.g.* for freshness monitoring)	• Inventory audit in forestry and animal-ID			
Logistics	• Container management			• Checking of shipments			
Tourism and leisure			• Competition time recording (*e.g.* tags in shoes)		• Ski passes • Event ticketing		
Financial sector							• Contactless payment cards
Luxury goods			• Tracking of finished products for diversion control		• Proof of authenticity of distri-buted goods	• Anti-theft systems at the point of sale • Tracking products from distribution centre to shop to minimise theft	
Public sector Educational institutions				• Lending systems in libraries • Exhibitions in museums			
Science				• Tagging animals and plants for research			
Public health	• Location of medical equipment and patient transport equipment		• Tracking medication from pharmacy to patient • Tracing blood bottles		• Patient authentica-tion for monitoring medication in hospitals		
Waste				• Waste management			
Border control					• e-passport		• Tolling systems • Public transport access and payment cards

Source: Authors' compilation

2. REVIEW OF ECONOMIC IMPACTS

Most RFID applications are still recent and it is very difficult to quantify the impact of the technology. In the recent past, market analysts have published projections on the growing RFID market, and studies are becoming available evaluating the economic impact for specific applications. Section 2.1 compares predictions from different market analysts. Section 2.2 focuses on selected aggregate impact studies for different applications; it does not look at micro-level impact studies.

2.1 RFID market estimates

In terms of technology application, RFID implementation is still at an early stage. For this reason, it is difficult to obtain market projections and a challenging task to evaluate the RFID market. Table 3 provides an overview of global market projections by different market analysts. When dealing with the notion "RFID market", projections usually cover whole RFID systems (*i.e.* readers, tags, RFID middleware). Only the study by IDTechEx analysts includes services.

Table 3: Estimates of the RFID global market (USD)

Market analyst	Date of release	2005	2006	2007	2010/2011	2015	2017
Gartner	2005	504 million	2.7 billion		3 billion (2010)		
RNCOS	2005	1.9 billion				26.9 billion	
BCC Research	2006	649 million	713.4 million		1.05 billion (2011)		
IDTechEx (Study includes systems and services)	2007			4.96 billion			27.88 billion

Source: Authors' compilation.

Overall, large differences between market estimates are observed. For example, whereas the market for RFID systems for 2006 was estimated at USD 2.7 billion by Gartner analysts, BCC estimated an RFID market of only USD 713.4 million in the same year.

There are various reasons for these large differences. Two important reasons are the early stage of RFID implementation in both public and private sectors and, as a result, divergent evaluations of the technology in terms of both coverage and evolution. According to the European e-Business Watch large-scale survey of RFID adoption strategies and impacts in four broad economic sectors,[3] 14% of the European companies interviewed were piloting, using or implementing RFID technology in 2007.[4]

Companies that were using RFID or planning to use RFID expected major effects on: *i*) inventory management (49% of companies using or planning to use RFID), *ii*) control and efficiency of inbound logistics (46%), and *iii*) merchandise management and reduced out-of-stocks (44%). These results correspond to those found in the WPIE qualitative country study for Germany [DSTI/ICCP/IE(2007)6/FINAL]. The major costs for those using or planning to use the technology were seen to be the costs of project implementation and system integration (39% of all companies using or planning to use RFID). Interestingly, for those companies *not* using or planning to use RFID technology, 64% stated that a relevant reason for not using it was the insufficient evidence of a strong return on

investment (ROI).[5] To further examine this issue at a more aggregated level, the next section focuses on selected quantitative impact studies.

2.2 Selected studies on the aggregate economic impact of RFID

Whereas section 2.1 deals with market estimates at aggregate level, this section aims at assessing the impact of RFID at a more detailed aggregate level from a user perspective. Apart from studies of toll applications and access control, to date there are very few studies assessing the economic impact of RFID technology in business applications. Of these studies, the majority assess RFID benefits at a qualitative rather than a quantitative level resulting in an even lower number. Of the quantitative studies, we chose two selected impact studies which are based on a well-defined methodology and which outline their assumptions and calculations. The first study deals with global financial impacts in the retail and healthcare sectors. The second study assesses the financial impact of RFID technology at cross-sectoral level in one OECD country.

In their 2006 study Barua, Mani and Whinston focus on the "financial impacts of RFID technology in the retail and the healthcare sectors". Health care sectors include pharmaceutical companies, healthcare distributors and hospitals. They analyse both reduction of costs and the increase of revenues by relying on RFID technology. Calculations are made based on different sources such as case studies of RFID pilot and implementation projects, documents of government and industry associations as well as synthesised results from prior studies. Overall, according to Barua, Mani and Whinston, benefits have already amounted to a global cumulated USD 40 billion in the retail and healthcare sectors.

Out of these estimated USD 40 billion, the retail sector has cumulated benefits of USD 12.05 billion from RFID applications. Total cumulated spending on RFID systems from 2003 to 2006 amounted to USD 2.37 billion according to the authors, resulting in a ROI of about 500%.

This results from both the reduction of costs and increased revenues. On the cost reduction side, economies result from the reduction of labour costs, reduced losses during production and shipment ("shrinkage") as well as from reduced inventory write-offs and non-working inventory. On the revenue side, benefits result from increased product availability at the point of sale, a faster time to market and "providing ubiquitous access to customers across multiple channels" (Barua, Mani and Whinston, 2006). Based on expected adoption rates of pallet tagging (45%) and item-level tagging (25%) in 2011, the authors estimate that benefits will reach USD 68.55 billion in 2011.

Total cumulated benefits in the healthcare sectors have been estimated at USD 27.95 billion. Investments in RFID systems have been USD 2.03 billion, leading to a significantly higher ROI (over 1 300%) compared to the retail sector. According to the authors, this is due to higher RFID adoption rates for the health sectors than for the retail sector.

Pharmaceutical companies have realised these benefits due to "*i*) a reduction in counterfeit, shrinkage and parallel trade, *ii*) efficient product recall, *iii*) efficient sample management, *iv*) enhanced inventory turns, and also shorter clinical trial cycles and faster time-to-market" (Barua, Mani and Whinston, 2006). For healthcare distributors, the authors attribute the benefits to enhanced inventory turns on the one hand and a reduction in labour costs at distribution centres on the other hand. Finally, by relying on RFID technology, hospitals have benefited from *i*) better asset utilisation, *ii*) higher inventory turns, *iii*) increased healthcare access and *iv*) higher patient safety because of fewer errors.

Overall, the report by Barua, Mani and Whinston is one of the first to discuss in detail how RFID benefits can be quantified. This is not an easy task as RFID implementation in these sectors has only taken place recently and the authors admit that "it is not easy to quantify the challenges for a successful

implementation". Furthermore, benefits are quantified in a rather optimistic way. Calculations are based on current case studies which are in general best practice examples and success stories of leading companies in these sectors. As a consequence, the results of successful projects have been taken to estimate economies and increased sales in a whole sector which may over-state total benefits across firms which are less efficient in implementation.

The study "RFID: Prospects for Germany" in 2007 focuses on a cross-sectoral analysis of RFID in Germany. Within this analysis, one part is dedicated to sales and productivity effects of RFID technology. Sectors assessed in the study include the consumer goods, retail, logistics and the automotive sector. Macroeconomic effects in Germany in 2010 are derived from sales and productivity effects of each of these sectors. Calculations for all sectors are based on sources such as preliminary case studies of RFID pilot and implementation projects. Overall, according to the study, sales and productivity gains amounted to EUR 3.24 billion in 2004 and are expected to rise to EUR 62.2 billion in 2010.

In **German retailing**, productivity effects are estimated at EUR 8.6 billion in 2010. Estimates are based on total retail sales and the estimation that companies having implemented RFID technology by 2010 will account for 40% of total retail sales. Moreover, the percentage of sales influenced by RFID is estimated at 30% and operational productivity effects (productivity gains from avoiding out-of-stock situations, less shrinkage, etc.) are estimated at 20%. Estimates on productivity gains are based on preliminary studies such as documentation of the Metro future store.

The model calculations for the **German logistics sector** differentiate between logistics and transport services only and auxiliary services in logistics (*e.g.* inventory management, order processing, logistics planning). In the logistics and transport services productivity effects will reach EUR 1.7 billion in 2010 according to the study. In the field of auxiliary services in logistics, RFID use will yield about EUR 4.3 billion in 2010.

Productivity gains in the **German automotive sector** are estimated at EUR 2.4 billion in 2010. Interestingly, these estimates are significantly lower than the estimated gains in the retail sector. This is explained by the estimates of the operational productivity effects directly attributable to adoption of RFID. In the automotive sector, the authors estimate these effects very conservatively at 2% by 2010. In the retail sector, however, these gains are estimated at 20%.

These sector analyses are the starting point for the macroeconomic assessments of RFID technology on the German economy. The calculation is based on the gross value added (*i.e.* the total value of goods generated in the production process minus inputs consumed during production). Industry subcategories were selected which will be influenced by RFID technology in the medium term. Table 4 shows that productivity gains triggered by the use of RFID will increase from EUR 3.24 billion in 2004 to EUR 62.2 billion in 2010.

Overall, the study "RFID: Prospects for Germany" is one of the first studies which analyses how productivity gains can be calculated for different industry sectors and how they can be aggregated to obtain gains at macroeconomic level. This is a demanding task as RFID implementation has only recently taken place. Furthermore, the authors estimate potential gains in a structured and logical way. However, in their penultimate step, the authors calculate the gains based on a percentage of the total output "influenced" by RFID technology rather than on a percentage of total (production) cost reduction. As a consequence, estimated gains are high. In addition, as in the report by Barua, Mani and Whinston, calculations are based on current case studies which in general tend to be success stories. This may be another factor leading to a potential overestimation of total benefits.

Table 4. Table 5: Model calculation: portion of value added due to RFID technology

	Year	Manufacture of transport equipment	Manufacture of textiles and textile products	Manufacture of chemicals and chemical products	Manufacture of machinery and equipment	Commercial agents/wholesaling	Retailing (except motor vehicles)	Transport, storage and communication	Health and social work	TOTAL
Gross value added (EUR, billions)	2004	73.1	37.4	45.6	67.2	89.5	84.0	116.4	141.2	654.4
	2010	71.4	34.4	55.4	85.5	133.5	88.1	148.1	148.1	764.5
Percentage of RFID pioneers	2004	10%	5%	5%	2%	10%	10%	7%	1%	--
	2010	40%	20%	15%	15%	40%	40%	25%	15%	--
RFID pioneers' value added (EUR, billions)	2004	7.3	1.9	2.3	1.3	9.0	8.4	8.2	1.4	39.8
	2010	28.6	6.9	8.3	12.8	53.4	35.3	37.0	22.2	204.5
Percentage of output "influenced" by RFID	2004	10%	5%	10%	2%	10%	10%	5%	1%	--
	2010	35%	30%	20%	20%	30%	30%	40%	20%	--
Portion of value added "influenced" by RFID (EUR billion)	2004	0.7	0.1	0.2	0.03	0.9	0.9	0.4	0.01	**3.24**
	2010	10.0	2.1	1.7	2.6	16.0	10.6	14.8	4.4	**62.2**

Source: OECD based on BMWi (2007).

3. REVIEW OF COUNTRY INITIATIVES

Country initiatives are divided into three main categories: *i)* the use of RFID by the public sector (section 3.1.), *ii)* information, awareness and education programmes (section 3.2), and *iii)* incentives for business R&D and public funding of projects (section 3.3). This categorisation is developed on the basis of literature review and the RFID country study in Germany.

3.1 The use of RFID by the public sector

The public sector is an important user of RFID technology in addition to rapidly increasing use of RFID in the private sector. Examples which are contributing to widespread use of the technology include using RFID technology in electronic passports (e-passports), and for tracking assets and items in the area of defence and equipment of hospitals.

Seven main application areas in the public sector are listed below:

- **E-passports and identity credentials**

  E-passports combine the traditional paper document with an RFID tag where the critical information is stored. The RFID tag often contains biometric data such as data for facial recognition and fingerprints. The format of the biometric data and communication protocols is defined in a standard adopted by the International Civil Aviation Organization to ensure international interoperability. The RFID tag runs on the standardised ISO/IEC 14443 communication protocol (Finkenzeller, 2006, p. 404). RFID technologies are also planned for national identity credentials or other official documents such as driving licences, residence permits, social security cards, etc.

- **Public services (*e.g.* waste management/waste control)**

  Public services include services such as the management of parking facilities and waste management. In waste management RFID is used for two main purposes: for tracking (hazardous) waste to protect the environment and to allocate costs according to the amount of waste. Currently applications can, for example be found in Korea where pilot projects in the field of hazardous waste tracking were conducted as well as in Germany where costs of waste are calculated according to the waste's volume or quantity.

- **Health (*e.g.* applications in hospitals)**

  A significant number of public sector RFID projects are implemented in healthcare. One area where multiple projects are already at the implementation stage is the hospital sector. RFID is used to track assets such as beds or containers, to identify patients for medication control and to track babies and dementia patients to increase their security. Other applications include health insurance cards which have already been introduced in Mexico, for example. Information such as username and prescribed drugs are stored on the embedded RFID chip.

- **Document administration/postal services**

  The public sector also uses RFID technology for the administration of documents. In this field, RFID tags are attached to documents to improve the location of documents and thus to increase

process efficiency and quality. RFID is also used for postal services in distribution centres to facilitate the sorting of mail items.

- **Defence**

  RFID technology in the area of defence is mainly used to streamline supply-chains and procurement processes. The most prominent example of a department relying intensively on RFID technology is the US Department of Defense. Both active and passive tags are attached to inbound and outgoing shipments at the case and pallet level.

- **Education/Cultural institutions/Science**

  The public sector also relies on RFID at its cultural institutions. Examples include lending systems at libraries and newer applications can be found in museums where artworks are presented via RFID technology via automatic display of information.

- **Logistics/Transport (*e.g.* toll collect systems)**
  Finally, RFID is used by the public sector in the fields of logistics and public transports. Toll collect systems were early applications of RFID technology. Newer applications are access cards for public transport, RFID-based bus schedules as well as particular location-based services.

Table 5 gives a non-exhaustive overview of RFID applications used by OECD countries indicating that applications are very diverse. Many projects in the fields of e-passports, health, transport and defence are already at the implementation stage. Newer applications can be mainly found in the fields of public services and education.

Overall, governments are currently developing and using RFID in a variety of different areas. To be an important user of RFID technology has a number of important effects both for further RFID suppliers and users. On the supply side, government projects can have significant effects. Pilot projects contribute to further development and testing of different components of RFID systems, and are seen as an important means to spur innovation. Moreover, important implementation projects support the formation of an RFID market at national and international level. These effects on the supplier side enhance a more reliable and sophisticated supply of different components of RFID systems.

On the user side, pilot projects conducted by governments provide pilot experiences for new RFID applications. Both the public and the private sector profit from technology feasibility studies and testing results. A further characteristic of government projects is their ability to generate valuable experience and robust results on a large scale. Furthermore, many of the governments' RFID projects may trigger wider applications.

Government projects are usually designed to disseminate results widely. A wide range of stakeholders involved in RFID technology benefit from these projects and results are usually made broadly available. If this process is organised in a highly efficient way, spill-over benefits of public sector RFID projects can be considerable.

Table 6: Selected RFID applications in the public sector in OECD countries

Country	Project category	Project description
Austria	Health	Tests by the municipal administration of Vienna on the applicability of RFID in the health care system
	Public services	Tests in the Viennese parking facility management
Denmark	Education	Lending systems in libraries
	E-passport	E-passport available since mid-2006; biometric passport relying on RFID embedded fingerprint technology to be introduced mid-2009
Germany	E-passport	E-passport (available since the end of 2005), electronic ID card (to be introduced at the end of 2009)
	Public services	Waste management in different communities
	Education	Lending systems in libraries
Japan	Logistics/Transport	Set-up of the "Free Mobility Assistance System" based on ubiquitous network technology including RFID tags, to provide information for seamless movement (*e.g.* transfer routes and transport modes)
Korea	Public services, health, defence, logistics/transport	Pilot projects in the fields of procurement, baggage handling, container management, ammunition management, tracking hazardous waste, museums, air cargo, etc.
Mexico	Health	Health insurance card: RFID technology is integrated in the "popular insurance" card where the username, information on doctors as well as prescribed drugs are stored
Netherlands	E-passport	E-passport
	Health	RFID technology used in hospitals
	Education	Libraries
	Logistics/Transport	Payment cards for public transport
Portugal	E-passport	E-passport and e-passport control systems at Portuguese airports (*e.g.* Lisbon, Faro)
Spain	Document administration/ postal services	The Spanish postal service uses RFID technology in 15 distribution centres in different locations in Spain (*e.g.* Madrid, Barcelona)
United Kingdom	E-passport	Biometric passport relying on RFID technology
United States	Defence	Use of passive and active RFID tags for inbound and outgoing shipments along the supply chain
Singapore	Logistics/Transport	Nationwide Electronic Road Pricing (ERP) system to control and manage traffic volume; payment of road usage charges. The ERP is applied to all of Singapore's 840 000 vehicles
	Public services	RFID tags replace paper season parking tickets at car parks in public housing estates
	Education	Lending systems in all national and community libraries

Source: Compiled from replies to the IT Outlook Policy Questionnaire 2008 and case studies.

3.2 Information, awareness and education activities

Apart from being a user of RFID technology, another important role for the public sector is in providing and sharing information and in the education of stakeholders. Information and education activities include for example:

- Conferences on RFID technology and its impacts.
- Discussion forums and online dialogue platforms.
- Information (*e.g.* studies providing an introduction to RFID, its benefits and barriers and assessing current and future RFID markets).
- Publication of guidelines (*e.g.* how the private sector could assure data protection).
- Demonstration projects.

Table 6 illustrates different information, education and awareness activities in OECD countries. Activities in this category primarily focus on the publication of studies and demonstration projects. Most of the studies are either directed at consumers or companies. In the first case, studies are published aiming at increasing public awareness. One of the challenges of studies directed at consumers is a balanced presentation of potential benefits and potential risks as potential risks vary greatly according to specific RFID applications. Another major challenge is to distinguish between applications which do not have an impact on consumers and users and where privacy is not an issue (*e.g.* supply chain applications), and applications which directly concern consumers and where privacy is an issue. In the first case, studies provide an introduction to RFID technology and information on fields of application and benefits and challenges in technology implementation.

A significant number of these studies focus on small and medium-sized enterprises (SMEs). These companies often face important transaction costs, especially in the case of new RFID applications where few off-the-shelf solutions exist and where different technology providers supply different parts of the RFID system. Further, SMEs often lack the necessary R&D budget, economic capacity and time to take large risks with new technologies. As SMEs are potentially important users of RFID systems, information and awareness on prospective applications as well as showcases are important for diffusion of RFID technology and reducing unnecessary risk. Publications on best practices can further facilitate RFID diffusion among SMEs.

Some OECD countries (*e.g.* Finland and Korea) have provided showcases and demonstration projects which include demonstrations in application centres and implemented projects, for example in the field of baggage handling.

Overall, as RFID implementation projects are still at an early stage, lack of knowledge potentially hampers further development and implementation. Governments are experienced in raising awareness of and disseminating information on new ICT technologies and fields of application, often in collaboration with other stakeholders, and can help devise collaborative mechanisms to improve diffusion and uptake in generic technologies. Projects are usually characterised by being developed in close collaboration with other stakeholder groups including industry groups and academics and they try to give a comprehensive overview of the technology. In Germany, for example, the report "RFID – Security Aspects and Prospective Applications of RFID Systems" gave a detailed overview of benefits and challenges, thus helping German companies to reduce transaction costs by reducing the time spent searching for information on RFID technology. Further activities aiming at discussing different facets of RFID implementation and the broad dissemination of these activities could contribute to better understanding of RFID technology and applications and thus foster its broader acceptance and diffusion.

Table 7: Selected RFID information and education activities in OECD countries

Country	Project category	Project description
Australia	Information (guide)	Publication of a guide "Getting the most out of RFID – A starting guide to radio identification for SMEs[6]"
	Information (event)	Educative events such as the "RFID Executive Breakfast" to build awareness of opportunities and challenges presented by RFID technology
Canada	Information (study)	"RFID Technologies and Consumers in The Retail Marketplace" – Study update discussing RFID technology, pilots and deployment in Canada, consumer concerns and policy developments[7]
Denmark	Information (study)	"RFID possibilities in the value chain" – study, published by the Independent Technology Council[8]
Finland	Demonstration projects (application centre)	Partly publicly funded RFID application centre providing information and piloting facilities[9]
Germany	Conference	Expert conference "RFID: Towards the Internet of Things"[10] organised by the Federal Ministry of Economics and Technology
	Discussion forums	"RFID-Dialogplattform": Forum pooling information on activities and initiatives both administrated by the government and industry
		"RFID und Verbraucherschutz (RFID and consumer protection)" aiming at providing transparency and creating trust
	Information (online portal)	"Netwerk elektronischer Geschäftsverkehr (Electronic Commerce Network)": Online portal to support SMEs. Special part on RFID technology including studies and checklists
	Information (studies)	A number of studies issued by the government such as "Leitfaden RFID - eine Chance für kleine und mittlere Unternehmen (RFID guide – an opportunity for small and medium-sized enterprises)"[11], "RFID – Security Aspects and Prospective Applications of RFID Systems"[12] or "RFID-Prospects for Germany" (BMWi, 2007)
Italy	Information (study)	The "National Centre for IT in Public Administration" (CNIPA) is working on a study evaluating the use of RFID in public administration[13]
Japan	Guidelines	Modification of the document "Guidelines for Privacy Protection with Regard to RFID Tags" according to technological changes and usage in order to improve dissemination conditions of RFID
Korea	Information (studies, guidelines)	RFID technology feasibility studies, guides for companies based on conducted pilot projects (see Part 3.1)
Netherlands	Information	"The Netherlands Digitally Connected", Information on RFID directed at SMEs via generic ICT awareness and educational programmes
Switzerland	Discussion forum	Risk dialogue foundation[14] (dialogue between stakeholders from industry, science, public sector, consumer protection, data security amongst others)
	Information (study)	"The precautionary principle in the information society"[15]
European Commission	Information (communication)	Communication from the Commission to The European Parliament, The Council, The European Economic and Social Committee and The Committee of the Regions: "Radio Frequency Identification (RFID) in Europe - steps towards a policy framework"[16]
Singapore	Information (knowledge base)	Creation of a knowledge base by the National RFID Centre to shorten learning curves and deployment times across industries
	Discussion forum	Creation of an RFID focus interest group with linkages to a network of local and overseas RFID labs by the National RFID Centre
	Demonstration projects	Demonstration of novel RFID technologies and solutions at the National RFID Centre

Source: Compiled from replies to the IT Outlook Policy Questionnaire 2008 and case studies.

3.3 Incentives for business R&D and public sector project funding

Public sector project funding (either wholly or in part) is a third category of country initiatives . They include *i)* projects funded and conducted by the public sector for business sector applications, *ii)* funding of mostly collaborative projects between business, research and public groups, and *iii)* funding projects conducted by the private sector. Some of these funding schemes are specifically focused on RFID, in other cases R&D and new applications as well as the development of standards are funded via general national technology development and support funding mechanisms.[17] It should be further noted that RFID R&D and investment can benefit from general R&D tax incentives and investment incentives, but that there are no reported RFID-specific R&D or other tax incentives for their development in OECD countries.

Table 7 provides an overview of funding projects in selected OECD countries. Further projects with important funding volumes are conducted by the European Commission within the 6th framework programme (see Box 1). Overall, projects range from RFID projects in specific fields of application, the funding of selected projects between different stakeholder groups, to a wide range of tax expenditures via general tax incentives.

Table 8: Selected RFID funding projects in OECD countries

Country	Project	Description	Stakeholders
Australia	National EPC Demonstrator Project (2006/2007)	Funding two phases of the National EPC Demonstrator Project: RFID in (open circulation) supply chains; interoperability and integration requirements	Government and industry
Austria	FIT-IT – Programme line 'embedded systems'	Ministry for Transport, Innovation and Technology. RFID projects funded in the programme 'embedded systems'	Government, industry, academics. Funding cooperative industry/academic research projects
	Competition: Development and Application of RFID Technology	Project within the programme "Digital Economy/ICT". Funding of seven projects. Total funding volume provided by the Federal Ministry of Economics and Labour: EUR 400 000	Government, industry and academics
	'PROACT' initiative	Joint private-public initiative by the university of Graz and NXP (former Philips Semiconductors) for RFID R&D	Public sector and industry
Canada	McMaster RFID Applications Lab (MRAL)	Creation of an RFID lab at McMaster University in joint public-private initiative. Hub for RFID applications promoting RFID research, social and economic impact and policy issues	Industry and public sector
Denmark	Train travel card	Test of RFID technology based e-ticket by major Danish train operator	Government and industry
	BroBizz (Bridge toll)	Use of RFID technology for commuters for the toll system on the bridge between Denmark and Sweden, as well as toll on bridges in Denmark	Government
	Mail delivery and registration	Implementation of smart phones to combine road planning, RFID scans, payment and postal registration by the major Danish mail operator in 2007	Government and industry
Finland	GIGA[18]- Converging networks	TEKES (main government body for funding R&D programmes). Programme focus areas: wireless access (including RFID), seamless networking, network support, telecommunication business	The programme is a combination of research and industrial projects

Country	Project	Description	Stakeholders
Germany	-	Targeted support of projects developing pioneering RFID activities and producing show-cases	Government and industry
Korea	Airline Baggage Tracking and Control System	RFID tags attached to baggage of domestic flight passengers and RFID readers deployed in destination airports to secure baggage traceability	Jeju, Busan, Daegu, Gwangju and Chungju airports
Mexico	PROSOFT[19] fund	Programme for development of the software industry (PROSOFT), supports RFID-related projects. About one third of funding from the Ministry of the Economy	Government, industry and academics
Spain	Interference tests	Interference tests in several Spanish towns (*e.g*. Madrid) to test the compatibility of RFID with radio links	Government
Turkey	RFID Research and Test Centre	Established by Istanbul Technical University. Research projects RFID use, especially logistics and manufacturing	Public sector and industry
Singapore	National RFID Centre (September 2006)	Funding RFID industry pilot projects	Government and industry
		Training for potential solutions for companies and end users	Government and industry

Source: Compiled from replies to the IT Outlook Policy Questionnaire 2008 and case studies.

Government support promotes RFID technology on both supplier and user sides. The funding of projects with a wider scope (*e.g.* the Finnish GIGA project) has the particular advantage that these projects have the potential to trigger wider and future applications. Finally, funding of long-term projects allows development and testing of more future-oriented applications such as applications combining RFID technology with other promising technologies (*e.g*. sensor technology). At all funding stages, collaboration with different stakeholders and intense information exchange are crucial and help to maximise benefits.

Besides the projects described above, the public sector may also need to address environmental and recycling issues related to RFID technology. The technology can very effectively track, minimise and assist efficient waste and pollutant disposal. But in addition, environmental impacts associated with the technology itself will need to be addressed. As the number of RFID tags continues to rise, they will have to be separated from other materials during recycling processes. Government support could encourage research on the impact of RFID technology on the environment and especially on recycling issues.

Box 1: Selected RFID funding projects in the 6th Framework Programme

BRIDGE (Building Radio frequency IDentification solutions for the Global Environment):

- Three year RFID application research and development project. Funding: EUR 7.5 million.
- Objective: "To research, develop and implement tools to resolve barriers to the implementation of RFID and EPCglobal technologies (solutions for network(s), application software, security, hardware, implementation, increasing the influence of European organisations in global standard processes" [20]

SMART

- 30-month project.
- Objective: "aims to support intelligent business networking and consumer services based on effective and efficient information/knowledge sharing and collaboration across supply chain partners, capitalizing on the fact that products are uniquely identified with the use of smart tagging technology in the supply chain".[21]

StoP

- 30-month project
- Objective: "aims at developing ambient intelligence-based and network-oriented systems for the efficient and secure authentication of products".[22]

Indisputable Key

- Objective: resource optimisation in the timber industry.

CE RFID (Coordinating European Efforts for Promoting the European RFID Value Chain)

- Objective: "CE RFID aims at improving the conditions of competition for RFID technology and its further development in Europe and at reinforcing the political environment of RFID at European level".[23]

Source: Authors' compilation

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NOTES

[1] For a discussion of different frequency ranges and further characteristics of RFID systems see the OECD RFID country study for Germany [DSTI/ICCP/IE(2007)6/FINAL].

[2] EPCglobal Inc. is an industry standards group which establishes industry-driven standards in the field of supply chain management (see also http://www.epcglobalinc.org/about/).

[3] European Commission, DG Enterprise and Industry: Sectoral e-Business Watch, Chart Report 2007. The final study by the Sectoral e-Business Watch is expected in June 2008. The e-Business Watch studies aim at analysing the impact of ICT and e-business on enterprises, industries and the economy in general.

[4] The survey sample consisted of 434 enterprises from 4 sectors (manufacturing, retail distribution, transportation, hospital activities) and 7 EU countries (France, Germany, Ireland, Italy, Poland, Spain, and the United Kingdom). Quantitative interviews were conducted by phone relying on computer-assisted telephone interviews (CATI).

[5] The survey question was stated as follows: "Please tell me for each of the following items whether or not this is a relevant barrier for an RFID project. Is this a relevant barrier for an RFID project or not? […](c) There is not enough evidence of a strong return on investment (ROI)."

[6] Small and medium-sized enterprises.

[7] http://www.ic.gc.ca/epic/site/oca-bc.nsf/en/ca02287e.html.

[8] English summary: http://www.tekno.dk/pdf/projekter/p06_rapport_RFID.pdf.

[9] http://www.rfidlab.fi/?1;2;1200;1200;14.html.

[10] http://www.nextgenerationmedia.de/Nextgenerationmedia/Navigation/en/rfid-conference.html.

[11] http://www.ec-net.de/EC-Net/Redaktion/Pdf/RFID/rfid-leitfaden-mittelstand,property=pdf, bereich=ec__net,sprache=de,rwb=true.pdf (in German).

[12] http://www.bsi.bund.de/fachthem/rfid/RIKCHA_en.htm.

[13] http://www.osservatori.dig.polimi.it/dettaglioOsservatorio.php (in Italian).

[14] http://www.risiko-dialog.ch/Themen/Kommunikationstechnologien/263 (in German).

[15] http://www.ta-swiss.ch/a/info_perv/2003_46_pervasivecomputing_d.pdf (in German).

[16] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2007:0096:FIN:EN:PDF.

[17] See for example the National Science Foundation (NSF) (http://www.nsf.gov/eng/iip/iucrc/directory/celdi.jsp) and the National Institute for Standards and Technology (NIST)

(http://www.nist.gov/public_affairs/techbeat/tb2006_0330.htm#rfid;
http://csrc.nist.gov/staff/Kuhn/phillips-karygiannis-kuhn05.pdf) for the United States.

[18] www.tekes.fi/giga.

[19] http://www.software.net.mx/en/prosoftp4p.htm.

[20] http://www.bridge-project.eu/.

[21] http://www.smart-rfid.eu/page.php?3.

[22] http://www.stop-project.eu/PROJECT/tabid/57/Default.aspx.

[23] http://www.rfid-in-action.eu/public/.