# Chapter 4
# Performance Measurement and Cost Benefit Analysis for RFID and Internet of Things Implementations in Logistics

RFID projects compete with other IT projects and therefore need to show a better performance in order to justify the corresponding investments (Lee and Lee 2010). A measurement leading to "a quantitatively expressed reduction of uncertainty based on one or more observations" (Hubbard 2010, p. 23) is needed. Current approaches to measure the performance of RFID and Internet of Things-related projects, including costs and benefits, will be analysed in this chapter and their uneven allocation among stakeholders will be shown. Additionally, there will be a look at how costs and benefits can be harmonised between participants of a supply chain using CBS. The findings will show that the existing methodologies have several shortcomings. An alternative approach to performance measurement and CBS, which relies on pricing and selling information, will be introduced.

## 4.1 Measuring Costs and Benefits of RFID Implementations

ROI calculations of information are usually considered appropriate methods for evaluation of information value (Department of the Navy Chief Information Officer 2005).

> "It is only when business users have actually generated business benefits in excess of the expenditure on IT and associated activities is value ultimately created." (Tiernan and Peppard 2004, p. 22)

In order to compare benefits and expenditures, both have to be investigated in detail. In an empirical study, Gille and Strücker (2008) asked 278 Chief Executive Officers (CEOs), Chief Information Officers (CIOs) and head of logistics, of which 124 answered, which performance measurement methods they used frequently. Performance Indicators were used most often (29.8%) followed by Scoring Methods (23.4%), Total Cost of Ownership (21.8%), Activity-Based Costing, Net Present Value (17.7%), Balanced Scorecard (7.3%) and Economic Value Added

D. Uckelmann, *Quantifying the Value of RFID and the EPCglobal Architecture Framework in Logistics*,
DOI 10.1007/978-3-642-27991-1_4, © Springer-Verlag Berlin Heidelberg 2012

**Table 4.1** Characteristics of RFID performance measurement methods and usage frequency (based on Gille and Strücker 2008; Strüker et al. 2008)

| | TCO | ABC | Indicators | Scoring | NPV | EVA | BS |
|---|---|---|---|---|---|---|---|
| Usage frequency at companies using RFID (projected and realised projects, multiple answers allowed) | 28.3% | 25.0% | 34.6% | 29.9% | 20.9% | 2.4% | 7.7% |
| Quantification of cash flows | ● | ● | ● | ○ | ○ | ○ | ● |
| Assessment of complete investment | ○ | ○ | ○ | ● | ● | ● | ● |
| Ex ante quantification | ● | ●[a] | ●[b] | ● | ● | ○ | ● |
| A posteriori quantification | ● | ● | ● | ○ | ● | ● | ● |
| Quantification of costs | ● | ○ | ○ | ● | ● | ● | ● |
| Quantification of benefits | ○ | ●[c] | ●[d] | ● | ●[e] | ● | ● |
| Financial quantification | ● | ● | ○ | ○ | ● | ● | ○/●[f] |
| Non-financial quantification | ○ | ○ | ● | ● | ○ | ○ | ● |
| Objective assessment | ● | ● | ○/●[g] | ○ | ● | ● | ○/●[h] |
| Subjective assessment | ○ | ○ | | ● | ○ | ○ | |

● *Supported*, ○ *Not supported*, ●/○ *Partially supported*

[a]"Quantifiable via field trials (measurement of resource savings on activity level)" (Gille and Strücker 2008)

[b]"Quantifiable via simulations, estimations and field trials" (Gille and Strücker 2008)

[c]Only automation benefits, or assumed 'avoided loss'; based on "soft" estimates rather than on "hard" monetary values analysis (Laubacher et al. 2006)

[d]Indicators are considered to be unreliable (Hubbard. 2010)

[e]Not useful in presence of high uncertainty levels (Madhani 2009)

[f]Financial quantification for BS in a single value is questioned (Jensen 2001)

[g]"Objective regarding measurement of individual indicators, possibly subjective regarding a selected set of indicators" (Gille and Strücker 2008)

[h]"If cause-and-effect chains between non-financial and financial performance indicators are established" (Gille and Strücker 2008)

(2.4%). Only about half (52%) of the companies that claimed to have benefits from automation, informatisation or transformation measured performance at all.

Gille and Strücker (2008) provide an overview about typical methods that are used to measure RFID performance. Table 4.1 lists these different methods, their characteristics and the frequency of usage, based on a study from Strüker et al. (2008) among 102 companies that are using RFID. Further comments from other authors in relation to quantification of benefits and financial quantification have been added.

A prominent method to measure performance of RFID applications is *Total Cost of Ownership* (*TCO*), which has been developed by Gartner. TCO has been criticised for its cost focus leaving benefits out of consideration (Gille and Strücker 2008).

*Activity-Based Costing* (*ABC*) provides enhanced control over overhead costs. It measures process cost reductions. Activities are decomposed into parts; the cost of each part is calculated and aggregated thus providing a detailed cost analysis (Laubacher et al. 2006). Benefits are usually generated in follow-up activities. Quality improvement programs, for example, reduce product defects thus leading

to reduced costs in the service cycle (Laubacher et al. 2006). ABC can quantify financial benefits that are related to automation (operational). Sometimes the 'avoided loss' is also integrated into ABC analysis, based on arbitrary values of what could have happened without the investment. Benefits usually are based on "soft" estimates rather than on "hard" monetary values analysis (Laubacher et al. 2006). Non-operational benefits are often excluded from any financial calculations (e.g., Miragliotta et al. 2007). Acquiring information for ABC-analysis may be a time-, labour- and cost-intensive task. Automatic data collection means, such as RFID, can help to reduce the manual labour for data collection as well as human errors (Varila et al. 2004).

*Performance indicators* can be used to measure non-financial benefits but do not consider costs. Performance indicators have been used for example to measure the benefits of out-of-stock reduction (Hardgrave and Miller 2006). Quite often relative figures (percentages) are used to quantify benefits and to measure performance in relation to competition (benchmarks) or historic values.

*Scoring methods* are based on weighted decision criteria to compare alternative investments. Scoring methods are used as a practical alternative if more accurate calculating methods prove to be too complex. Scoring methods have been used quite frequently for RFID performance measurement (Schuster et al. 2007; Scholz-Reiter et al. 2007). Hubbard (2010) questions though, if scoring methods are providing a real measurement.

*Net Present Value* (*NPV*) considers costs as well as benefits and provides a financial assessment based on discounted cash flows. Therefore, only benefits that can be monetarily quantified can be addressed. Most often estimations are used (Gille and Strücker 2008). Madhani (2009) does not consider NPV to be useful in presence of high uncertainty (e.g. in projects considering new technologies such as RFID), except for basic analysis purposes.

*Economic Value Added* (*EVA*), which is trademarked by Stern Stewart & Co., subtracts the capital charge from the net financial benefits and therefore includes the cost of capital. EVA is more suited for public traded companies, as it considers the equity for stakeholders. Instead of using the net operating profit after taxes, net financial benefits are used to evaluate pure IT investments, as operating benefits usually cannot be generated through IT investments. Nevertheless, in case of RFID operating benefits may be calculated through the impact of RFID on the 'real world' based on reduction in operating costs (automation) and increased revenues through, for example, increased on-shelf availability.

*Balanced Scorecards* (*BS*) were first created by Schneiderman (2006) in 1987. In a cause-and-effect approach it measures financial outputs and influencing factors. As usually financial outputs cannot be directly influenced, BS focus more on the factors that can be changed through management intervention. In the initial concept four main perspectives were identified: financial, customer, internal business process, and learning and growth (Kaplan and Norton 1996). While BS provide certain metrics, they fail to give a single-valued performance measure. Instead, they urge managers into maximising in more than one direction with uncertainties concerning the tradeoffs between the measures (Jensen 2001). To define management target

values, Balanced Scorecards rely on historical data, making it difficult to determine the initial influence of RFID on non-financial process performance (Gille and Strücker 2008).

All the described performance measurement approaches are used for evaluating the success of RFID-adoption and offer advantages as well as disadvantages. The problem of forecasting and controlling non-financial process improvements as a result of informatisation and transformation, such as reducing error correction initiatives due to better information quality, remains unsolved. The input data is based on estimations and "educated guessing" rather than on real values (Gille and Strücker 2008; Laubacher et al. 2006). Pure financial measures, such as NPV or EVA, "imply a precision that doesn't exist", often exclude intangible benefits and future opportunities and fail to consider risk (Symons 2006, p. 3). Cheremushkin (2008, p. 2) even suggests to "be careful about following performance measure. You may get to the wrong number". Additionally, "because most organisations lack a method for measuring the value of conducting a measurement, they are almost guaranteed to measure all the wrong things" (Hubbard 2010, p. 112).

All risks in any project investment can be expressed by the ranges of uncertainty of costs and benefits as well as on probabilities on affecting events (Hubbard 2010). In order to incorporate uncertainty of input data in economic assessments, risk-related additions or deductions, sensitivity analysis or risk analysis, for instance through Monte Carlo simulation, may be used (Lange et al. 2009). However, there is a need for procedure standardisation to achieve consistent results (Hubbard 2010).

Even though the quality of the input and output data is questionable, 78% of 64 SME that have been questioned in an empirical study by EC-Ruhr (2008) claim they have achieved an ROI within 5 years. In another study even more than 70% of the questioned RFID end-users claimed an ROI within 4 years (Strüker et al. 2008).

In a study by ChainLink Research in 2006 71% of 275 manufacturing companies highlighted that it is too soon to project a ROI (McBeath 2006). In the study by EC-Ruhr (2008) only 64 out of 298 companies that were participating answered the question of how long they needed to achieve an ROI. The reason for this low participation may reflect the uncertainty about which tools to use for performance measurement as well as a high level of companies that will not measure performance at all. Lee and Lee (2010) claim that traditional accounting and financial methods are less important in RFID performance measurement, as many benefits are non-quantifiable. Nonetheless, quite a few studies using financial methods can be found for RFID projects. It may be assumed that the pressure to provide 'numbers' prior to IT investments leads to questionable performance estimations. The measurements taken provide a "comfort level" and sometimes are even influenced by a tendency to "produce good news" (Hubbard 2010). In a similar manner, Gille and Strücker (2008) raise the following questions:

> "Does RFID performance measurement contribute to RFID success or do successful RFID users simply exhibit greater willingness to measure performance (e.g., to justify the technology investment)?" (Gille and Strücker 2008, p. 11)

Additionally, quite often it is not clear why researchers have chosen one method over the other. Hubbard (2010) argues that people tend to use the methods they know or use frequently. He also mentions that people sometimes measure the wrong things, just because it is easier. Consequently, he cites a quote by Abraham Maslow (American psychologist):

> "If your only tool is a hammer, then every problem looks like a nail." (Maslow as cited in Hubbard 2010, p. 112)

Even within one company multiple different performance measurement methodologies are used. Therefore, a comparison of different projects is difficult. A consistent methodology should be chosen (Symons 2006).

There is a need for objective financial quantification of benefits – and there is a simple method to measure the value of nearly anything by asking people how much they are willing to pay for it (Hubbard 2010). This method combines and reduces financial and non-financial benefits to a single potential value – money. It would be even more accurate to use actual payments as a basis for measuring and collecting data for future investments. This would require a technical solution to enable automated performance measurement. An integrated payment and billing solution can help to measure what could not be measured before (e.g., the access to product-related information) and provide a single-valued financial performance measurement.

### *4.1.1 Costs of RFID and Internet of Things Adoption*

Numerous studies on costs and benefits of RFID have been published (see, e.g., Agarwal 2001; Li and Visich 2006; Feinbier et al. 2008; Visich et al. 2009). This is hardly surprising, as one of the problems of RFID adoption has been the difficult calculation of a business case or a positive ROI (Schmitt and Michahelles 2008).

While the Internet of Things is not synonymous with RFID (even though some publications falsely stimulate this impression), results from cost analysis for RFID can be used as a basis for further calculations. In the following there will be a short overview about the costs involved for RFID installations. While some of the financial data is based on other publications and cited correspondingly, other data is based on experience from corresponding purchases in the Log*Dynamics* Lab at the University of Bremen between 2006 and 2009.

Agarwal (2001, p. 11) lists six different costs for manufacturing firms: "cost of the tag itself, cost of applying tags to products, cost of purchasing and installing tag readers in factories and/or warehouses, systems integration costs, cost of training and reorganisation, (and) cost of implementing application solutions".

It is not quite clear why Agarwal separates the cost of tags from the application process, while he sees cost for readers and their integration as one subject. Feinbier et al. (2008) list relevant costs for RFID installation in detail, based on experiences in the steel industry. On the basis of both approaches, similar cost structures can be

inferred for the Internet of Things. The structure in Table 4.2 is based on the semiotic levels as described in Sect. 3.4 (page 63). Maintenance, training and other operational costs are not listed separately in the table as they apply to all semiotic levels.

The *physical world cost level* in the Internet of Things includes mobile devices that are linked to physical objects as well as readers and other edgeware devices. Mobile devices include RFID tags fixed to a product, as well as sensors, actuators (e.g., signal lights, power switches) or smart devices that combine multiple technologies. The price of RFID tags has been an important issue over the last years. User acceptance for tag prices differ in relation to the aggregation level of the product to which they are attached. In a study from 2004 (ten Hompel and Lange 2004), 100 companies were asked what was the highest price they would accept for tags on item- and unit-level. For item-level a tag price of 0.10 EUR or less was most often required. For unit-level a higher tag price was still reasonable. The measured average price for 2008 was 1.13 USD per tag, although this average represents High Frequency (HF) as well as Ultra-High Frequency (UHF) tags (IDTechEx 2009b). UHF standard smart labels can be bought at a cheaper price, though. The lowest price that was offered to the Log*Dynamics* Lab at the University of Bremen for a standard ISO/IEC 18000/Amd 1 (2006) compliant UHF self-adhesive inlay was 0.08 EUR in 2009. Large retailers were able to buy tags at about 0.07 EUR in 2007 (see, e.g., Al-Kassab et al. 2010). On-metal UHF tags with a robust housing usually cost in the range of 3–7 EUR, due to the housing, the adjusted antenna design and the low quantities compared to smart labels. IDTechEx (2009b) predicts an average price per tag of 0.22 USD by 2014 for both HF and UHF tags. The discussion on RFID tag costs is mainly focused on passive RFID. For active RFID the cost per tag is considerably higher and will be typically in the range of 15–75 EUR. While the lower end of the range is mainly defined by the cost for the battery and the housing, the higher end is more determined by the market position of the individual vendors. Usually, non-standardised tags and readers have to be bought from the same vendor, thus leading to a long-term tie-up with one company. With the availability of ISO/IEC 18000-7 (2009), providing parameters for active air interface communications at 433 MHz, RFID tags for this frequency range can be bought from different providers. In fact, the US DoD – one of the largest customers for active tags – placed its first orders of corresponding tags to Unisys, Savi, Systems and Processes Engineering Corp. (SPEC) and Northrop Grumman. Previously, they were tied-up to Savi for sourcing active tags. Savi owns some intellectual property rights that require licensing from Savi to provide ISO/IEC compliant active tags. Nevertheless, the DoD claims that they pay half the price for the Unisys tags, compared to the prices they had to pay for the previous proprietary Savi tags. Unisys themselves use Identec Solutions and Hi-G-Tek as subcontractors to supply the tags. The active tags need to comply with the DoD military standards, which require safe and reliable operation in helicopters (Swedberg 2009). The corresponding tests are quite expensive and add to the high cost of these tags. Other active tags operate in the range of 860–960 MHz, 2.4 GHz or in the Ultra-Wide-Band (UWB) range. These tags sometimes offer additional features, such as

**Table 4.2** Cost levels for the Internet of Things

| Cost levels based on semiotics | Cost of tagging (Agarwal 2001) | Cost considerations for RFID (Feinbier et al. 2008) | Cost of Internet of Things adoption |
|---|---|---|---|
| Physical world | Cost of the tag itself | Tags | Cost of mobile technologies, such as data-carriers (e.g., tags), sensors, actuators or smart devices |
| | Cost of applying tags to products | Readers | |
| | Cost of purchasing and installing tag readers in factories and/or warehouses | Antennas and cabling | |
| | | Installation | Cost of applying mobile technologies to things |
| | | Tuning | Cost of edge devices (e.g., readers, gateways, controllers) and edgeware Follow-up costs in the physical world |
| Empirics | – | Controllers | Costs associated to middleware components for filtering and efficient data handling |
| | | Software platform (middleware) | |
| Syntactics | Systems integration cost | – | Systems integration and data storage costs including new interfaces, necessary updates, extensions, and replacements of existing systems to ensure seamless communication on a syntactic level |
| Semantics | (not implicitly required for internal solutions, instead handled on the pragmatic level) | | Integration of standardised semantics (ontologies, semantic web) to provide seamless communication on a semantic level |
| Pragmatics | Cost of implementing application solutions | Integration (to legacy systems) | Cost of implementing internal application solutions |
| | | Process (incl. redesign and human elements) | Business reengineering / business model innovation |
| | | | Software agent integration with pragmatic knowledge |
| Social world | - (maybe limited to company internal issues for internal solutions) | | Cost for networking (e.g., improved security, fine layered access control, multi-directional communication, product data contracts, SLA, trust concepts and mashups) |
| | | | Cost of internal and public information activities explaining, justifying or promoting the usage of the Internet of Things |

location sensing. Considering the prices of active tags and their successful deployment in industry, the isolated price discussion about passive tags seems rather inappropriate. Consequently, the price for the tags should always be compared to the benefit it generates. Nonetheless, if RFID is compared with other IT investments, one has to bear in mind the reoccurring costs for tags. When considering the integration of sensors, actuators and smart devices in the Internet of Things, there will be even more expensive ubiquitous mobile technologies that need to be paid for. Therefore, the costs of mobile devices and their installation on things will remain a major topic in the cost discussion for the Internet of Things.

RFID reader kits can be as cheap as 50 EUR for a HF reader with USB connection, some sample tags and a software that triggers websites or applications. A good example is provided by Violet (www.violet.net). These new offerings will allow RFID to be used in smart home scenarios and for fun purposes. In the midterm, they may also put pressure on RFID offerings for industrial purposes. Today, ISO/IEC 18000-6c compliant readers with 4 antenna ports can already be bought for less than 1,000 USD in the USA, while prices in Europe currently are still higher and usually are in the range of 1,300–2,500 EUR. In some publications (e.g. Feinbier et al. 2008), reader costs are considered to be correlated with functionality. Instead, the price is more related to the company position, the sales strategy of the individual companies, and the number of middlemen involved. Corresponding UHF antennas in general are in the price range of 80–300 EUR. Antenna cables can be considered to cost about 10–30 EUR in usual length of 1–10 m. Handheld RFID Personal Data Terminals (PDT) are priced between 1,000 and 4,000 EUR. RFID printers start at about 1,000 and may go up to 30,000 EUR or more for integrated and automated labelling solutions. Other hardware costs include hardware portal frames to hold the reader and antennas. Some retailers have used large metal housings to shield between dock doors in order to avoid false reads. Other installations rather use intelligent filtering mechanisms provided by corresponding middleware components (see, e.g., MoreRFID 2007). The setup of the gates may require considerable costs for hardware and installation. An RFID site survey will cost about 1,000 EUR (Feinbier et al. 2008). They consider 20,000 EUR installation cost per read point in a harsh environment, such as the steel industry. This seems rather high for standard dock-door installations, but still illustrates that the cost for installation should not be neglected.

The *empiric cost level* includes aggregation devices and aggregation software, such as readers, antennas, cabling, controllers and other edge hardware and software as well as the corresponding installation cost. Controllers and middleware are used for managing low-end hardware and abstracting these from the applications. Sometimes the middleware is further divided into solutions interfacing with hardware (edgeware) and the middleware interfacing with applications. Middleware can be based on freeware, such as the Fosstrak-system (www.fosstrak.org ) or it may also be provided by large integrators, such as IBM, software giants, such as Oracle or SAP, EDI-specialists, such as Seeburger, and RFID-specialists, such as Savi and REVA. In the Internet of Things, middleware does not only link to internal

applications, but additionally allows multidirectional communication between companies, end-users and public institutions (see social level below).

The *syntactic cost level* contains all integration costs, including interfaces as well as necessary updates, extensions, or replacements of existing systems to ensure seamless communication on a syntactical level. It includes specifications, such as the EPCglobal Framework, languages, such as HTML or XML, and interfaces, such as ALE.

The *semantic cost level* includes ontologies, vocabularies and the semantic web, which represents a network of semantic data that can be directly interpreted and processed by machines. As this level is not yet well defined in the Internet of Things, some companies, especially in retail, rely on EDIFACT instead. Even the EPCglobal Network will not replace EDI, as it does not cover issues such as purchasing or forecasting. Cost for semantic integration can start from tens of thousands of Euros and may reach several million Euros in large installations (e.g., EDIFACT). For machine-to-machine communication, even more detailed syntax and semantics are required.

The *pragmatic cost level* includes costs for updating applications, such as ERP, SCM and PLM systems and for new internal applications, which are rolled out in a firm to unleash the full potential of the Internet of Things. These applications interface to the Internet of Things and provide tools for data-analysis, planning, forecasting and more. In general, they provide the context in which information from the Internet of Things is used. In the future, situation-aware contextual decisions could be based on software agents. The pragmatic level also includes the cost of reorganising the business processes or newer approaches, like business model innovation. As a result, further infrastructural investments on the physical level may be required. Ford Cologne (Germany), for example, paved a new roundabout for optimising their car distribution process to vessels, trains, trailers and storage areas, based on RFID and automated access gates (Harley 2008). It can be estimated that the costs for the new roundabout exceeded the costs of the RFID infrastructure. While this example shows an investment in a single process optimisation, new business models may require extensive organisational changes.

The *social cost level* considers the fact that an Internet of Things needs communication and collaboration across enterprise boundaries, non-commercial stakeholders, such as governmental institutions, and end-users. The social level is usually excluded from cost calculations. While middleware provides some functionality in the Internet of Things for collaboration and communication, further investments are necessary. Additionally, certain aspects of the Internet of Things raise privacy and security concerns from workers and unions, which may lead to a total failure of the project. Training and education, as well as an open company communication help to provide the corresponding information to address technology-related fears. Negotiations with partners, suppliers and customers about data requirements and SLA will be necessary. Finally, trust and security issues need to be addressed in a networked environment. When compared to traditional 1-to-1 information sharing there may be a cost advantage in an open Internet of Things where there are less opportunity costs. Opportunity costs, in this context, describe

the financial disadvantages of being tied to a specific partner (McLaren et al. 2002). However, this cost advantage has to be measured against the technical investment costs for changing a business partner. In the Internet of Things, changing a business partner supposedly is easier and cheaper than for example in relations that are based on EDIFACT structures.

Additionally, operating costs for maintaining, running, improving and extending the system need to be taken into account. The hardware and software need to be maintained and updated regularly. An annual amount of 10–15% of the hardware and software investment cost should be considered. Electricity costs, to operate the infrastructure, are usually quite low in comparison with the other costs involved, but as Green IT initiatives are becoming more and more significant, the Internet of Things is no exception. Above all, the labour involved to provide high-quality product data has to be taken into account. As these costs are difficult to calculate, they are most often omitted from any calculations. Besides keeping the technical infrastructure alive, day to day tasks, such as data storage and analysis as well as overall improvements and upgrades to cope with growth, are adding up to substantial recurring costs.

As the cost of RFID tags will become less important with decreasing prices the primary cost of RFID-adoption will be related to changes in information technology infrastructure (Schuster et al. 2007).

In an early study from AMR Research (McClenahen 2005), cost for system integration, changes for supply chain applications and for data storage and analytics were expected to reach between 8 and 13 mn USD for a full implementation of RFID by a Consumer Packaged Goods (CPG) manufacturer shipping 50 mn cases per year. The cost for readers and tags were estimated at about 5–10 mn USD.

The calculation has been rightly attacked by Hardgrave and Miller (2006) in their publication about "The Myths and Realities of RFID". In a study by Incucomm (2004), 137 Wal-Mart's suppliers were questioned about the actual cost of implementation. Incucomm estimated a median of less than 200,000 USD and an average of 500,000 USD. Estimated reasons for this huge difference to the AMR Research results were the limited scope of RFID usage, declining technology prices, less than expected deployment difficulties and RFID data storage requirements (Hardgrave and Miller 2006). However, a company-wide implementation and utilisation of RFID will require considerable investments.

Bearing in mind the further costs in an Internet of Things, including multiple different devices and collaboration costs, it can be expected that the overall cost will be higher than for an isolated RFID deployment, especially if all semiotic levels are taken into account.

There are different options to pay for the costs of RFID adoption. These differ between implementation and operation. In a study from Bensel and Fürstenberg (2009), more than 100 end-user companies have been asked (five-point Likert scale) which payment options they prefer for implementation and operation. For implementation there was a clear preference towards a target agreement-based payment scheme. Variable payment options based on number of tags, data volume, process times or pay-per-read were not well accepted (see Table 4.3).

**Table 4.3** Preferred payment options for implementation and operation (based on Bensel and Fürstenberg 2009)

| | Weighted results/average | |
|---|---|---|
| | Implementation | Operation |
| Transponder volume | –0.79 | –0.50 |
| Data volume | –1.51 | –1.26 |
| Process times | –1.38 | –1.33 |
| Pay-per-read | –1.54 | –1.37 |
| Work package | –0.05 | –0.81 |
| Target agreement | 0.27 | –0.12 |
| Fixed monthly payment | –1.29 | –0.89 |
| Single payment | –0.79 | –1.03 |

One of the reasons for this could be the missing technical infrastructure to measure and bill the corresponding usage. For operation, a usage-based accounting did receive higher acceptance levels. While pricing based on target agreements still was preferred, a pricing scheme based on transponder volume followed as second preference.

It may be assumed that a transparent technical billing solution would help to overcome the reluctance to use usage-based pricing schemes, based on pay-per-read, process times or data volume, as it would provide an easy-to-use approach.

### *4.1.2 Benefits of RFID and the Internet of Things*

Measuring costs and cost-savings has its problems, yet it is easier than measuring benefits (Laubacher et al. 2006). Investments in IT may be rejected, just because benefits could not be measured. Consequently, strategic investments are sometimes ignored, as the knowledge of how to measure its benefits is missing (Hubbard 2010). There have been numerous analyses to identify and structure benefits of RFID in supply chains. While the benefits are named in relation to RFID adoption, the corresponding IT infrastructure, including, e.g., the EPCglobal Network, is most often implied. Baars et al. (2008) have identified four different approaches towards systemisation of RFID benefits:

- Collecting and grouping – benefits are collected and grouped. Examples for these types of studies are Agarwal (2001), Li and Visich (2006), and Veeramani et al. (2008).
- Layer of impact – benefits are structured to impact layers such as short term and long term or automation, informational and transformational benefits, proven or potential (Bovenschulte et al. 2007).
- Locus of impact – these studies highlight who benefits, thus they automatically consider benefits to multiple stakeholders (Wong et al. 2002; Tajima 2007; Hardgrave et al. 2008; Visich et al. 2009).
- Indicator system – evaluation systems, such as Balanced Scorecards, are used to structure RFID benefits (Schuster et al. 2007; Scholz-Reiter et al. 2007).

Sometimes combinations of these structures are used (e.g., Hardgrave et al. 2008). In a layer of impact-based approach to classify RFID benefits, Baars et al. (2008) have listed multiple different criteria. Firstly, they distinguish three groups – *automation*, *informational* and *transformational* benefits. According to the authors, RFID *automation benefits* are derived for example through replacing manual data collection (e.g., manual barcode scanning) with automatic measurement, such as in sorting procedures. Automation benefits in manufacturing are generated locally, as opposed to other benefits that may have local as well as distant benefits and include other units of the firm or outside companies (Laubacher et al. 2006). *Informational benefits* are based on improved information quality for decision making. They can be achieved without modifying structures and procedures and include benefits from more frequent data collection at low additional costs compared to manual data collection. Informational benefits are expected by 78% of all respondents, according to Strüker et al. (2008). *Transformational benefits* on process level require a redesign of information and goods flow as well as responsibilities. The possibility of generating transformational benefits is only seen by 57% of the companies (Strüker et al. 2008). A redesign of the money flow to information and goods flow is not investigated. Secondly, Baars et al. (2008) differentiate between *direct* and *indirect* benefits. Direct benefits can be easily measured in terms of cost savings or performance indicator values. Benefits resulting from more precise, more accurate or more frequent data collection are considered to be indirect benefits. They require a purposeful distribution and utilisation of RFID-related data. As quantification of indirect benefits are based on future estimations, a differentiation in worst case, average case and best case is an appropriate method to reflect a certain degree of uncertainty within the prospective developments (Lange et al. 2009). Thirdly, Baars et al. (2008) separate *monetary* from *qualitative* benefits. All direct and some indirect benefits, such as reduced storage cost, based on better replenishment processes, are listed as monetary benefits. Qualitative benefits include for example reduced mistakes in material handling. However, even "non-quantifiable benefits have to be translated into something that eventually has a real monetary value" (Tiernan and Peppard 2004, p. 19). Usually RFID projects include both, monetary as well as qualitative improvements. Fourthly, *innate* and *collateral* benefits are considered. Innate benefits, such as better cost-efficiency or data quality result directly from the implementation of RFID compared to collateral benefits, such as standardisation of identification codes (e.g., EPC). Lastly, Baars et al. (2008) distinguish between *operational* and *managerial* support. Automation benefits, reduced out-of-stocks, and aligning production and demand are examples for operational support, whereas managerial support benefits through advanced RFID data collection, analysis and applied Business Intelligence, thus the managerial benefits are always indirect. Data collected on the operational level may be stored, aggregated over time and used for future managerial decisions.

Laubacher et al. (2006) distinguish between *localised* and *distant* benefits. Localised benefits can be generated within one organisational entity. Distant benefits occur within other units or outside firms. Achieving localised benefits lies within the control of the entity. Distant benefits rely on participation of other

entities to achieve its full potential. Instead of *distant* benefits, the term *shared* benefits should be used, as these benefits may depend on distant business units or companies, but may benefit the distant as well as the local entities. Several benefits cannot be achieved alone, but only in collaboration with other stakeholders. RFID implementations will gain acceptance when mutual benefits can be achieved (Véronneau and Roy 2009). In the benefit group model provided by Tajima (2007), localised benefits are further separated for each stakeholder.

Tajima (2007) differentiates between benefits from *exploitation* and *exploration* based on studies from organisational learning. While exploitation aims to improve existing processes through standardisation, streamlining, better process control and automation, exploration is used to discover new ways of creating values or solving old problems through improved business intelligence. A further differentiation of benefits can be based on its sustainability level. Tajima (2007) distinguishes between *short-term* and *long-term* benefits. Adjusting processes delivers short-term competitive advantages as it can be easily copied, whereas learning to transform based on exploration delivers long-term advantages. She expects that supply chain visibility may be short-term, as a competitive advantage is lost once visibility across a supply chain is available to all stakeholders. This would imply though, that information access is not restricted to trusted parties. First movers-marketing benefits may be considered short-term as well.

Veeramani et al. (2008) distinguish between *operation costs* and *revenue increases* and sees reduced stock-outs as a means to grow revenue. Similarly, Fleisch et al. (2005) see the smart services and smart products as being focused on revenue generation, whereas SCM, PLM and CRM are more focused on reducing costs, even though they see a soft transition between cost and revenue generation.

Additionally, the *measurability* of the benefits should be considered. While measurable benefits most often refer to monetary aspects, there are as well qualitative benefits that can be measured, such as customer satisfaction. Measurability may be limited through regulations, e.g., time measurements are not allowed in some companies.

Based on these nine different layers, a table of profiling criteria for RFID benefit classification is provided in Table 4.4.

For this dissertation it will be important to understand who benefits (locus of impact) from RFID and the Internet of Things usage on an inter-organisational or even end-user level. The following list is based on Wong et al. (2002), Tajima (2007), Veeramani et al. (2008), Hardgrave et al. (2008), and Visich et al. (2009). Benefits to society are added. Service and infrastructure providers are not named and researched, as they benefit only indirectly, e.g., through sales, services and new business opportunities, rather than directly from accessing the Internet of Things.

***Collective benefits*** can be achieved by all stakeholders. These include:

- *Reduced shrinkage* is based on reduction of loss of goods such as products, assets and RTI through misplacement, spoilage, and theft. Aberdeen (2010) sees a 0.8% year-over-year decrease in in-store shrink through RFID. Theft on a

**Table 4.4** Profiling criteria for supply chain benefits in the Internet of Things

| Based on | Level | Criteria | | |
|---|---|---|---|---|
| Baars et al. (2008) | Impact level | Automation | Informational | Transformational |
| | Immediateness level | Direct | Indirect | |
| | Value measurement | Monetary | Qualitative | |
| | Autarchy level | Innate | Collateral | |
| | Business level | Operational | Managerial | |
| Laubacher et al. (2006) | Benefit allocation | Localised | Distant | |
| Tajima (2007) | Learning orientation | Exploitation | Exploration | |
| | Sustainability level | Short-term | Long-term | |
| Veeramani et al. (2008) and Fleisch et al. (2005) | Cost vs. revenue benefits | Cost benefits | Revenue benefits | |
| Uckelmann (new) | Measurability | Measureable | Immeasurable | |

construction site may be reduced by 50% (Plant Services 2010). Shrinkage of RTI may be reduced considerably as well. Miller (as cited in Wilding and Delgardo 2004) claims that keg losses at a brewery have decreased from 4% to 2%. About 4% of all RTI need to be replaced because of loss or damage every year (BRIDGE 2007). Replacing lost RTI, such as wooden pallets, has a huge environmental impact that may be reduced through better supply chain visibility based on RFID.

- *Improved information sharing* can be achieved by sharing product-related data between multiple stakeholders in a defined format. Problems resulting from converting paper-based information to digital information can be avoided and manual data-entry is drastically reduced. Collaborative businesses that have been sharing data through EDI may utilise this infrastructure in combination with RFID in order to combine material and information flow today, which may be complemented by the Internet of Things in the future. Improved information sharing can help to reduce the bullwhip effect (Verein Deutscher Ingenieure e.V 2008). In a simulated beverage scenario there was no significant influence on the bullwhip effect, though (Uckelmann et al. 2009).
- *Compensatory benefits* provided through other stakeholders, including, for instance, CBS, funded research, bonus payments, vouchers or information (e.g., sales data), may be needed to initiate projects when other benefits are too small or cannot be calculated in detail.

***Benefits of companies in general*** are separated from warehouses, distributors and logistic service providers. However, goods receipt, storage and distribution are common tasks in logistics that are not always outsourced to corresponding specialists. Therefore, these benefits will not be further separated here:

- *Reduced material handling* leads to time savings through faster inventory, goods receiving, loading and unloading as well as reduced human errors through Auto-ID. Ninety per cent of 147 asked companies using or planning to use RFID expect benefits from reduction of manual data collection through RFID (Strüker et al. 2008). Inventory counting with mobile terminals based on RFID may lead to 87% time-savings over corresponding barcode-applications (Al-Kassab et al. 2010). Quantity checking on pallet-level is expected to be reduced from 180 to 40 s/pallet (Laubacher et al. 2006). Labour represents 50–80% of the cost for most distribution centre operations including receiving, shipping, and picking (PWC Consulting 2002). Loading and unloading of trucks can be reduced up to 13%. Administrative overhead at the goods receipt may be reduced up to 70% and time savings at the goods receipt may be as high as 90%, if bulk reading can be applied (Grote 2006). In cross-docking and customs clearance, delivery lead times as well as reduced delays may lead to further savings.
- *Improved space utilisation* can be achieved through reduced buffers and reduction of product storage incompatibilities, based on better data accuracy through RFID usage. In a retail scenario, a conservative improvement of 5.7% was calculated (Veeramani et al. 2008). Additionally, safety in relation to placement of hazardous goods can be improved. A solution approach based on RFID to avoid incompatible products in close proximity has been researched in the OPAK project (Schnatmeyer 2007).
- *Increased inventory, shipping and data accuracy* refers to eliminating differences between real stock numbers and assumed stock, based on false data. In a survey among 141 companies, 70% estimated a deviation between real and IT data of up to 10%. Thirteen per cent of the companies even estimated a higher inaccuracy of 10–30% (Gille and Strüker 2007). Best-in-Class retail companies are expected to achieve 92% inventory system accuracy through RFID (Aberdeen 2010). Dispute resolution and charge backs can be avoided and may contribute to substantial financial savings (Veeramani et al. 2008). In a field study at a third-party logistics provider claims incidence fell by 54.3% after RFID implementation and the financial value of claims decreased by 29.7% (Langer et al. 2007).
- *Reduced backlogs* can be achieved through better information sharing. In a simulated beverage scenario backlog reductions of 34% for the bottler and 49% for the wholesaler where calculated (Uckelmann et al. 2009). The DoD claim that their backlog has fallen from 92,000 to 11,000 shipments in their Iraq operations because of RFID (Collins 2006a).
- *Subsequent fault reduction* refers to inaccurate and incomplete visibility that may lead to false decisions and can be avoided through the Internet of Things. As an example, Wal-Mart reduced unnecessary manual orders, due to inaccurate stock visibility by 10% (Sullivan 2005).
- *Faster exception management and lead time reduction* describes the capabilities of responding to (unplanned) events in a timely manner.
- *Improved tool management* may lead to a reduced administration, better shipment consolidation, reduced energy consumption and improved reverse

logistics. The implementation of RFID at a construction site led to an 87% reduction in job cards (Plant Services 2010).

- *Product rotation* can be improved through more accurate inventory control based on RFID to ensure efficient stock rotation, for instance, in time sales of perishable goods (Hardgrave et al. 2008).
- *Replacement of other technologies* such as barcode labels, printers, and readers or shipping documents can partially compensate RFID investments (Üstündag and Cevikcan 2007).
- *Short term effects,* such as marketing benefits for first movers and innovative companies and associated stock-quote rises, may exceed all other benefits and are sometimes easier to calculate. Jan Vink, director ICT of BGN Selexyz Bookstores mentioned in his presentation at RFID Journal LIVE! Europe 2007 in Amsterdam that after getting the positive numbers of the marketing effects (about 1 mn EUR) of their RFID deployment, there was no need for a further cost benefit analysis. Stock-quote rises of companies related to their RFID-activities are difficult to calculate and need to be separated from other effects. Nevertheless, a look at the historic stock-quote development of Metro in relation to their RFID activities at least provides the vague impression that there have been positive RFID-based effects between 2003 and 2005, when Metro outperformed the German DAX index. Additionally, some RFID technology suppliers claimed in personal communications that Metro was asking between 50,000 and 200,000 EUR for adding the offered RFID-products to their RFID-activities (Future Store, Innovation Centre) to compensate for the marketing benefits that Metro was providing. This will surely be more difficult to achieve today. The marketing effects may also explain why Metro as a retailer was one of the largest exhibitors with 2,800 $m^2$ (Heise 2006) at a computer fair with about 25 participating sub-exhibitors. These assumptions should not be quoted without care, as they cannot be proven. Nonetheless, they are mentioned here to illustrate that the 'published benefits' of RFID may not always correspond directly to the 'achieved benefits'.

***Manufacturers and suppliers benefit*** from improvements in production, quality control and sales execution:

- *Better production tracking* includes tracking of raw material, work-in-progress inventory, assembly status, and finished products within a single location as well as in extended enterprises that are spread across different geographical locations (Zhang et al. 2010).
- *Quality control* can be improved through unique identification of products and parts and retracing of errors to their initial cause.
- *Product recycling* is becoming more and more important for manufactures. There are several reasons for this, such as new laws and regulations, commercial refurbishing opportunities, as well as marketing perspectives. RFID can help to automate recycling and capitalise on product lifecycle data (Strassner et al. 2005), but RFID-tags may also disturb other waste management and recycling

processes and have a negative impact on the environment (Erdman and Hilty 2009).

- *Supply/production continuity* including concepts such as Vendor Managed Inventories or Just in Time/Just in Sequence production scenarios can be ensured through RFID as they require information transparency along value chains (Strassner et al. 2005).
- *Compliance*, for example, in case of mandates issued by large retailers (Aberdeen 2007b) or directives by legislators and regulators is a major benefit, as not meeting mandates may lead to drastic penalties.
- RFID and the Internet of Things may be used for *promotion execution* to obtain better visibility for timely placements of promotional items and, consequently, increased product availability during the promotion time frame leading to increased sales. Procter & Gamble estimates an average of 20% increase in sales by timely placements (Collins 2006b). Other studies indicate an increase in sales of between 48% and 140%, due to increased promotion product availability (Visich et al. 2009). Aberdeen (2010) sees a more conservative 3.8% improvement for Best-in-Class retailers on in-store product promotions. Commonly promotion execution is seen as a retailer benefit, but promotions are quite often initiated by the manufacturers in combination with marketing efforts for their own benefit to gain market shares. Retailers may benefit less, as selling promotional items has to be seen in relation to missed sales of non-promotional items.

***Retailer benefits*** are mainly customer driven and include better on-shelf availability, customer services and after-sales services as well as potentially lower inventories and smaller buffer stocks:

- In *customer service* scenarios, RFID can be used to simplify checkouts and payments as well as for promotion management (Thiesse and Condea 2009). Customer wait time can be reduced by 2.1% (Aberdeen 2010). RFID may also be used to design and enhance service operations, for example, through customer touch points (Heim et al. 2009).
- *Lower inventory and smaller buffer stocks* can be achieved due to improved inventory data. However, improved information sharing may also lead to higher inventories in order to satisfy customer demands, especially if seasonal fluctuations are considered (Uckelmann et al. 2009).
- *Reduced stock outs and increased shelf availability* may be achieved through RFID. Wal-Mart has achieved up to 30% reduction in out-of-stocks by using RFID-tagged cases to improve shelf-stocking processes (Hardgrave et al. 2006). Other companies report 10–50% reduction on out-of-stocks resulting in a gain of 7.5 to nearly 25 sales basis points (Laubacher et al. 2006). Aberdeen (2010) sees a continuous improvement of 8.5% year-over-year on out-of-stocks.
- In *after-sales services* RFID may be used for warranty issues, repair and goods authentication.

Benefits through RFID are not limited to companies. There are possible benefits for ***consumers*** based on usage simplification and interaction in holistic supply network scenarios. Unfortunately, RFID readers have not yet been integrated with mobile phones on a larger scale and dedicated home RFID reading devices are still uncommon. Benefits to consumers have not yet been quantified. The following list provides an overview of possible consumer benefits:

- *Personal access to product specific information* may be used in buying scenarios, for instance, for price comparisons, allergy checking, and reordering consumables (Rodunner and Langheinrich 2010). It may also simplify the usage of products, for example, through accessing online manuals or in case of service requests. The main requisites are corresponding publishing and look-up services for tagged products (Roduner and Langheinrich 2007).
- *Active participation opportunities* for beta testing, product ratings, field reports, applications and more may be supported through RFID and lead to enhanced co-creation of products.
- *Interactions with other stakeholders* including automatic updates and repairs, dynamic safety warnings, product recalls and public interaction applications can be supported through RFID.
- *Quality of life improvement through home automation and leisure applications* are becoming more and more popular. Convenience and enjoyment are part of the dimensions to be valued in this context and should be addressed, for example, in RFID related service applications (Heim et al. 2009). Room monitoring, smart devices, such as a coffee maker controller (Rodunner and Langheinrich 2010), and intelligent toys may lead to a 'silent' usage of RFID, where the technology itself is hidden.

Besides benefits to companies and consumers, there are possible benefits to ***society***. While the dominance of economic considerations is obvious, social aspects in the e-age for value estimation should be taken into account as well (Verrijn-Stuart and Hesse 2002):

- *Consumer protection/safety* such as food and health safety as well as environmental monitoring are of relevance to society (see, e.g., Wasserman 2010; Shen et al. 2007).
- *Security improvements*, for instance, to avoid terrorist attacks and support customs are of increasing importance. While currently container security is more focussed on scanning, RFID and the Internet of Things may add to improved security through improved visibility (see, e.g., ISO/TS 10891 2009).
- *Trade facilitation* using IT has been enhanced, for example, through the introduction of EDIFACT in 1988. RFID and the Internet of Things will further contribute to this.
- *Infrastructure optimisation* is a key requirement where infrastructure growth, such as new roads and enlarging public transportation systems, is not feasible because of sustainability issues and financial limitations. RFID may help to

optimise usage of existing infrastructures. A popular example is the Oyster Card and corresponding research on origination-destination data (Chan 2007).

In the list of benefits above, actual results have been provided where possible and appropriate. Some of these figures are questionable, as they rely on estimations rather than on measurements. Lee and Özer (2007) see a "credibility gap" for industry white papers and reports. Visich et al. (2009) have deliberately excluded estimated benefits, results from unidentified or masked companies as well as aggregated multi-year benefits from their list of empirical evidence. Nonetheless, they still see limitations of their results as they cite secondary sources and cannot provide consistent performance measurement across the different studies. Dutta et al. (2007) are concerned that it may be difficult to isolate the value of RFID in projects that require structural changes.

Unfortunately, a "credibility gap" may also be given in some scientific research reports, as these sometimes try to fulfil expectations from funding institutions or companies involved. Few companies are willing to accept and to publish that they have been active in a long term project that did not achieve measureable benefits. Sometimes failures are only honestly communicated internally. In search of industry partners for a funded project I have been forwarded the following email response from an IT manager of a food supplier to my contact person at the company (translated from German):

> "We did have an RFID project with .. [a large retailer] lately. This has been finished unsuccessfully. Furthermore, we had a similar project with .. [a large research institute]. The project has only delivered empty promises additionally to the hype in the beginning and has not been successfully applied until now. Furthermore, [I believe participation would be] potentially dangerous, as information would be passed on to competitors." (The names of the companies have been blanked by me for obvious reasons. Original email including names has been archived.)

A search on the Internet with the name of the supplier and the mentioned research institute leads to a sector specific RFID guideline as a result of a project funded by public money and industry sponsors. Interestingly, the (positive!) ROI calculation in this guideline was based on a fictitious company rather than on the actual project participants. They did however provide 'results' with 2 decimals accuracy.

However, the benefits of RFID and the Internet of Things cannot be neglected. As long as there are no reliable and quantifiable measures though, the "black hole around RFID technology" (Visich et al. 2009, p. 1292) will widen. Researchers as well as practitioners, venture capital companies, investors and even governments will continue to quote unreliable results, thus leading to 'a situation where the RFID industry starts to believe in their own lies'. This is not a new situation – this phenomenon is well known from the dot-com bubble that busted in the year 2000. Measurability of benefits of new IT developments remains an ongoing problem. For more reliable results it would be helpful to separate the people who do projects from those who measure their performance.

Even though the mentioned benefits are mostly collected from RFID-related research, some of the benefits can be achieved with barcode or 2D-code just as well, a fact that is quite often ignored. Tajima (2007), for example, tries to connect the following benefits to RFID-specific advantages that are partially built on false assumptions. She assumes that:

- *RFID generally supports more automated material handling* – if processes are well automated using barcode, the generated extra benefit through RFID (if any) is very small.
- *RFID is capable of providing a unique identifier to an object* – while this is true, it is not an advantage over barcodes or 2D-codes that can hold a unique identifier as well.
- *RFID allows tracking and tracing* – again this is true, but is no advantage over optical identification.

For the Internet of Things different means of unique automatic identification can be used. RFID is only one of the possible technologies.

Cost benefit analysis has been used as the main tool for economic analysis. According to a study by Seiter et al. (2008), 87% of companies planning to implement and 81% of companies that have already implemented RFID use cost benefit analysis. This seems surprising, as it has been shown that it is quite often difficult to calculate reliable costs and benefit values.

## 4.2 Example of Uneven Cost Benefit Allocation in the Beverage Supply Chain

This study, concerning RFID-based information sharing within the beverage industry, was carried out by the Bremen Research Cluster for Dynamics in Logistics (Log*Dynamics*) in 2008 (Uckelmann et al. 2009). It will be used again in Sect. 7.2 (page 125).

A specialised set of RTI is used in this beverage industry scenario (see Fig. 4.1). A pallet made of metal holds four dollies – a mobile platform with four casters. On every dolly there are multiple layers of plastic trays, each holding six six-packs. The pallet can therefore be split in four piles and rolled to the best point-of-sales without the need of a pallet jack. The trays provide stability to the pallets and serve as tidy sales displays for the bottles. A time- and cost-consuming placement in shelves is avoided. The same RTI are used for filled as well as returnable (empty) bottles. This is a huge advantage for reverse logistics of empty returnable bottles as there is no need to keep a stock of empty crates for collecting empty bottles. The RTIs are rented to the stakeholders. Therefore, a deposit system as well as a usage-fee is needed to ensure the timely forwarding of RTI within the closed loop, including breweries, bottlers, wholesalers and retailers.

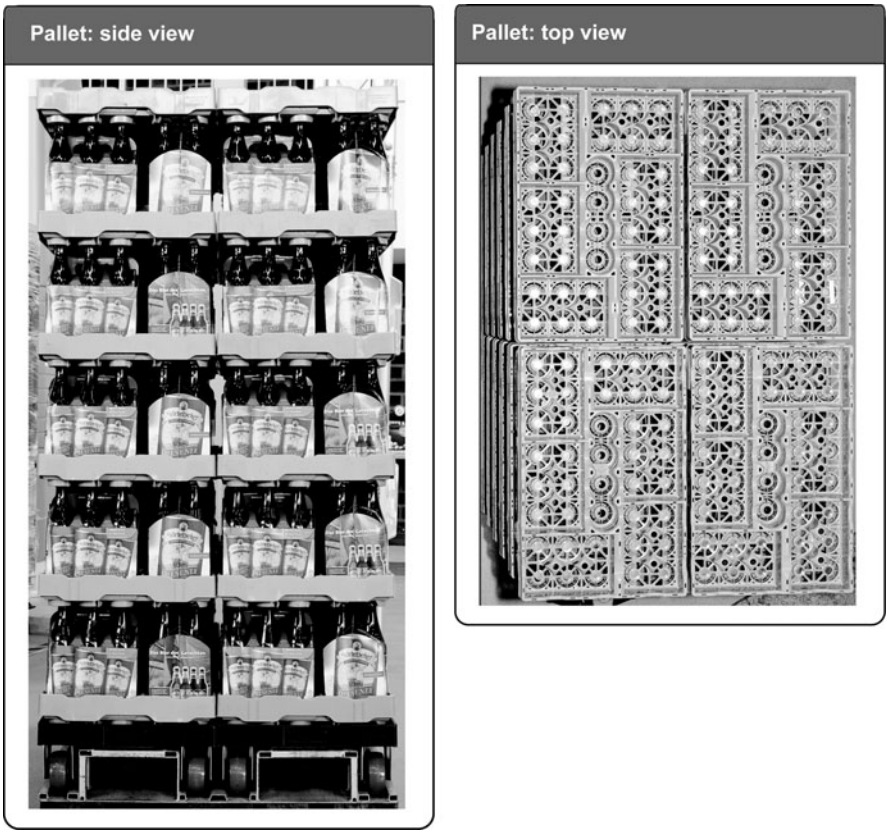



**Fig. 4.1** Side and top view of the beverage pallet

While the concept originates from Finland, the system is licensed to Logipack in Germany (Weber 2007). In its starting phase the trays were only used by one bottler. When a large retailer started a roll-out of this system in more than 2,000 stores, there was soon a demand from other bottlers to offer the same system. Due to the transition from a simple supply chain to a more complex supply network, the need for increased supply-chain visibility was rising.

In order to achieve the highest level of supply chain visibility, identification on bottle-level would have been necessary, but due to cost reasons, recording the material flow on item-level was not feasible in this case. Instead, an 'appropriate level of visibility' was achieved on RTI-level. The appropriate level of visibility is achieved where a further increase of the visibility level generates higher costs than potential savings (Dittmann 2006). Using UHF RFID in the beverage industry has it limits as liquids absorb energy, thus reducing read-ranges substantially. However, isolated and empty RTI can be read quite well. Additionally, movement, such as rotating pallets in the pallet-wrapping process, helps to achieve adequate read rates.

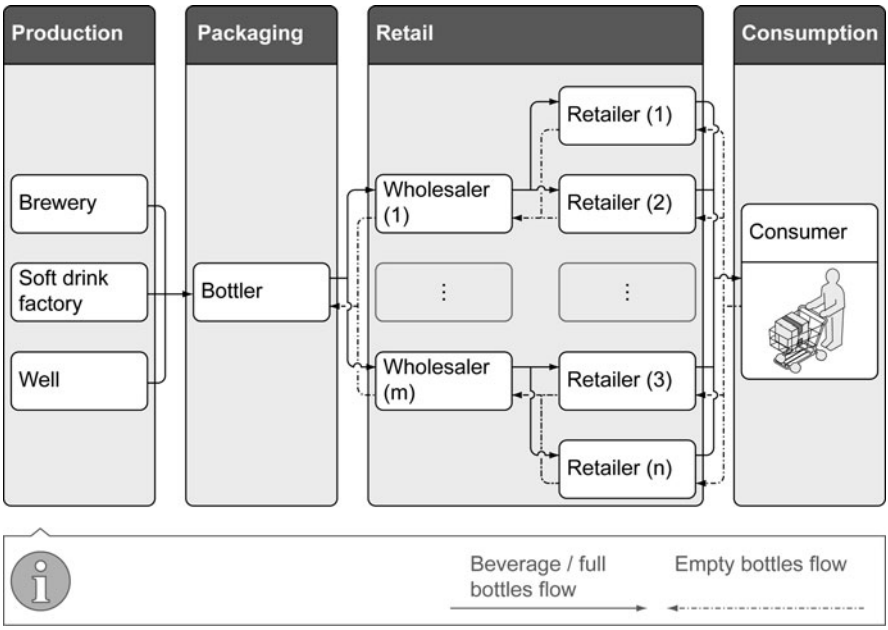



**Fig. 4.2** Material flow in a simplified beverage supply chain

The schematic diagram of the simplified beverage supply chain that has been used for evaluation is shown in Fig. 4.2.

The material flow is divided into the flow of full bottles and the reverse flow of empty bottles using the same RTIs. The supply chain, in this special case, has five different levels. There are several beverage factories; these are a brewery, a factory for soft drinks and a well for water. Furthermore, there are 40 wholesalers, about 6,000 retailers and a great many consumers.

The bottler controls the flow of empties to fulfil the wholesale demand for full bottles. Additionally, the wholesale demand is characterised by dynamic trend changes, high uncertainty, and a large variety of products. The demand uncertainties for the bottler are caused by fluctuant market demand and the ad-hoc order policy of the wholesalers and retailers.

Based on a qualitative model, two scenarios were compared with each other. The first scenario was called ‘basic’ and approximated the ‘as is’ supply chain coordination without information sharing. In this scenario, the production, capacity and order decisions were based on the forecasted orders of the downstream supply chain members. The second scenario was called ‘info sharing’ and included the partial information sharing between two supply chain members. This indicated that the inventory information as well as the order policies of the downstream supply chain members were shared with the upstream members. The customer demand of the beverage scenario was divided into 23 drink types with a seasonal demand and

weekly demand fluctuation. Seasonal and weather fluctuation was considered within the model.

The accounted operating costs in the system were the labour capacity of the bottler, the average necessary full bottles inventory in the supply chain, and the necessary amount of empties in the supply chain. The performance of the system was measured by the backlog of the system, the fluctuations of the orders and the fluctuations of the inventory.

As part of our simulation model, we could only prove economical feasibility for RFID infrastructure at the bottler and the wholesaler. RFID installations at the retailer sites would have been cost intensive and would have generated little benefits in this scenario. Nevertheless, the total logistical result would have been improved due to the relatively high amount of unlost sales.

The benefits accruing to the bottler and the wholesaler were not equally distributed. On the one hand, the bottler had a backlog improvement of 34%, higher capacity utilisation and lower empties inventory – but a higher inventory of full bottles. The wholesaler's inventory of full and empty bottles only marginally changed, and the backlog was reduced about 49%. On the other hand, both would have had to invest into the necessary infrastructure for information sharing. We calculated that 64.6% of the cost for the RFID infrastructure would need to be paid for by the bottler, whereas 35.4% had to be covered by the wholesaler. However, the brewery and the retailer would have been able to benefit as well from improved information sharing, mainly through increased sales, without a need to invest in RFID hardware. We approximated that the monetary benefits would have been split between brewery (28.5%), bottler (19.1%), wholesaler (24.7%), and retailer (27.6%) (Uckelmann and Hamann 2010). Unfortunately though, cost calculations were limited to the usual directly RFID-related costs and did not consider all possible costs of the semiotic ladder, nor did we find a measure to calculate a monetary value for most of the generated benefits. As such, we suffered from the same problem as many other researchers in their cost benefit analysis.

## 4.3 Cost Benefit Sharing and Its Limitations

As shown in the last paragraph, numerous stakeholders may benefit from information sharing in supply chains, but unfortunately not to the same extent. The reason for sharing costs and benefits is to achieve win–win (Véronneau and Roy 2009) situations in projects that would otherwise be non-profitable for some stakeholders. In information technology CBS is a popular instrument, especially in early-adopter research projects to motivate participation of stakeholders who benefit to a lesser extend or have no direct benefits at all. Riha defines CBS as follows:

> "Cost Benefit Sharing (CBS) is a method to accomplish process changing projects in networks. It is based on a stakeholder oriented total cost analysis of all packages of measures in a project. Based on the achieved transparency of positive and negative effects

> a win-win-situation is provided through reallocation strategies for all stakeholders. Therefore an incentive to a network-wide optimisation is given." (Riha 2008, p. 13)

CBS in combination with RFID has been researched by several authors (Riha 2008; Hirthammer and Riha 2005; Wildemann et al. 2007; Bensel et al. 2008; Véronneau and Roy 2009). Sharing benefits and investments in multi-tiered situations is seen as a core requirement for wide-scale deployment of RFID (Schuster 2007).

Lee et al. (1997) identified information asymmetry to be the main reason for the bullwhip effect. They demand that retailers provide information access to the manufacturers in order to overcome the bullwhip effect but they leave the question of why they should share the information open. Nevertheless, they consider a CBS model:

> "In theory, the net benefit from efficient supply chain management can be redistributed among members. The subject of how to split the gain and cost appears to deserve attention of its own." (Lee et al. 1997, p. 558)

In this definition a cost and benefit transparency between the stakeholders is suggested to achieve a win–win situation. Unfortunately, this level of transparency is quite often not wanted by companies.

The structural requirements for CBS can be quite complex and cost intensive. Hirthammer and Riha (2005) even suggest having different institutions on a structural level, including a board of company representatives, a mediator, and a company independent controller. According to Hirthammer and Riha (2005), the CBS process loop can be structured in several sub-tasks:

1. Detailed process analysis in the network through auditing
2. Enquiry of weak points through benchmarking
3. Development of corresponding actions to solve or lessen the effect of the weak points based on overall strategies and goals
4. CBS
   (a) Calculation of costs
   (b) Evaluation of benefits
      - Calculate monetary benefits
      - Calculate qualitative benefits
      - Evaluate total benefit
      - Calculate share of benefit
   (c) Distribution of costs
5. Implementation of actions proposed in step 3
6. Controlling
7. Feedback loop to adjust the system to external dynamics

While tools have been developed to calculate costs as well as benefits, it becomes apparent, why CBS approaches have failed to gain wider acceptance. The effort involved to install and maintain such a system may even exceed the advantages. One of the fundamental mistakes in the usual CBS models is to look for

a 'fair' scheme to level cost and benefit, rather than to look for a model that accepts market forces. Hirthammer and Riha (2005) suggest using a mediator to settle disputes, which does not seem appropriate for highly-dynamic information sharing processes. An IT infrastructure that supports a self-regulating approach, based on supply and demand of information, may be more promising.

## 4.4 Summary Performance Measuring As Well As Cost Benefit Sharing Approaches and Deduction of an Alternative Market Driven Approach

Measuring costs as well as benefits is a time and resource consuming task, yet it fails quite often to provide reliable numbers (Sect. 1.1, page 2). Additionally, costs and benefits are not symmetrically distributed between supply chain partners (Sect. 1.2, page 4). Sharing costs and benefits in current CBS approaches is even more complex and does not provide a scalable solution (Sect. 1.3, page 5). There may be a fundamental problem in current performance measurement and CBS approaches for RFID and Internet of Things investments. Information does not follow the same economic laws as other assets. Therefore, it is difficult to apply traditional performance measurements (Moody and Walsh 2002). There is another possibility though to value information. The valuation concept, according to Moody and Walsh (2002), can be based on

- *Cost* (or historical cost),
- *Utility* (present value), or – and this may be the clue to overcome the described problems in IT performance measurement,
- *Market* (or current cash equivalent).

The cost-based model relates the information value to the overall cost paid for, for instance, purchases, developments and maintenance. The utility-based approach considers the present value of future expected benefits. Both have been described in detail in this chapter. The market driven approach focuses on how much people or organisations are willing to pay for accessing information. If traditional performance calculation has its limits concerning accuracy and reliability for IT investments, it may be more appropriate to use a market value approach:

> ". . .one way to value most things is to ask people how much they are willing to pay for it, or better yet, to determine how much they have been paying for it by looking at past behaviours." (Hubbard 2010, p. 207)

Unfortunately, there is not a lot of historical data on how much people have been paying for business relevant information in logistics. Additionally, mere questioning of people may lead to false figures as well.

Actual payments, however, would provide 'real' figures for existing IT offerings as well as historical data for future investments. According to Porter (2001, p. 71), "economic value is created when customers are willing to pay a price for a product

or service that exceeds the cost of producing it". This does require a (technical) ability to pay for information, though. In the context of web services Kaye (2003) already identified billing and accounting services as "missing pieces" to enable pay-per-use business models. The demand for these services is just as relevant for RFID and the Internet of Things.

## References


Aberdeen. (2007b). *Winning RFID Strategies for 2008*. Retrieved November 1, 2009, from http://www.barco.cz/data/download/rfid/Winning_RFID_Strategies_for_2008_Aberdeen.pdf

Aberdeen. (2010). *Item-Level RFID Tagging in Retail: Improving Efficiency, Visibility, Loss Prevention, and Profit*. Retrieved January 4, 2011, from http://www.rfidkit2009.com/whitepapers/aberdeen-report.pdf

Agarwal, V. (2001). *Assessing the benefits of Auto-ID technology in the consumer goods industry*. Retrieved November 11, 2009, from http://www.autoidlabs.org/uploads/media/CAM-WH-003.pdf

Al-Kassab, J., Blome, P., Wolfram, G., Thiesse, F., & Fleisch, E. (2010). RFID in the Apparel Retail Industry: A Case Study from Galeria Kaufhof. In D. Ranasinghe, Q. Sheng, & S. Zeadally, *Unique Radio Innovation for the 21st Century: Building Scalable and Global RFID Networks* (pp. 281-308). Heidelberg, Germany: Springer.

Baars, H., Sun, X., Strüker, J., & Gille, D. (2008). Profiling Benefits of RFID Applications. *Proceedings of the 14th Americas Conference on Information Systems (AMCIS'08)*. Toronto, Canada.

Bensel, P., & Fürstenberg, F. (2009). Partnerintegration im Rahmen von RFID-Projekten. In F. Straube (Ed.), *RFID in der Logistik – Empfehlungen für eine erfolgreiche Einführung* (pp. 40-47). Berlin, Germany: Universitätsverlag der Technischen Universität Berlin.

Bensel, P., Günther, O., Tribowski, C., & Vogler, S. (2008). Cost-Benefit Sharing in Cross-Company RFID Applications: A Case Study Approach. *Proceedings of the International Conference on Information Systems (ICIS 2008)*. Paris, France.

Bovenschulte, M., Gabriel, P., Gaßner, K., & Seidel, U. (2007). *RFID: Prospectives for Germany*. Retrieved November 7, 2009, from http://www.bmwi.de/BMWi/Redaktion/PDF/Publikationen/rfid-prospectives-for-germany,property=pdf,bereich=bmwi,sprache=de,rwb=true.pdf

BRIDGE. (2007). *Returnable Transport Items: the market for EPCglobal applications*. Retrieved January 12, 2011, from http://www.bridge-project.eu/data/File/BRIDGE WP09 Returnable assets market analysis.pdf

Chan, J. (2007). *Rail transit OD matrix estimation and journey time reliability metrics using automated fare data*. Retrieved September 14, 2010, from http://dspace.mit.edu/handle/1721.1/38955

Cheremushkin, S. V. (2008). *What's Wrong with the Economic Value Added?* Retrieved November 24, 2009, from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1120917

Collins, J. (2006a). *DOD Quantifies Payback From RFID*. Retrieved October 25, 2010, from http://www.rfidjournal.com/article/articleprint/2313/-1/1/

Collins, J. (2006b). *P&G Finds RFID 'Sweet Spot'*. Retrived October 25, 2010, from http://www.rfidjournal.com/article/articleview/2312/1/1

Department of the Navy Chief Information Officer. (2005). *Tutorial: The Value of Information*. Retrieved September 15, 2010, from http://nnlm.gov/evaluation/workshops/measuring_your_impact/Navy-tutorial.pdf

Dittmann, L. (2006). *Der angemessene Grad an Visibilität in Logistik-Netzwerken – Die Auswirkungen von RFID*. Wiesbaden, Germany: Deutscher Universitätsverlag.

Dutta, A., Lee, H., & Whang, S. (2007). RFID and Operations Management: Technology, Value, and Incentives. *Production and Operations Management, 16*(5), pp. 646-655.

EC-Ruhr. (2008). *RFID – ein Thema für den Mittelstand*. Retrieved November 6, 2009, from http://www.ec-ruhr.de/system/files/vortraege/broschuere-rfid-umfrage.pdf

Erdman, L., & Hilty, L. (2009). *Einfluss von RFID-Tags auf die Abfallentsorgung*. Retrieved January 12, 2011, from http://www.umweltdaten.de/publikationen/fpdf-l/3845.pdf

Feinbier, L., Schittko, L., & Gallais, G. (2008). *The benefits of RFID for slab- and coil-logistics*. Retrieved November 16, 2009, from http://www.accenture.com/NR/rdonlyres/20C9A517-C0E4-40D8-81A9-60FAC76CC735/0/Accenture_Metals_The_Benefits_of_RFID.pdf

Fleisch, E., Christ, O., & Dierkes, M. (2005). Die betriebswirtschaftliche Vision der Internets der Dinge. In E. Fleisch, & F. Mattern (Eds.), *Das Internet der Dinge* (S. 3-37). Berlin, Germany: Springer.

Gille, D., & Strücker, J. (2008). Into the Unknown – Measuring the Business Performance of RFID Applications. In W. Golden, T. Acton, H. van der Heijden, & V. Tuunainen (Eds.), *16th European Conference on Information Systems (ECIS 2008), CD-ROM*. Galway.

Gille, D., & Strüker, J. (2007). *RFID in Deutschland 2007 – Chancen und Hürden für den Mittelstand*. Retrieved November 6, 2009, from http://www.stiftung-industrieforschung.de/innovationen/petersberg_05juni07/1_RFID_in Deutschland.pdf

Grote, W. (2006). RFID – eine Technologie mit hohem Nutzenpotenzial. In K. Nagel, & J. Knoblauch (Eds.), *Praktische Unternehmensführung, 62. Nachlieferung* (pp. 10.1-10.24). München, Germany: OLZOG.

Hardgrave, B. C., Waller, M., & Miller, R. (2006). *RFID's Impact on Out of Stocks: A Sales Velocity Analysis*. Retrieved November 2, 2009, from http://itri.uark.edu/104.asp?code=rfid&article=ITRI-WP068-0606

Hardgrave, B., & Miller, R. (2006). *The Myths and Realities of RFID*. Retrieved September 14, 2010, from http://www.celdi.ineg.uark.edu/Conferences/Spring 2006 Conference/myths paper.pdf

Hardgrave, B., Riemenschneider, C., & Armstrong, D. (2008). Making the Business Case for RFID. In H.-D. Haasis, H.-J. Kreowski, & B. Scholz-Reiter (Eds.), *Dynamics in Logistics* (pp. 25-35). Berlin, Germany: Springer.

Harley, S. (2008). *Shipper's eFreight vision: RFID technology in vehicle logistics at Cologne vehicle operations plant*. Retrieved November 16, 2009, from http://www.euro-case.org/documents/HARLEY.pdf

Heim, G., Wentworth, W., & Peng, D. X. (2009). The Value to the Customer of RFID in Service Applications. *Decision Sciences, 40*(3), 477-512.

Heise. (2006). *Metro zeigt RFID auf der CeBIT*. Retrieved September 14, 2010, from http://www.heise.de/newsticker/meldung/Metro-zeigt-RFID-auf-der-CeBIT-165331.html

Hirthammer, K., & Riha, I. (2005). *Framework for cost-benefits sharing in logistics networks*. Retrieved November 7, 2009, from http://publica.fraunhofer.de/documents/N-35547.html

Hubbard, D. (2010). *How to Measure Anything: Finding the Value of "Intangibles" in Business* (2 ed.). Hoboken, USA: Wiley.

IDTechEx. (2009b). *RFID market forecasts 2009-2019*. Retrieved November 1, 2009, from http://www.idtechex.com/research/articles/rfid_market_ forecasts_2009_2019_00001377.asp

Incucomm. (2004). *Wal-Mart's RFID Deployment – How is it Going?* Retrieved September 14, 2010, from http://www.incucomm.com/releases/Wal-Mart Jan 2005 Status - Executive Summary.PDF

IISO/IEC 18000/Amd 1. (2006). *Information Technology – Radio Frequency Identification for Item Management – Part 6: Parameters for Air Interface Communications at 860 MHz to 960 MHz, Extension with Type C and Update of Types A and B*. Genf, Switzerland: International Organization for Standardization.

ISO/IEC 18000-7. (2009). *Information technology – Radio frequency identification for item management – Part 7: Parameters for active air interface communications at 433 MHz*. Genf, Switzerland: International Organization for Standardization.

ISO/TS 10891. (2009). *Freight containers – Radio frequency identification (RFID) – Licence plate tag*. Genf, Switzerland: International Organization for Standardization.

Jensen, M. C. (2001). Value Maximization, Stakeholder Theory, and the Corporate Objective Function. *Journal of Applied Corporate Finance, 14*(3), pp. 8-21.

Kaplan, R. S., & Norton, D. P. (1996). *The Balanced Scorecard: Translating Strategy Into Action*. Boston, USA: Harvard Business School Press.

Kaye, D. (2003). *Loosely Coupled*. Marin County, California, USA: RDS Press.

Lange, V., Alberti, A., Becker, M., Hoffmann, J., Maaß, J.-C., Meiss, C., et al. (2009). *Entwicklung eines Verfahrens zur Kosten-Nutzen-Bewertung von RFID-Systemen: CoBRA – cost and benefits of RFID-applications*. Retrieved December 17, 2009, from http://cobra.iml.fraunhofer.de:8080/index.php?option=com_remository&Itemid=0&func=startdown&id=14

Langer, N., Forman, C., Kekre, S., & Scheller-Wolf, A. (2007). Logistics, Assessing the Impact of RFID on Return Center. *Interfaces, 37*(6), 501-514.

Laubacher, R., Kothari, S., Malone, T. W., & Subirana, B. (2006). *What is RFID worth to your company? Measuring performance at the activity level*. Retrieved November 15, 2009, from http://ebusiness.mit.edu/research/papers/223 Laubacher_ APBM.pdf

Lee, H. L., Padmanabhan, V., & Whang, S. (1997). Information distortion in a supply chain: The bullwhip effect. *Management Science, 43*(4), pp. 546-558.

Lee, H., & Özer, O. (2007). Unlocking the Value of RFID. *Production and Operations Management, 16*(1), S. 40-64.

Lee, I., & Lee, B.-C. (2010). An investment evaluation of supply chain RFID technologies: A normative modeling approach. *International Journal of Production Economics, 125*(2), pp. 313-323.

Li, S., & Visich, J. K. (2006). Radio Frequency Identification: Supply Chain Impact and Implementation Challenges. *International Journal of Integrated Supply Management, 2*(4), pp. 407-424.

Madhani, P. (2009). Investment Decision Tool: Real Options. *SCMS Journal of Indian Management*, 5-17.

McBeath, B. (2006). *RFID for Manufacturers – How Manufacturers are Improving Processes by Using RFID*. Retrieved November 9, 2009, from http://www.chainlinkresearch.com/media/docs/original/RFID for Manufacturers_Executive Summary.pdf

McClenahen, J. S. (2005). *Wal-Mart's big gamble*. Retrieved November 15, 2009, from IndustryWeek: http://www.industryweek.com/articles/wal-marts_big_gamble_10055.aspx

McLaren, T., Head, M., & Yuan, Y. (2002). Supply chain collaboration alternatives: understanding the expected costs and benefits. *Internet Research: Electronic Networking Applications and Policy, 12*(4), pp. 348-364.

Miragliotta, G., Perego, A., & Tumino, A. (2007). RFId technology in a container port: an activity-based model to assess costs and benefits. *Proceedings of the Logistics Research Network (LRN) Annual Conference*, (pp. 101-106). Hull, UK.

Moody, D., & Walsh, P. (2002). Measuring the Value of Information: An Asset Valuation Approach. In B. Morgan, & C. Nolan (Eds.), *Guidelines for Implementing Data Resource Management* (4 ed.). Seatle, USA: DAMA International Press.

MoreRFID. (2007). *METRO Group Deploys Reva Systems' RFID Network Infrastructure for Europe's Largest Retail RFID Rollout*. Retrieved March 22, 2011, from http://www.morerfid.com/details.php?subdetail=Report&action=details&report_id=3198&display=RFID

Plant Services. (2010). *Best Practices Awards: Management — A mobile asset management solution features RFID technology*. Retrieved January 13, 2011, from http://www.plantservices.com/articles/2010/03BestPractices.html

Porter, M. E. (2001). Strategy and the Internet. *Harward Business Review, 79*(3), pp. 63-78.

PWC Consulting. (2002). *Focus on the Supply Chain: Applying Auto-ID within the Distribution Center*. Retrieved November 3, 2009, from http://www.autoid.org/SC31/clr/200305_3824_PWC DC.pdf

Riha, I. V. (2008). *Entwicklung einer Methode für Cost Benefit Sharing in Logistiknetzwerken*. (A. Kuhn, Ed.) Dortmund, Germany: Praxiswissen Service.

Roduner, C., & Langheinrich, M. (2007). Publishing and discovering information and services for tagged products. *LNCS: CAiSE'07 Proceedings of the 19th international conference on Advanced information systems engineering. 4495*, pp. 501-515. Berlin, Germany: Springer.

Rodunner, C., & Langheinrich, M. (2010). BIT – A Framework and Architecture for Providing Digital Services for Physical Products. *2nd Intl. Conference on the Internet of Things (IOT 2010, USB-Stick)*. Tokyo, Japan: IEEE.

Schmitt, P., & Michahelles, F. (2008). *Economic Impact of RFID Report*. Retrieved November 1, 2009, from http://www.bridge-project.eu/data/File/BRIDGE_WP13_Economic_impact_RFID.pdf

Schnatmeyer, M. (2007). *RFID-basierte Nachverfolgung logistischer Einheiten in der Kreislaufwirtschaft*. Aachen, Germany: Verlagsgruppe Mainz GmbH.

Schneiderman, A. M. (2006). *The First Balanced Scorecard*. Retrieved November 24, 2009, from http://www.schneiderman.com/Concepts/The_First_Balanced_Scorecard/BSC_INTRO_AND_CONTENTS.htm

Scholz-Reiter, B., Gorldt, C., Hinrichs, U., Tervo, J. T., & Lewandowski, M. (2007). *RFID – Einsatzmöglichkeiten und Potentiale in logistischen Prozessen*. Retrieved November 24, 2009, from Mobile Research Center Bremen: http://www.mrc-bremen.de/fileadmin/user_upload/mrcMobileResearchCenter/RFID.pdf

Schuster, E. W. (2007). Building a Business Case for the EPCglobal Network. In E. W. Schuster, S. J. Allen, & D. L. Brock (Eds.), *Global RFID: The Value of the EPCglobal Network for Supply Chain Management* (pp. 187-198). Berlin, Germany: Springer.

Schuster, E. W., Allen, S. J., & Brock, D. L. (2007). *Global RFID: The Value of the EPCglobal Network for Supply Chain Management*. Berlin, Germany: Springer.

Seiter, M., Urban, U., & Rosentritt, C. (2008). *Wirtschaftlicher Einsatz von RFID – Ergebnisse einer empirischen Studie in Deutschland*. Retrieved November 7, 2009, from http://www.ipri-institute.com/wissen_verbreiten/research_paper.htm

Shen, H., Li, L., & Zhou, Y. (2007). Fully integrated passive UHF RFID tag with temperature sensor for environment monitoring. *Proceedings of 7th International Conference on ASIC, (ASICON '07)* (pp. 360-363). Guilin, China: IEEE Press.

Strassner, M., Plen, C., & Stroh, S. (2005). Potenziale der RFID-Technologie für das Supply Chain Management in der Automobilindustrie. In E. Fleisch, Mattern, & Friedemann (Eds.), *Das Internet der Dinge: Ubiquitous Computing und RFID in der Praxis: Visionen, Technologien, Anwendungen, Handlungsanleitungen* (pp. 177-196). Berlin, Germany: Springer.

Strüker, J., Gille, D., & Faupel, T. (2008). *RFID Report 2008 – Optimierung von Geschäftsprozessen*. Düsseldorf, Germany: VDI Nachrichten.

Sullivan, L. (2005). *Wal-Mart RFID Trial Shows 16% Reduction In Product Stock-Outs* . Retrieved February 22, 2011, from http://www.informationweek.com/news/mobility/RFID/showArticle.jhtml?articleID=172301246

Swedberg, C. (2009). *DOD Tests, Buys New ISO 18000-7 Tags From Four Companies*. Retrieved November 16, 2009, from http://www.rfidjournal.com/article/print/5317

Symons, C. (2006). *Measuring the Business Value of IT*. Retrieved July 27, 2011, from http://www.cornerstone1.com/SAP/SAP_Forrester_Measuring_the_Business_ Value_of_IT.pdf

Tajima, M. (2007). Strategic Value of RFID in Supply Chain Management. *Journal of Purchasing and Supply Management, 13*(4), pp. 261-273.

ten Hompel, M., & Lange, V. (2004). *RFID 2004: Logistiktrends für Industrie und Handel*. M. ten Hompel, & V. Lange, (Eds.) Dortmund, Germany: Praxiswissen Service UG.

Thiesse, F., & Condea, C. (2009). RFID data sharing in supply chains: What is the value of the EPC Network? *International Journal of Electronic Business, 7*(1), pp. 21-43.

Tiernan, C., & Peppard, J. (2004). Information Technology: Of Value or A Vulture? *European Management Journal, 22*(6), pp. 609-623.

Uckelmann, D., & Hamann, T. (2010). Nutzenpotentiale in der Supply Chain. *RFID im Blick: Sonderausgabe "RFID in Bremen"*, pp. 46-47.

Uckelmann, D., Hamann, T., & Zschintzsch, M. (2009). Performance increase and benefit compensation in supply chains by partial information sharing and billing based on identification of returnable transport items. *International Journal of RF Technologies: Research and Applications, 1*(1), pp. 23-43.

Üstündag, A., & Cevikcan, E. (2007). Return on Investment Analysis for Evaluation of RFID Implementation on Cargo Operations. *Proceedings of the 1st Conference RFID Eurasia, 2007* (pp. 1-5). Istanbul, Turkey: IEEE.

Varila, M., Seppänen, M., & Suomala, P. (2004). Automatic data collection in logistics costing: Analysing the Causes and effects of variation. *4th Conference on New Directions in Management Accounting: Innovations in Practice and Research*. Brussels, Belgium.

Veeramani, D., Tang, J., & Gutierrez, A. (2008). A Framework for Assessing the Value of RFID Implementation by Tier-One Suppliers to Major Retailers. *Journal of Theoretical and Applied Electronic Commerce Research, 3*(1), pp. 55-70.

Verein Deutscher Ingenieure e.V. (2008). *VDI 4472 Blatt 5: Anforderung an Transpondersysteme zum Einsatz in der Supply Chain – Einsatz der Transpondertechnologie in der Mehrweglogistik*. Düsseldorf, Germany: VDI-Gesellschaft Produktion und Logistik.

Véronneau, S., & Roy, J. (2009). RFID benefits, costs, and possibilities: The economical analysis of RFID deployment in a cruise corporation global service supply chain. *International Journal of Production Economics, 122*(2), pp. 692-702.

Verrijn-Stuart, A., & Hesse, W. (2002). The value of information in the "e-age". In K. Liu, R. Clarke, P. Anderson, & R. Stamper, *Proceedings of the IFIP TC8 / WG8.1 Working Conference on Organizational Semiotics: Evolving a Science of Information Systems* (pp. 1-17). Deventer, Netherlands: Kluwer Academic Publishers.

Visich, J., Li, S., Khumawala, B., & Reyes, P. (2009). Empirical evidence of RFID impacts on supply chain performance. *International Journal of Operations & Production Management, 29*(12), pp. 1290-1315.

Wasserman, E. (2010). *Canadian Beef Processor Deploys RFID for Food Safety*. Retrieved March 22, 2011, from http://www.rfidjournal.com/article/purchase/7331

Weber, B. (2007). Der dritte Weg. *Lebensmittel Zeitung*, 35.

Wildemann, H., Wahl, P., & Boeck, B. (2007). *NutzLog – Vorteilsausgleich-Nutzenverteilung*. Retrieved November 7, 2009, from http://www.forlog.de/pdf/ForLog_ZB07.pdf

Wilding, R., & Delgardo, T. (2004). RFID Demystified: Part 3 Company Case Studies. *RFID Demystified: Part 3 Company Case Studies, 6*(5), 32-42.

Wong, C., McFarlane, D., Zaharudin, Ahmad, & Agarwal, V. (2002). The Intelligent Product Driven Supply Chain. *2002 IEEE International Conference on Systems Man and Cybernetics; Bridging the Digital Divide Cyber-Development Human Progress Peace and Prosperity*. Hammamet, Tunisia.

Zhang, Y., Jiang, P., Huang, G., Qu, T., Zhou, G., & Hong, J. (2010). RFID-enabled real-time manufacturing information tracking infrastructure for extended enterprises. *Journal of Intelligent Manufacturing*, pp. 1-10.

Springer

http://www.springer.com/978-3-642-27990-4

Quantifying the Value of RFID and the EPCglobal Architecture Framework in Logistics

Uckelmann, D.

2012, XXIV, 144 p., Hardcover
ISBN: 978-3-642-27990-4