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A model based approach for calculating the process driven business value of RFID investments

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ABSTRACT

Calculating the process driven value of RFID investments is very difficult. It is important to understand the concrete contribution of an RFID system for the planning and configuration of individual processes, especially among supply chain stakeholders. However, profitability analyses in information system (IS) investments are problematic because they cannot be calculated as an economic standard investment. Hence, we propose a reference model for referential RFID impacts. Our artefact supports the structuring and evaluation of RFID benefits along business processes as we propose indicators for the derivation of an individual RFID cause-and-effect-chain. For evaluation, the model is applied in a Russian automotive project.

1. Introduction

With the rise of global supply chains, the planning and configuration of efficient interorganizational processes has gained importance. The reliable allocation and identification of supply chain entities help improve competitiveness and benefits of all its stakeholders. In this context, Radio-frequency identification (RFID) is estimated to be one of the greatest technological enhancements in the twenty-first century (Chao et al., 2007; Bendavid et al., 2008). RFID is aimed at automatic identification of objects, by storing data on tags (located on, e.g., products) and remotely retrieving these data via radio waves using RFID transponders within companies, supply chains or international supply networks. The transponder transmits a predetermined message or identification number in response to a predefined received signal. It allows the tracking of objects in real-time. As a result, the development of the global RFID market is expected to be very strong, especially in the area of supply chain management (Becker et al., 2009).

Investments in RFID technologies are expected to reduce costs and at the same time contribute to business value. Nevertheless, research indicates that many RFID projects may not be economically profitable despite a positive forecast (Gaughan and D'Aquila, 2005; Bendavid et al., 2008). From a supply chain's perspective it is important to understand the concrete contribution of an RFID system with regard to individual processes. However, profitability analyses in information system investments (IS) are problematic because such investments cannot be quantified as an economic standard investment. It is hardly possible to identify and measure all positive aspects of a new information system. For example, higher customer satisfaction due to more reliable information within the call center may lead to more contracts, but it is hardly possible to isolate the customer satisfaction effect from other effects. It is difficult to measure all effects of an RFID introduction in terms of quantity savings (labor hours, processing times, etc.) and money. Surveys by AMR

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Research and IDC especially highlight problems in evaluating the effects and effectiveness of RFID systems (Gaughan and D'Aquila, 2005; Wilson and Vesset, 2004). Hence, a systematic and transparent structuring of the investment decision is necessary to overcome these evaluation problems.

The article contributes to overcoming these evaluation problems and structuring problems by introducing a multi-perspective reference model for the measurement of the business value of RFID technologies in different implementation scenarios. It is a starting point for the ongoing development of an RFID investment evaluation tool with a generic knowledge base for referential RFID impacts in supply chains. We aim at developing a domain neutral IT artifact that can be adapted to specific needs. Starting from the previous work, we have examined different logistics processes in accordance with the supply chain operation reference (SCOR) model regarding RFID effects. SCOR enables companies to analyze their supply chain performance in a systematic way, to enhance communication among the stakeholders in the supply chain, and to design a better supply chain network (Hwang et al., 2008).

Our reference model helps companies and supply chains to understand the potential impacts of investments in the new technology. It supports the structuring and evaluation of RFID investment benefits along business identification of impact types and impact places within the value chain as well as the basis for a structured analysis combining logistics processes, RFID impacts and impact measurement indicators. In particular, the paper seeks to identify and discuss indicators for the derivation of an individual cause-and-effect-chain for measuring the success of RFID investments. The paper provides a list of propositions that form a broad basis of the empirical research agenda to explore and to identify the mechanisms through which investments in RFID influence stakeholders and their actions in the supply chain. Finally, a case study from the automotive industry serves as a practical example.

2. Related work

2.1. RFID

More and more, RFID is supposed to replace barcode labeling in the supply chain as it allows manufacturers and retailers to identify the product, quantity and location without physical and time consuming audits, and hence, improve business processes (De Kok et al., 2008). RFID is a wireless Automatic Identification and Data Capture (AIDC) technology. It mainly consists of an RFID chip (transponder) that is tagged to the object itself and an antenna (reader) that allows the identifying of RFID tags. The chip is able to store data and is, under some circumstances, rewritable.

Researchers conducted research on various topics related to RFID. For example, Asif and Mandviwalla (2005) drew attention to the technology itself and Becker et al. (2009) gave an overview of the technological roadmap. Embracing literature reviews on RFID research were provided by Chao et al. (2007) as well as Ngai et al. (2008).

2.2. Previous work on performance measurement in the supply chain and RFID impacts on it

In a literature study, Gunasekaran et al. (2004) identified six categories for performance measurement in supply chain management (order planning, evaluation of supply link, production level, evaluation of delivery link, customer service and satisfaction, supply chain and logistics costs). It is a valuable reference for identifying the performance indicators in RFID-enabled supply chains (Kim, 2009; Wang et al., 2008). As a supplement, Bayraktar et al. (2009) came up with a framework identifying the general causal links among supply chain management and information systems practices. Empirical evidence confirms that the way companies handle their operation's system complexity has a deep effect on how well they perform (Perona and Miragliotta, 2004).

RFID is regarded as a promising technology for the optimization of supply chain processes since it improves manufacturing and retail operations from forecasting demand to planning, managing inventory, and distribution (Ustundag and Tamyas, 2009). Having this in mind, two research streams can be identified that are related to RFID performance measurement in supply chains. First, there is a variety of articles with either quantitative or qualitative data from field and laboratory studies. Various authors such as Hardgrave et al. (2005), Fosso-Wamba et al. (2007), and Véronneau and Roy (2009) examined RFID effects in supply chains. Secondly, some researchers have already contributed to a better understanding of RFID effects in general. Contrary to various studies that focused on output ratios on a company level, for example specific increase in market share, increase in turnover, ROI (Mooney et al., 1996), these ratios have been estimated to be important but not sufficient for the derivation of a cause-and-effect-chain. In fact, a fine granular examination of individual business processes in their overall context seems reasonable. For example, Gaukler (2005) introduced a model for RFID investment effects on two supply chain members. Hou and Huang (2006) presented six models for cost-benefit analysis in different supply chain activities in the printing industry. Fleisch and Tellkamp (2005) discussed the relationship between supply chain performance and inventory accuracy. Tellkamp (2006) conducted process based examinations of the RFID potential whereas Bendavid et al. (2008) presented key performance indicators for the evaluation of RFID-enabled B2B e-commerce applications based on a single supply chain field study. Starting from their work, we have examined different logistics processes regarding RFID impacts in order to develop a fine granular conceptual model for the measurement of RFID technologies in supply chain logistics.

3. Model artifacts for the reference model

3.1. Relevant reference objects

In our reference model, processes are organized hierarchically. A process belongs to a set of similar processes or can be an activity that is part of a bigger process chain. For example, a level 1 process in this sense is "delivery," which is a major logistical process with different process refinements on a fine-granular process level. On level 2 a sub-process for a level 1 "delivery" process may be "one stage commissioning" as opposed to "two stage commissioning." In turn, on level 3 a more granular process within the process chain "one stage commissioning" is the process "collection of items" followed by the "compilation of logistical units." The reference process hierarchy only observes processes that are relevant to an RFID investment; relevant processes in this sense may be positively or negatively influenced by RFID investments. The selective collection of processes narrows the decision problem down to relevant objects and therefore reduces the complexity.

The reference process hierarchy contains seven core processes. They are grouped by their relation to customers or suppliers. On supplier side, processes interact or may be shared with suppliers; on the customer side, processes interact or may be shared with customers. Each core process can be broken down to a fine granular process level with individual process objects that can be equipped with RFID transponders. We understand process objects as business objects that are processed within the activity chain. Whether or not an object is a relevant process object in the supply chain depends on the context of the process. The framework classifies these process objects according to ISO classification as product → packaging → transport unit → shipping unit → container → vehicle. Logistic unit level 5 (vehicle) is the highest logistical aggregation level. For example, identical products (level 0) can be combined on a pallet (level 3) and can be loaded on a truck (level 5).

The process object hierarchy serves as a decision hierarchy for the conceptual evaluation of the technical realization of RFID value. The allocation of process objects to RFID values within the reference framework helps identify the right logistic unit level for RFID transponder investments. Such a classification helps managers in defining the right RFID implementation scenarios. Furthermore, the allocation lightens the calculation of the process driven business value of RFID investments. From the organizational perspective different players within the supply chain (e.g., manufacturers, retailers, and logistics service providers) can execute the processes.

3.2. Relevant RFID effects

To identify effects of RFID investments on processes we take a top-down approach analyzing IT effects in general before deriving RFID effects in our given context. Mooney et al. (1996) argue that there are three different types of IT effects: automation effects when information technology replaces human labor, information effects caused by the ability of information systems to collect, store, process and distribute information, and transformation effects derived from the ability of information technology to permit or facilitate process innovations and changes.

Thanks to the abstract nature of these IT effects, the classification can also be used to structure RFID effects (Tellkamp, 2006). Nevertheless, for the development of a process-driven reference RFID effect model, this division is too generic because no immediate conclusions regarding appropriate assessment methods can be drawn, since these IT effects have a lack of focus on business processes. In addition, a later ratio-based formalization of RFID effects, in the context of an individual economic analysis, also requires an adequate specialization of general IT effects. Therefore, our reference effect model will comprise four specific RFID effects that are closely related to a process view and correspond with the general IT effects.

3.2.1. RFID effect type "processing time reduction" (PTR)

Results from numerous case studies such as that by Tellkamp (2006) have shown that process automation of formerly manually performed activities is the most common benefit of RFID systems. Process automation in this sense refers to the partial and complete transformation of manual tasks performed by people toward automatically performed activities operated by RFID systems. Primarily, these tasks include data entry and data processing. An automation of these tasks is important, since manual tasks offer several disadvantages such as longer durations, error proneness and consumption of auxiliary materials. The RFID effect type "processing time reduction" therefore refers to the savings achieved solely by avoiding human resources for data entry and data processing. A high potential can be seen especially in the automation of routine activities.

3.2.2. RFID effect type "error reduction" (ER)

A high proportion of manual process execution not only binds human resources, but is also error-prone. An error (especially incorrect data collection or processing) here refers to a deviation from a standardized process execution. The focus lies on the reduction or even avoidance of possibly multiplying consequences that data and processing errors can have throughout the value and supply chain. Not all errors in a supply chain must have multiplying consequences due to a certain fault tolerance in processes and process networks. This is the case, for example, if a supplier delivers the wrong articles to a retailer, but the retailer can compensate for this wrong delivery by using his safety stock to deliver the articles to a customer on time. The RFID effect type "error reduction" only refers to those errors that can be avoided or reduced through the use of RFID technology; errors that cannot be reduced by the use of RFID technology are not relevant for the added value of the RFID system.

3.2.3. RFID effect type "resource consumption reduction" (RCR)

Material assets of a company (in opposition to human resources, which are expressly excluded since they are already subject to the RFID effect "processing time reduction") in the context of RFID effects are referred to as resources. Resource consumption therefore means that money and material resources are consumed in a company. If, however, an RFID effect type "resource consumption reduction" takes place, we conclude that consumption of resources in relevant processes (process costs) is minimized:

- material: material costs, especially operating materials and consumption tools;
- funds: costs for external services or capital commitments (e.g., the need for security stocks), warehousing and depreciation (e.g., for the use of a vehicle fleet).

For example, in taking a look at the commissioning process of a transfer station in the supply station, which is supported by RFID technology, some possible resource consumption reduction effects can occur in the following areas:

- elimination of consumables for the printing of commissioning lists (material);
- reduction of depreciations for a commissioning PC and printers (funds);
- reduction of the number of conveyance vehicles (funds);
- reduction of the fuel consumption for conveyance vehicles (material).

3.2.4. RFID effect type "process information" (PI)

Enhanced "process information," as an effect of RFID investments, can occur when electronic data is captured, processed and disseminated by RFID systems. Enhanced "process information" in our understanding depends on the nature of the process information, which is obtained through the RFID system. Here, only process information that results in more effective and/or efficient processes is considered to be a relevant RFID effect. Therefore, new process information needs to be available upfront. Furthermore, information granularity and or timeliness of process information can be an indicator for enhanced process information. RFID implementations typically enable more in-depth information; for example, on products being produced, products entering and leaving a supply chain member, and also delivering timely information on the status of these products (for example, location in a warehouse). Error reduction due to better process information, however, is not considered to be part of this effect type since the other RFID effect type "error reduction" already relates to this effect.

4. Deriving the RFID business value model

The core of our model is built upon the four component types: processes within a process hierarchy, process objects, and the four already discussed RFID effect types as well as relevant supply chain roles.

The seven RFID relevant core processes within a supply chain (procurement, production, redemption transport, customer service, delivery, and return) are first organized in an H-form depending on their proximity to the supplier side or customer side. In addition, each core process is broken down into another two levels for a deeper process insight. On the lowest level, processes are mapped to supply chain roles. This mapping allows a quick documentation of the typical processes that are relevant for supply chain stakeholders for a RFID cost-benefit analysis, depending on the individual supply chain role. On the process level we also recorded which of the six RFID relevant process objects (product, product packaging, transport unit, reusable shipping unit, cargo container, and vehicle) typically must be considered for process analysis. The RFID effect types are also mapped on the lowest level processes and thus illustrate the extensive impact that RFID solutions can have on enterprises (Fig. 1). For example, articles in a one-stage commission (D1a) can be collected (D1a.1) either by manufacturers, suppliers, retailers or logistic service providers. RFID objects can be used on the product level, product packaging level or transport level. The usage of RFID can lead to processing time reduction, error reduction and resource consumption reduction.

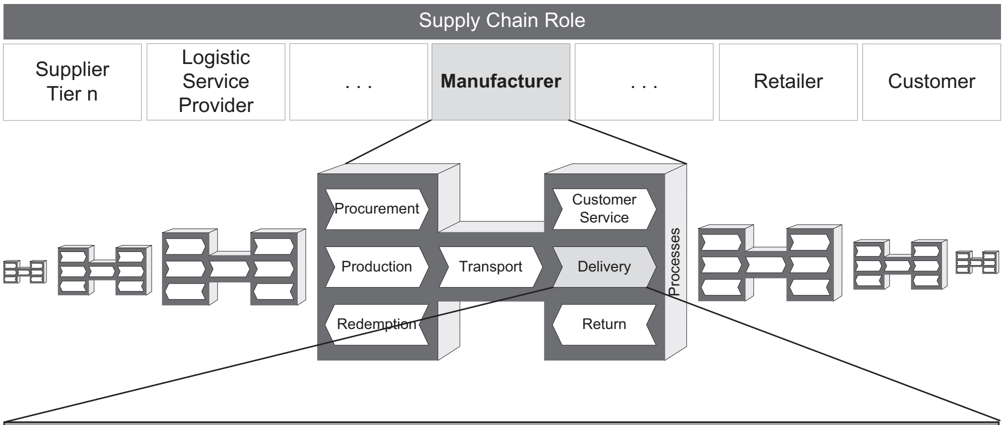
For the use of the RFID reference effect model in the context of supply chain specific RFID cost/benefit analyses, we recommend adjusting the underlying reference processes according to the individual business processes. The transformation of the general reference effect model toward a specific RFID effect model for processes can be done by two routines: attribute-based or generic. Attribute-based transformation refers to the selection of processes of the reference effect model based on an individual supply chain role. Generic transformation refers to the modification of processes in the reference model, as well as the insertion of new processes, which may be company specific and not already documented in the reference process model. Both of these adjustment mechanisms can be used individually as well as in combination. In the ideal case an attribute-based selection is first executed to filter relevant processes for a specific supply chain. Then—if necessary—a more time- and cost-intensive generic adaptation of the reference effect model is done. In the following case study we demonstrate the application of the RFID reference model in a real-world business case.

5. Case study: applying the RFID business value model in a warehouse supply chain within the automotive industry

5.1. Case background: optimizing warehouse management in the automotive industry

For the evaluation of the reference model we have been working together with SAP as well as with one of its customers and his supply chain in the Russian automotive sector who produce Jeeps for the Russian market. They faced the challenge of evaluating if RFID technology at that time could yield a benefit for the improvement of management operations.

The warehouse had a size of 5500 m^2 and constantly had 3500 different articles on average in stock, of which 2500 articles were moved frequently. The processes in the warehouse supply chain were based on the best practices defined by SAP R/3 4.6C for Automotive. The challenge was that all parts and accessories were recorded manually



Delivery

Process	Supply chain role: Manufacturer	Supplier	Retailer	Logistic service provider	Other Service Provider	Consumer	Process object: Product	Product packaging	Transport unit	Reusable transport unit	Freight container	Vehicle	RFID effect: Processing time reduction	Error reduction	Resource consumption reduction	Process information
D1a One-stage commissioning																
D1a.1 Collection	x	x	x	x			x	x	x				x	x	x	
D1a.2 Compilation of logistical units	x	x	x	x	x		x	x	x	x			x	x	x	x
D1b Two-stage commissioning																
D1b.1a Collection	x	x	x	x			x	x	x				x	x	x	
D1b.1b Placing of articles into sales area			x				x	x	x				x		x	x
D1b.2a Resorting	x	x		x	x		x	x	x				x	x		x
D1b.2b Shelf replenishment			x				x	x	x				x		x	x
D1b.3a Compilation of logistical units	x	x		x	x		x	x	x	x			x	x	x	x
D1b.3b Removal of articles from shelves			x				x	x								x
D2 Goods issuing																
D2.1a Creation of accompanying documents	x	x		x	x		x	x	x	x	x		x	x		x
D2.1b Generation of sales slip			x				x	x					x			x
D2.2a Book out	x	x		x	x		x	x	x	x	x		x	x	x	x
D2.2b Check-out			x				x	x	x				x			x
DS Delivery support																
DS.1 Delivery evaluation	x	x	x	x	x											x
DS.2 Customs	x	x	x	x			x	x	x	x	x	x	x			x
DS.3 Status tracking	x	x	x	x		x										x

Fig. 1. Extract from the RFID framework for delivery processes.

and each year the demand for spare parts doubled roughly. An RFID solution to speed up time-consuming routine processes in the supply chain (i.e., goods delivery, goods receipt and goods issue as well as inventory management) was seen as a possible future investment, which could save valuable resources by not having to increase the number of workers to keep up with the increasing number of goods movements.

5.2. *Approach: a methodology for the assessment of the business value of an RFID system*

5.2.1. *The big picture: a procedure model for assessing the business value of an RFID solution*

In order to assess the benefits of an RFID investment a reference framework for applying the RFID reference model was developed, which comprises 2 phases with 7 steps altogether (Fig. 2). In the first phase, the RFID effects are identified within the given project scope. Therefore, the first step is to define the scope and goal of the project to give a first overview of the processes that need to be analyzed. In the second step implementation scenarios have to be drafted to explicate possible specifications (functionalities and configurations) of the planned RFID system. It is reasonable to derive implications for the existing process landscape. With the specifications of the system in mind and the relevant set of top-level processes selected, the processes then have to be modeled in detail with regard to the RFID reference model in order to locate the RFID effects. Modeling the processes in detail helps to achieve process transparency using the vocabulary and process-oriented thinking pattern of the individual case. This step is critical since it links the generalized RFID reference model to the specific business case and serves as a way of achieving acceptance for the application of the reference model. To derive what RFID effects occur in which parts of the business processes the detailed activities from the as-is process models are analyzed and mapped to the RFID reference model. Based on the as-is-process landscape and the highlighted RFID relevant activities the to-be-processes are developed in the final step of the first phase.

The second phase of the RFID effects assessment focuses on building a process-oriented key performance indicator (KPI) framework to measure each effect along the business processes throughout the whole process landscape with ratios. KPIs are quantifiable ratios that help an organization define and measure progress toward organizational objectives. The creation begins with the generation of a process-hierarchy which is supplemented by KPIs for each RFID effect type. The resulting model is called the process-KPI-framework. In a second step as-is data is gathered to calculate the as-is KPIs for each business process. In a final step the to-be data has to be approximated in order to evaluate the benefits of the RFID investment with regard to the as-is KPIs.

5.2.2. *Defining the goal and scope of an RFID investment evaluation project*

At the outset of the project the goal and scope of the project have to be clearly defined. In our case the project goal was defined as identifying the business value of an RFID investment in the parts and accessories supply chain. The scope of the project refers to the top-level business processes which should be analyzed and will most likely be changed. From our case study a process-oriented structuring of the problem domain has the following advantages: it defines the scope of the RFID system within the supply chain, it simplifies the specification and selection of deployment scenarios, it reduces the number of processes to be modeled to the necessary minimum, and it helps to identify the process owners and employees, whose activities will be affected by the RFID system.

Applying the proposed RFID reference model in this context is a deductive approach. However, the deductive approach does not exclude an individual analysis of RFID effects, which may be specific to a company. This becomes apparent as the RFID reference model is first adapted by an attribute-based transformation (which reduces the set of reference processes to those that apply within the scope of the project and the companies' position in the supply chain) and is then supplemented by a generic transformation (where individual processes can be added, other processes deleted from the reference model and reference processes can be renamed/adapted for better specific understanding).

In our selected case the configuration of our reference model would be "manufacturer" regarding the supply chain role and "procurement, redemption, transport, delivery, and return" regarding the core processes to be analyzed. Via a database, which was used to store the reference model, a specific report regarding the relevant processes can be generated.

The outcome of step 1 is a defined goal as well as scope of the project by means of a defined set of processes to be

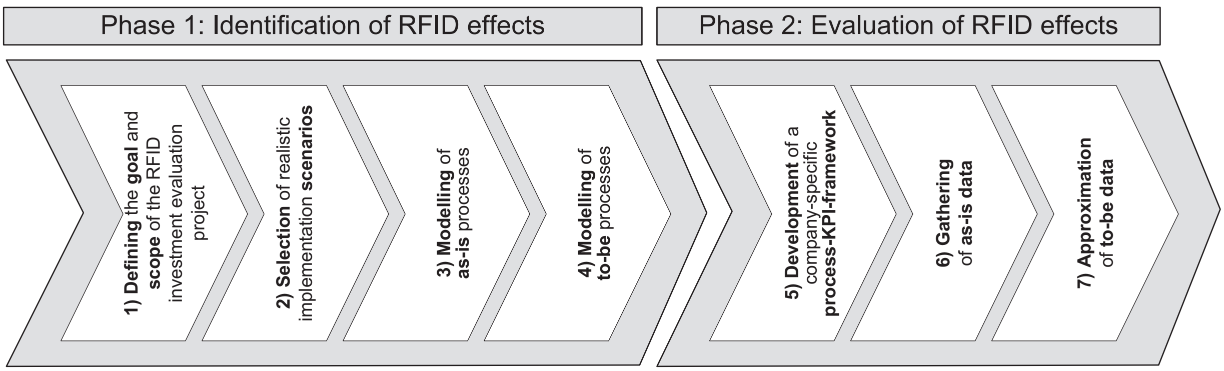


Fig. 2. Reference framework for applying the RFID reference model.

analyzed in the context of the RFID business value assessment.

5.2.3. *Defining realistic to-be implementation scenarios for the RFID investment*

In the second step we suggest defining implementation scenarios to further focus the analysis on the relevant business processes and activities with the right underlying assumptions regarding the RFID implementation. For this purpose we propose explicating two groups of characteristics for each implementation scenario that shall be analyzed:

- Technical characteristics of the RFID system represent the desired target state in relation to the selection and design of the RFID system. These are important as they affect how and where RFID system elements (i.e., RFID-readers) can or shall be used in the existing business context.
- Organizational characteristics of the RFID implementation represent the desired target state with regard to the design of processes when technology is implemented. They give a first insight into which activities of the business processes need to be analyzed in detail (i.e., regarding what is and will be handled with and without the RFID system—single items as opposed to batch items, etc.) when it comes to as-is modeling and especially to to-be modeling of the process landscape.

To illustrate how we suggest describing implementation scenarios we present some potential implementation alternatives from our case as an example (Fig. 3).

Regarding the development of these implementation scenarios we have identified several heuristics which support a goal-oriented RFID business value assessment:

- Identify a maximum of 2–3 scenarios: many different configurations of the RFID solution to be implemented can lead to a vast variety of possible scenarios which would cause a large effort for the to-be modeling and analysis later on that cannot be handled anymore. The development of these scenarios is a partially creative task with the goal of focusing on those scenarios which are realistic and seem most promising regarding their potential business value. Ideally, a study can focus on just one scenario or very few scenarios. However, if the company needs the business value assessment to decide between different possible solutions for RFID investments, several scenarios need to be created.
- Focus on critical characteristics: there can be many characteristics defining each scenario. The more characteristics and values for these characteristics are defined the more possible scenarios evolve. Therefore, scenario creators should focus on "critical characteristics" (i.e., data processing method or process object) that are important for the modeling of to-be processes. In theory, characteristics can be prioritized according to the concepts of utility analysis from the discipline of decision science.

The final outputs of step 2 are different to-be scenarios and their major characteristics need to be analyzed within the business value assessment case.

5.2.4. *Documenting the as-is process landscape using the RFID reference model*

Once the focus of the process-oriented analysis is defined, the as-is process landscape needs to be modeled in order to locate RFID effects in accordance with the RFID reference model and derive to-be processes later on. The challenge in modeling as-is processes is to choose a level of detail that is appropriate for the analysis. Some guiding aspects that help to determine the right level of detail for modeling are as follows (Gaitanides, 1983):

- the level of detail of as-is processes must ensure that RFID effects can be retraced with the help of the formal process representations;
- the level of detail of as-is processes determines the level of detail of to-be processes and thus the level of detail of the whole benefit analysis;
- the accuracy of the business value assessment tends to be better if a higher level of detail is applied to the modeling phase;
- the time needed for the whole business value assessment is positively correlated to the level of detail of the process models.

In order to apply the RFID reference model to the existing process landscape we suggest modeling the actual as-is process in a commonly used process modeling language (i.e., event-driven process chain, EPC). Created as-is processes will have more detail (which we call "level 4") than the reference model to show how each activity is interconnected in the process flow (Fig. 4) and in which parts of the business processes the relevant RFID activities (level 3 of the reference model) are located. To avoid a decoupling of the created as-is models from the activities of the RFID reference model we suggest tagging the activity sequences in the detailed level 4 process models with the corresponding level 3 activity of the reference model (Fig. 5). Level 3 would be the minimal level of detail that needs to be pursued while modeling the process landscape; however, from our case studies with retailers we know that level 3 is not sufficient for most supply chain members as the process flows cannot be seen from the reference model, thus causing a non-acceptance of the application of the RFID reference model. Ideally, the reference model level 3 is therefore extended to level 4 by modeling further activities in between each RFID relevant reference activity to achieve process transparency regarding the actual company-specific processes. Optionally, a fifth level can be added to the process models if this adds to process transparency and understanding and helps in determining as-is and to-be data later on. An example of an as-is business model from the case can be seen in Fig. 5. Since the main goal of this third step is to identify the activities in the as-is processes which are also seen as relevant by the RFID reference model and for which RFID effects can thus be located, we have not just modeled the

Characteristic \ Scenario	Scenario 1	Scenario 2	Scenario 3
Technical characteristics of the RFID system			
Data processing method	online	online	batch
IT infrastructure	WLAN and mobile RFID readers	WLAN and mobile RFID readers	LAN and mobile synchronizable RFID readers
...	...	...	...
Organizational characteristics of the RFID implementation			
Process object	transport box	spare part	transport box
Labeling of stocking area	transponder	visually	transponder
Transponder box content	pure	mixed	pure
Shipping notice from supplier	yes, mandatory	yes, not mandatory	yes, mandatory
Quantitative control	manually	automatic	manually
...	...	...	...

Fig. 3. Specification of realistic implementation scenarios.

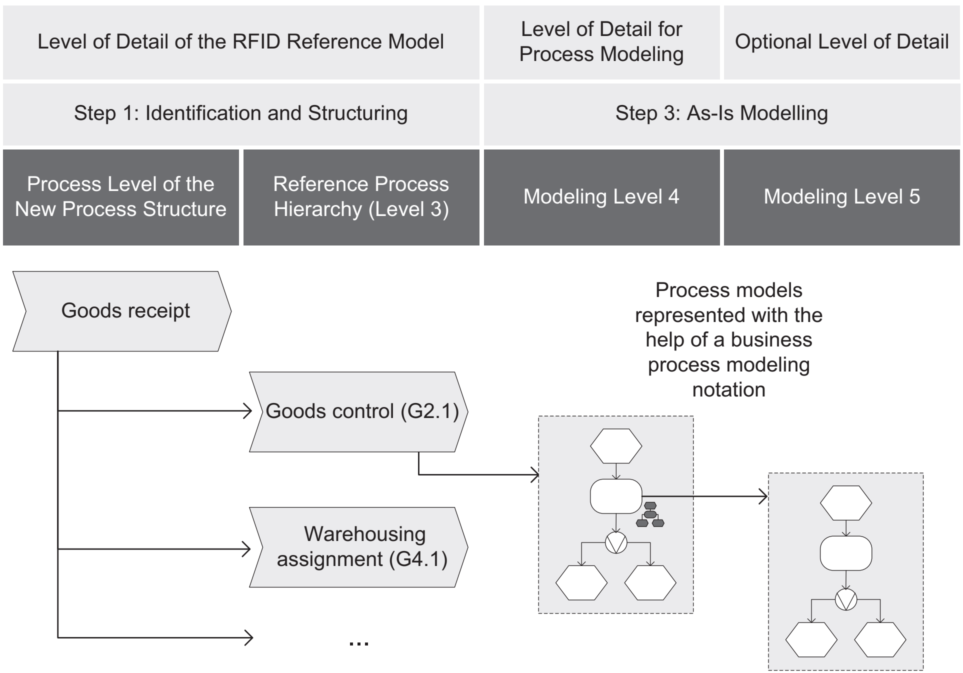


Fig. 4. Proposed level of detail of as-is modeling.

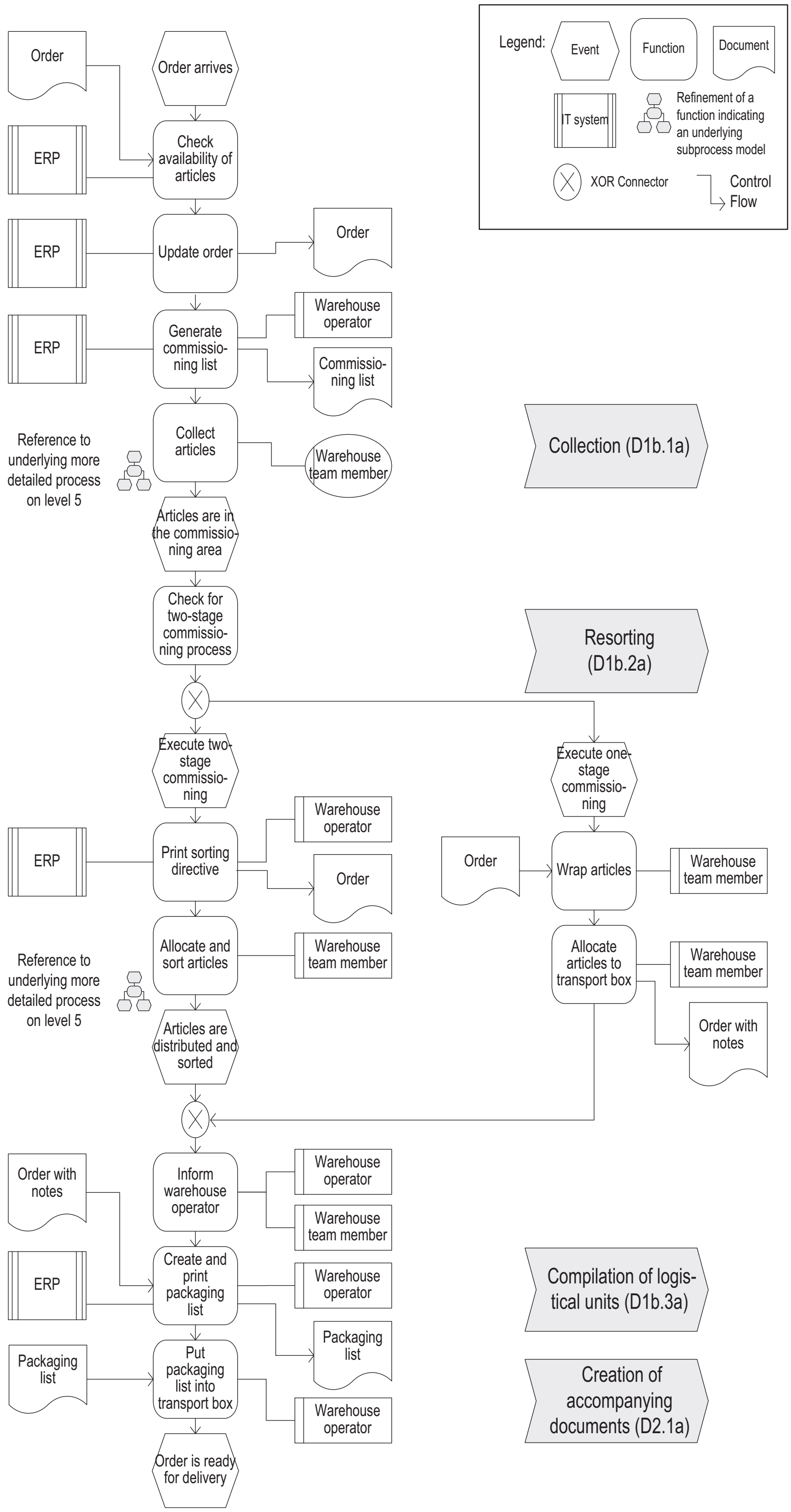


Fig. 5. As-is process with an appropriate level of detail and tagged corresponding elements of the RFID reference model.

process in EPC notation, but have also mapped the corresponding level 3 processes of the reference model to the activity sequences within the real-world example.

The main output of the third step is the set of relevant as-is processes (level 4) with the mappings of level 3 elements of the reference process model.

5.2.5. Modeling of to-be processes using the reference model

To-be processes need to be created in a fourth step on the basis of the as-is processes and the predefined to-be scenarios. The transition of as-is into to-be processes usually takes place by means of three different ways:

- Automation: The process structure (i.e., the sequence of individual process activities and their interactions) remains basically unchanged. It is de facto a "pure" process acceleration which reduces lead times as well as errors made in processes.
- Transformation: Transformation means that the process structure changes significantly due to a change in tasks performed in the new to-be processes as well as a change in the sequence the tasks are performed in.
- Joint transition: In a mixed transition from as-is to to-be processes both automation and transformation occurs in the new target processes. This type of mixed transition is usually the case regarding the deployment of an RFID solution: the as-is process will be made more effective (transformation) and more efficient (automation).

In Fig. 6 we show an example of the same process as in Fig. 5, which has been adapted to derive a to-be process model that locates RFID relevant process parts and their effects. In our example the concept of automation has been the driving concept behind the transition. This can be seen as the structure of the process model does not change significantly and the tasks performed are largely similar. Applying the concept of automation as opposed to transformation is less time consuming when deriving to-be process models from as-is models. The resulting RFID-enabled to-be process in Fig. 6 can be described as follows: within the delivery process, articles have to be collected in the warehouse. For that, the warehouse operator has to generate a commissioning list. In some warehouses, where the list is compiled manually, many companies already use modern technologies such as pick-by-voice or pick-by-light in combination with automatic generation through the ERP system. An electronic generation that will be sent to RFID handheld readers helps to reduce processing time and resource consumption. Even though picking technologies decreases the processing time already, they are not able to identify articles with serial numbers that are stored on the same storage cell. Hence, RFID helps reduce picking errors and also helps reduce picking times as employees do not have to confirm each pick and are faster with the picking of goods. In addition, the electronic preparation of sorting directives for RFID readers can improve processing times and resource consumption as well because employees are able to allocate and sort articles faster and less erroneously. Furthermore, the allocation of articles to transport boxes is less error-prone because the article combination can be checked during any time of the process.

The major goal of the to-be modeling step, however, is not only to derive the to-be processes, but also to visually highlight the activities in which RFID effects occur, according to the RFID reference model. We have illustrated this in Fig. 6 by emphasizing the RFID-enabled activities and tagging the RFID effects (i.e., PT for processing time) onto these as well as annotating a tendency to the RFID effect indicated by an arrow (i.e., processing time "is reduced").

The product of this fourth step is thus the set of to-be process models with the illustrated RFID effects, which are built upon the as-is process models and our RFID reference model. With this final step of the first phase of our suggested reference framework for the application of our RFID reference model, all modeling activities are done and we proceed to the evaluation phase, in which the effects of the RFID investment are quantified.

5.2.6. Development of a supply chain specific process-KPI-framework for comparison of as-is and to-be processes

Having identified the RFID effects in the supply chain specific business processes, the RFID reference model needs to be adapted to the terminology used in the as-is and to-be process models. This results in an adapted version of the RFID reference model. New processes that are not in the reference model would have to be defined with RFID effect types and their RFID relevant activities on the third level of the process hierarchy.

The adapted process hierarchy is the starting point for building a process-KPI-framework, which can later be used to compare as-is and to-be scenarios and thus assess the value each RFID effect type has on the whole process landscape. For this purpose the process hierarchy is extended by designing specific KPIs for each RFID effect type and using the same KPIs with the same units as well as scale basis. Fig. 7 shows an example from the manufacturer's perspective with fictional, although realistic data that are similar to those of the case study as we are not allowed to disclose the original data. These calculations can be done for every stakeholder in the supply chain. However, the calculations may differ to some extent. For example, an RFID introduction may lead to profit increases at the manufacturer's site from day one, but the supplier may have to invest into adding the RFID tags to his products. Hence, he can only benefit from subsequent processes. As the calculation only displays relevant KPIs for relevant processes in order to avoid an information overload, there may be differences in the calculation framework of each supply chain stakeholder. To calculate each KPI the formulas of each KPI are explicated by listing the different sub-KPIs or basic elements of the formulas. On this fine granular level the resulting process-KPI-framework will then be used to compare as-is and to-be data and aggregate the lowest level KPIs to the highest level KPIs on level 1 or level 2 processes.

5.2.7. Gathering of as-is data

The central problem of data gathering is to supply the necessary as-is data in order to use them in the process-KPI-framework. In many cases supply chain partners will not have the requested information in the needed form and thus it is the project manager's responsibility to

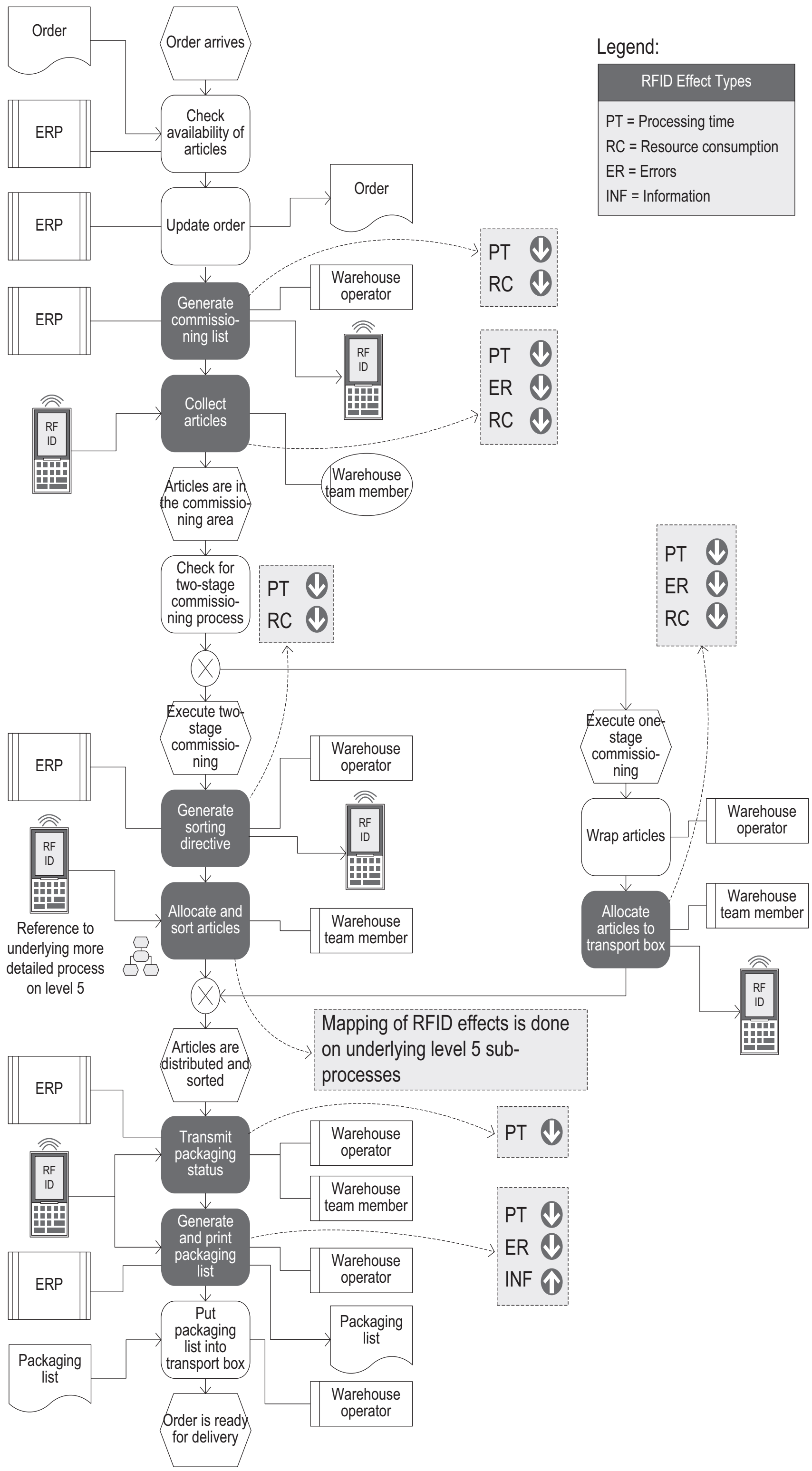


Fig. 6. To-be process with changed activities according to RFID reference model and annotated RFID effects.

collect these data. From our case study experience we have found that process-oriented information can be gathered well through interviews with the executing employees, if the project manager can ask them questions that they can easily approximate. If the questions are, however, too specific and cannot be answered through the

Supplier, Tier 2 - Production

Manufacturer - Delivery

Process Hierarchy	KPI: RFID effect type specific KPI	KPI: KPI elements	Unit	Scale Basis	As-Is Data	To-Be Data	RFID-Savings-Potential
Goods issue			€	year	565,250.00	462,500.00	102,750.00
Commissioning			€	year	565,250.00	462,500.00	102,750.00
Print commissioning list (as-is) / Generate commissioning list (to-be)							
	Processing Time Reduction		€	year	5,000.00	0.00	5,000.00
		Processing time needed	seconds	process object	40.00	0.00	40.00
		Number of process objects	pieces	year	75,000.00	75,000.00	0.00
		Average hourly earnings	€	hour	6.00	6.00	0.00
	Resource Consumption Reduction		€	year	750.00	0.00	750.00
		Number of consumed items	pieces	year	75,000.00	75,000.00	0.00
		Price per consumed item	€	pieces	0.01	0.00	0.01
Collect articles (as-is/to-be)							
	Processing Time Reduction		€	year	500,000.00	437,500.00	62,500.00
		Processing time needed	seconds	process object	360.00	315.00	45.00
		Number of process objects	pieces	year	1,000,000.00	1,000,000.00	0.00
		Average hourly earnings	€	hour	5.00	5.00	0.00
	Error Reduction		€	year	12,000.00	0.00	12,000.00
		Processing time needed	hour	year	1,200.00	0.00	1,200.00
		Number of employees	employees	process	2.00	0.00	2.00
		Average hourly earnings	€	hour	5.00	5.00	0.00
	Resource Consumption Reduction		€	year	10,000.00	0.00	10,000.00
		Number of consumed items	pieces	year	1,000,000.00	1,000,000.00	0.00
		Price per consumed item	€	pieces	0.01	0.00	0.01
Allocate articles to transport box (as-is/to-be)							
	Processing Time Reduction		€	year	37,500.00	25,000.00	12,500.00
		Processing time needed	seconds	process object	27.00	18.00	9.00
		Number of process objects	pieces	year	1,000,000.00	1,000,000.00	0.00
		Average hourly earnings	€	hour	5.00	5.00	0.00

Fig. 7. Extract from resulting process-KPI-framework.

individual employee's everyday routine experience they will remain unanswered. A second method of gathering as-is data is to use internal statistics, if these are available. A third more time-consuming method for gathering as-is data is to make observations as the processes are handled. If data vacancies remain then the project responsible will have to make assumptions in order to approximate the missing data needed for the overall process landscape calculation. However, making assumptions adds to the inaccuracy of the calculations and may also lead to a lower acceptance of the calculated value among decision makers in the company.

5.2.8. Approximation of to-be data and final evaluation of the RFID benefits

To-be data needs to be approximated in order to calculate the value of the RFID investment as the difference between each to-be and as-is value for each row of the process-KPI-framework. For this task the authors have identified four types of methods that can be used to assist in the approximation of values for the to-be data:

- Experiments: In the context of an experiment, to-be processes are tested (ideally under realistic circumstances) to get accurate results for the necessary to-be data. Some RFID solution providers, however, offer test centers in which customers can test their future processes, which saves costs on the customer side for this method. If there are no such offers this method is time-consuming and expensive but yields creditable results.
- Process simulations: If live experiments are improvident, simulations are a second possible method. Simulations, however, cannot be performed with the to-be models but need extended to-be models with sophisticated assumptions regarding each variable in the model. Simulations can be very complex and need experts, and even then may not lead to very reliable results.
- Experts: An efficient way of deriving to-be values can be from "thought experiments" using expert knowledge and logic to argue within which bandwidth results the to-be data can be in. Values found are based on a consensus among experts but may not yield very accurate results.
- Process benchmarking: A fourth method for obtaining to-be data can be from process benchmarking. Here the idea is to look at other similar supply chains who have had a similar environment and similar challenges when implementing the RFID solution and already have data regarding their new RFID-enabled processes. These data can come close to the accuracy of experimental data, but in practice it remains an unlikely challenge that a possible competitor will hand out this critical data. However, since the RFID reference model is based on the SCOR reference model this argument can be disarmed since commercial benchmarks for SCOR metrics exist, which can be a solid basis for to-be data.

6. Limitations

The question of how the human can achieve "true" cognition and therefore a qualitative causal model for RFID investments aims at the question of whether "true" knowledge can be achieved (Haak, 1978). It is hardly possible to develop and evaluate qualitative research results such as modeling techniques and procedure models, as well as to verify information out of reference models in an objective manner. For the verification of the method description and the information contained in reference models and reorganization recommendation, methods like observation, interviews and interpretation of texts are used. The structuring of findings in our reference model especially depends on the subjective experience of the authors. Hence, we propose a reference framework approach that helps to ease the identification of impact types and impact places within the value chain. It still needs continuous testing and evaluation in the scientific community and practice in order to further develop the approach.

The model proved to be valuable for first evaluation cases. However, there are also some drawbacks and future research demands. Understood as a generic reference model, our artifact can only support generic processes that apply to the broad majority of companies and supply chains. However, it is very hard also to take non-generic, specific processes into account. Although we intend to extend future versions of the reference model in order to better cover individual or domain-specific processes, the problem still remains. Furthermore, the concrete quantification of benefit data is very challenging. Although we provide a valuable structure with helpful indicators for measuring the business value of RFID investments, it is still a difficult manual task to analyze real-world performance data.

7. Conclusion and future research

Calculating the process driven value of RFID investments is very difficult but our reference framework approach alleviates the identification of impact types and places within the value chain. Hence, we provide a valuable structure for the support of investment decisions and also a procedure model for doing so. With the adaptation of the reference effect model to a specific situation, a basis for a process-driven economic analysis of RFID investments is given. Hence, it serves as a generalized model for investment justifications in all processes of the supply chain. In addition, it can be adapted to specific RFID supply chain needs in order to meet individual company requirements. Both the reference model and its applied procedure model can improve the individual performance measurement of potential RFID investments.

The application of our reference model turned out to be very helpful in the described case according to our propositions. Hence, we believe it to be a valuable contribution for RFID investment justifications:

- Our approach offers help in identifying the right investment scenarios and reference objects as well as relevant RFID effects.
- It turned out that the structure and content of our model was very helpful for the assessment case because it enabled a faster RFID investment assessment. The matching of individual as-is processes with our reference model processes enforces a critical questioning of all processes regarding RFID potential. Furthermore, it helps developing individual KPIs.
- The reference model offers a flexible 3-level structure. Hence, it is possible to extract suitable reference processes on one of the three levels in order to meet individual requirements.

The reference model is a work in progress. By creating a comprehensive ratio framework for the processes and RFID effects in each process, we expect to be able to define ratio hierarchies and aggregate ratios to calculate key ratios, giving an overall estimation of the value of an RFID investment based on underlying empirical data from various branches and projects. With an increasing maturity of RFID application in companies and supply chains, we expect more research to go into concrete RFID application scenarios and individual performance ratios for different supply chain processes. Our reference model in combination with documented experiences of RFID projects can be a very valuable help in calculating the process driven business value of RFID investments.

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