Reference Model for Management of RFID System Implementations

Von der Wirtschaftswissenschaftlichen Fakultät
der Universität Leipzig
genehmigte

DISSERTATION

zur Erlangung des akademischen Grades
DOCTOR RERUM POLITICARUM
DR. RER. POL.
vorgelegt

von NIAZ MUHAMMAD KHAN (MBA)
geboren am 28. November 1977, in Karachi (Pakistan)

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Tag der Verleihung: 24.10.2018

To my late grandfather Razi Khan and my lovely daughter Sophia Raz Khan

Acknowledgements

This research is conducted in cooperation with University of Leipzig, Anhalt University of Applied Sciences, and Food Manufacturing Enterprises of Saxony-Anhalt. For the completion of this challenging endeavor, I would like to express my deepest gratitude to the involved people from both academia and practice for supporting my research. Firstly, I would like to express my sincere gratitude to my advisor Prof. Dr. habil. Bogdan Franczyk. He patiently provided advises and feedback, which were crucial for my dissertation. My sincere gratitude goes also to my advisor Prof. Dr. Ute Höper-Schmidt for her encouragement, support, and understanding. The encouragement and support of my advisors guided and formed my research.

Besides, I would like to thank the involved enterprises and their employees as well as the network of food businesses Saxony-Anhalt for their interest and support. Without this cooperation it would had not been possible to conduct this research. I would like to thank Prof. Dr. Ulrich Eisenecker and Prof. Dr. Rainer Alt for their comments in university seminars. I thank also my fellow researchers for the stimulating discussions in seminars.

Last but not least, I would like to thank my family for their unconditional love: specially my grandparents and parents for their encouragement throughout my life and my studies, my wife for her endurance and stand by my side, and my little daughter for giving me the strength since her birth.

Bibliography

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Reference Model for Management of RFID System Implementations

University of Leipzig, Dissertation

221 pages, 177 References, 29 Figures, 12 Tables, 30 Appendices

Summary

Radio frequency identification (RFID) technology is adopted in supply chain as it possesses high potential for optimization. However, the adoption is constrained with management and technological issues for certain domains. Applicability and profitability of the technology and implementation approaches as well as maturity of the technology and data integration are few of the concerns in this regard. Therefore, many enterprises are still skeptical about investment in RFID technology.

Rightly, for instance, there are no appropriate approaches for management of the RFID system implementations at present that consider specific concerns of preparation of the food manufacturing enterprises. This research suggests a reference model for the purpose. The model is a result of extensive literature reviews and practice-oriented research aiming practical solutions to the problems of the respective domain. The model, which involves planning, organization and realization of RFID system implementation activities, considers multiple facets of RFID system implementations in order to increase understanding of RFID technology (i.e. knowledge development), ease decision making of an RFID implementation (i.e. willingness), and reduce cost and complexity of RFID system implementations (i.e. effectiveness and efficiency). It is an artifact of design-oriented information system research and includes a frame of reference, a process model, input and output templates, and tools and techniques.

The model is applied in 'real life context' in order to achieve objectives of the involved enterprises. Similarly, the model aims effectiveness and efficiency in the future use, for example, by providing free of cost acquisition and appropriateness for manufacturing industries of food businesses of Saxony-Anhalt. However, adaptation efforts (e.g. by instantiation or specialization) may vary depending on the skills of users of individual enterprises. The reference model provides flexibility in terms of independence from specific vendors, openness by complying with available standards (e.g. PMBOK), and relationship to RFID system development artifacts during technical work realization.

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Abbreviations

ALE	Application Level Event
ANSI	American National Standards Institute
API	Application Interface
ARIS	Architecture of Integrated Information Systems
Auto-ID	Automatic Identification Technology
BSI	British Standard Institute
CASE	Computer-aided software engineering
CCM	Critical Chain Method
CPM	Critical Path Method
CRM	Customer Relationship Management
DCI	Discovery Configuration and Initialization
DNS	Domain Name System
DOD	Department of Defense
DoS	Denial-of-Service
EAN	European Article Number
EC	European Commission
EPC	Event-driven Process Chain
EPCIS	EPC Information Services
ERM	Entity Relationship Modeling
ERP	Enterprise Resource Planning
FDX	Full-duplex mode
HDX	Half-duplex mode
SEQ	Sequential procedures
FIFO	First-in-First-out
ft	Feet
Gen 2	Generation 2
GHz	Gigahertz
GS1	Global Standard 1
HF	High Frequency
IC	Integrated Circuit
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IFF	Friend or Foe

IIoT	Industrial Internet of Things
IoT	Internet of Things
IP	Internet Protocol
IPRRC	Initiation, Planning, Realization, Review, Closing
IS	Information Systems
ISO	International Standards Organization
IT	Information Technology
KHz	Kilohertz
LAN	Local Area Network
LES	Logistic Execution System
LF	Low Frequency
LLRP	Low Level Reader Protocol
M	Meter
MaRSI	Management of RFID System Implementation
MBA	Master of Business Administration
MHz	Megahertz
MIT	Massachusetts Institute of Technology
ONS	Object Naming Service
OS	Operating System
PERT	Program Evaluation and Review Technique
PLC	Public Limited Company
PLM	Product Life Cycle Management
PMBOK	Project Management Body of Knowledge
PMI	Project Management Institute
PRINCE2	Projects in Controlled Environments Version 2
PVC	Polyvinyl Chloride
RFID	Radio Frequency Identification
RM	Reader Management
RS232	Recommend Standard 232
RUP	Rational Unified Process
SCM	Supply Chain Management
SDLC	System Development Lifecycle
SME	Small and Medium-sized Enterprise
SWEBOK	Software Engineering Body of Knowledge
TDS	Tag Data Standard

TDT	Tag Data Translation
UHF	Ultra High Frequency
UII	Unique Item Identifier
UK	United Kingdom
UML	Unified Modeling Language
UP	Unified software development process
US	United States
USA	United States of America
V-Modell-XT	Process model for IT systems development eXtreme Tailoring
WBS	Work Breakdown Structure
WLAN	Wireless Local Area Network
WMS	Warehouse Management System
XP	Extreme Programming

1 Introduction

The radio frequency identification (RFID) technology is a promising technology for optimization of supply chain since its first implementations in 2004.[1] Whereas, primary reasons for adoption of RFID in supply chain are cost reduction, risk management, supply chain transparency, and customer proximity and demands.[2] This research focuses on specific issues of food manufacturing enterprises related to RFID technology adoption, for example, in case of customer proximity and demands. As RFID is an innovative technology[3], the enterprises were confronted with typical management concerns[4] of compatibility and applicability of RFID and capability of existing IT.[5] From practical point of view, the research aimed to explore economic and technical feasibility of RFID along with optimization potentials of the technology in intra-logistics. From academic point of view, it was aimed to develop an approach that addresses specific issues and requirements of the respective domain.

This research consists of two projects with a focus on RFID implementation and RFID implementation issues involving two enterprises, and a project addressing pallet management in intra-logistics of respective domain involving four enterprises. The research on RFID system implementation was started in cooperation with a medium-sized food manufacturing enterprise, and advanced with a large food manufacturing enterprise and the network of food businesses of Saxony-Anhalt[6]. The food manufacturing industries of the region are characterized as companies with low-priced and sometimes liquid containing products, less documented logistics processes, and less influence in the supply chain.

Starting with problem description, the following sections portray research objectives, research methodology, and dissertation structure.

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[1] For optimization potentials of RFID in supply chain see Chapter 2.

[2] For trends in supply chain management see studies: Straube/Pfohl 2008, IBM 2009, Nair et al. 2015, Purdy/Davarzani 2015.

[3] For innovativeness of RFID in supply chain see Chapter 2.

[4] For business concerns in dealing with new technologies see Leonard-Barton/Kraus 1985 and Dietrich/Schirra 2005, 21-22.

[5] For business concerns in dealing with RFID technology see Banks et al. 2007, 18.

[6] Netzwerks Ernährungswirtschaft Sachen-Anhalt, http://www.netzwerk-ernaehrungswirtschaft.de (last accessed 05.05. 2016).

1.1 Problem Description

RFID technology possesses high potential for optimization of supply chain processes [Franke/Dangelmaier 2006; Schuster et al. 2007, 49; Hedgepeth 2007, 4–9] and creation of new opportunities [Nair et al. 2015; Lasi et al. 2014; RFIDimBlick 2015; Purdy/Davarzani 2015]. Historically, early initiatives of RFID system implementations in supply chain were taken by large retailers such as Wal-Mart in United States of America (USA), Tesco in United Kingdom (UK), and Metro Group in Germany in 2004 and 2005 [Franke/Dangelmaier 2006, 79; InformationsforumRFID 2006; Hedgepeth 2007, 3]. Studies on trends in supply chain management show that RFID technology is seen as problem solving technology for supply chain issues [BVL 2008; IBM 2009], a building block for internet of things (IoT), and the backbone for Industry 4.0 or industrial internet of things (IIoT)[7] [Nair et al. 2015; Purdy/Davarzani 2015; Lasi et al. 2014; RFIDimBlick 2015]. However, manufacturing industries, particularly with low-priced products, are still skeptical about investments in RFID technology [Nair et al. 2015, 7–8].

The reviews [Khan 2015][8] and studies[9] of the author showed that appropriate approaches are crucial for food manufacturing industries for the purpose of RFID system implementation along with general knowledge of RFID technology, enterprise willingness to change, and economic profitability. The reviews reveal that there are different facets of an RFID system implementation and consequently different approaches for respective purposes.[10] These facets involve different perspectives by enterprise size, differences by business domain, and variation by approach focus (e.g. project management, system development, or economic analysis). The state of the art reviews show that project management aspects of RFID system implementations are inadequately addressed at present as discussed in section 4.2. Furthermore, none of the approaches address specific requirements of the food manufacturing enterprises as described in section 4.1 [Khan 2015].

In view of that, this dissertation presents a reference model for management of RFID system implementations focusing on food manufacturing industries.

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[7] i.e. fourth industrial revolution as called in Germany and industrial internet of things (IIoT) as called e.g. in UK.

[8] For state of the art of RFID technology and implementation approaches see also chapters 2 and 4.

[9] See Sections 6.2 and 6.3.

[10] For state of the art of approaches see also sections 2.2 and 4.2.

Hypothesis: Appropriate approaches that consider multiple facets of RFID system implementations increase understanding of RFID technology (i.e. knowledge development), ease decision making of an RFID implementation (i.e. willingness), and reduce cost and complexity of RFID system implementations (i.e. effectiveness and efficiency).

The resulting model aims appropriateness for the respective domain by addressing management concerns, management perspectives and domain specific requirements.[11]

1.2 Research Objectives

The research follows a practice-oriented research approach. In response to the practical issues of respective enterprises and research gaps, it was aimed to provide solutions to the problems of the enterprises and develop approaches that help in preparation of an RFID system implementation. Preparation, in the context of RFID system implementation for respective domain, refers to development of knowledge of RFID implementation involving technology and approaches, identification of rationalization potentials of enterprise internal supply chain, exposure of economic feasibility of the technology, and design of an RFID system.

The research and consequently the research objectives evolved over time. Initially, the aim of the research was providing solutions to the issues of the medium-sized food manufacturing enterprise and development of a model for RFID system implementation.[12] Subsequently, it was intended to improve the model in order to provide solutions to the issues of a large food manufacturing enterprise and the respective domain of food manufacturing industries.[13]

In general, RFID system implementations are business or technology driven initiatives involving issues of management (e.g. stakeholder and domain requirements) and technology (e.g. RFID characteristics).[14] The process of RFID system implementation is a multifaceted process and the implementation objectives of enterprises vary depending on business strategy and context. This, consequently, results in complexity of RFID projects [Khan 2015]. Implementation of RFID technology is a business initiative and management concern for the food manufacturing enterprises. From management point of view, an RFID

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[11] See Section 4.1.

[12] See Section 6.2.

[13] See Section 6.3.

[14] See Section 2.3.2.

system implementation as innovative project requires consideration of compatibility, applicability and profitability of RFID technology as well as RFID implementation approaches, and capability of information technology in place. Accordingly, the focus of the research remained on preparation aspects (i.e. management concerns) and intra-logistics.

The state of the art reviews of the author revealed that there are few approaches available that focus on system development (i.e. technical concerns) and economic feasibility (i.e. management concerns) [Khan 2015].[15] However, management aspects of RFID system implementations are not addressed properly at present.[16]

In view of that, this research presents a reference model that explicates management and technical concerns according to different viewpoints of stakeholders in order to reduce the complexity of RFID system implementations. The reference model primarily focuses on management concerns. It addresses management of RFID system implementations aiming efficiency and effectiveness in consideration of various business objectives of respective domain.

The dissertation titled as "*Reference Model for Management of RFID System Implementations*" is based on the concepts of project management and IT project management involving, for example, theories of system, requirements and software engineering, and principles of economics. It aims to answer the following questions.

a. How an RFID system implementation can be managed?
b. How an RFID system implementation can be managed in consideration of various business requirements of a domain?
c. How an RFID system implementation can be managed in consideration of various stakeholder requirements?
d. How an RFID system implementation can be managed in consideration of internal supply chain requirements?

The need for the reference model was realized during reviews of current approaches and practice-oriented research on RFID system implementation. Accordingly, the practice-oriented research, reviews of relevant literature, and the experience of the author make the foundation of the reference model.

The reference model includes a frame of reference, a process model, input and output templates, and tools and techniques. The frame of reference is an abstract frame that aims

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[15] See also Sections 2.2 and 4.2.

[16] See Section 4.2.

fundamental understanding and provides guidance in project work. It covers five perspectives (i.e. strategy, project, process, change, and technology) and five management processes (i.e. initiation, planning, realization, review, and closing). The perspectives are plotted against processes that form the views of organization along management levels and organization along RFID system implementation process. The process model divides the work of RFID system implementation in phases and activities, where the work of management and system development are separated. Accordingly, management work consists of project starting, methodical planning, organizational planning, organizational work realization, review, and closure, whereas system development work involves technical work realization, which is integral part of RFID system implementation management. The process model applies scheduling strategies of requirements and resources of the project work. The activities of process model are supported by inputs and outputs for the purpose of applicability and comprehensiveness. The inputs and outputs are provided as templates involving business case, requirements list, charter, plan with iteration plans, RFID system, status report, lessons learned document, and final report. Furthermore, tools are techniques are provided to realize the work of project management. These include requirements engineering techniques, communication methods, reference modeling techniques, scheduling techniques, budget estimation techniques, process and system improvement techniques, and inspection and review techniques. The reference model is applied and improved in two projects "real life context" in order to achieve enterprises' objectives. The practice-oriented research showed that appropriate approaches for RFID system implementation increase understanding of RFID implementations and consequently ease decision making of RFID system implementation. Furthermore, sophisticated management of RFID system implementations ensures efficiency and effectiveness.[17]

The resulting model is an artifact of design-oriented information system research that applies reference modeling approach for construction. The model itself, application of reference modeling to project management, and the context of RFID system implementation are innovative and the contribution of this research to information systems or Wirtschaftsinformatik. The reference model addresses practitioners of food manufacturing industries, primarily, top manager (i.e. decision maker), and project manager. It also provides guidelines for logistics managers, change managers, and

[17] See Chapter 5 and 6.

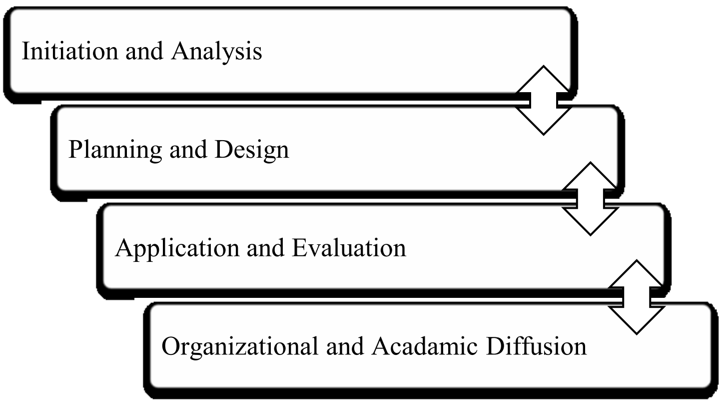
technology managers of the focused industries, specialists of related technologies, and researchers of related disciplines.

1.3 Research Methodology

The research in information systems (IS) concentrates on interdisciplinary issues of business by designing the business realty in a code of practice. Its statements are normative and judgmental that generates solution oriented models and procedures for businesses [Heinrich et al. 2011; Hess 2010; Gutzwiller 1994]. Basically, two different types of approaches are used for the purpose, namely behavioristic or behavioral science approach and design-oriented or design science approach [Österle et al. 2010, 1–4; Hevner et al. 2004, 75–105]. The behavioristic approach aims observation of organizational[18] and human behavior, whereas design-oriented approach focuses on design of innovative information systems and artifacts [Österle et al. 2010, 1–4; Peffers et al. 2008, 45–77].

The design-oriented information systems research approach consists of analysis, design, evaluation and diffusion phases that are conducted iteratively. The research methods used in design-oriented information systems research originate from business, social, computer, and engineering sciences. For exploration during analysis phase, it applies methods such as surveys, reviews, case studies, expert interviews. For artifact design, the design-oriented information systems research typically uses demonstration or prototype construction, modeling with CASE tools, method engineering, and reference modeling methods. The evaluation of an artifact is performed through laboratory experiments, pilot applications, simulation procedures, expert reviews, and field experiments [Österle et al. 2010, 3].

Figure 1: Research Methodology



Source: According to Österle et al. 2010, 3.

This research is a practice oriented research that is initiated by the author and based on mutual interest of food manufacturing industries. The research applies a systematic and

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[18] i.e. IS characteristics.

iterative process to design and apply artifacts for solution of the practical problems. Accordingly, it involves three iterations of analysis, design, evaluation and diffusion phases as shown in figure 1. The construction process of the model is illustrated in section 6.1 of the dissertation.

The research used methods such as literature reviews [Khan 2015], on-site surveys and interviews,[19] and case studies[20] for exploration during analysis phase. The method of reference modeling is applied for construction of research artifact during design phase. Reference modeling provides means of construction and problem solving for innovative models and technologies, for example, by analogy. It facilitates efficient and effective ways of application of constructed models for example by specialization.[21] Reference modeling is a suitable method for solutions of business and management concerns in the context of information systems. In evaluation[22] phase of the research, the constructed model is instantiated in two "real life" contexts (i.e. food manufacturing industries) as field experiment and assessed[23] against specific requirements[24]. The diffusion of results occurs through instantiation and presentations in food manufacturing enterprises, presentations at Universities[25], a scientific paper, and this dissertation.

1.4 Dissertation Structure

The dissertation is structured in three parts consisting of seven chapters. The first chapter discusses research motivation and problem description referring to optimization potentials

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[19] See Sections 6.2 and 6.3.

[20] See Section 2.1.1.1.

[21] See Section 3.2.

[22] Validation is the "process of evaluating a system or component during or at the end of the development process to determine whether it satisfies specified requirements" (see IEEE 90). Institute of Electrical and Electronics Engineers (edt.) IEEE std. 610.12-1990: IEEE standard Glossary of software engineering Terminology. IEEE Standards Association, Piscataway 1990. Models' evaluation requires a systematic approach involving possible variety of requirements and specific constrains for (re-) usability (Frank 2007, 119-123).

[23] It aims to provide mid-range or substantive theory – evaluation from theoretical perspective. See Järvinen, Pertti 2007 for assessment against criteria of values and utility (in action research is similar to design science).

[24] See Section 4.2.

[25] This includes presentation of work in seminars at University of Leipzig, and presentations at Anhalt University of Applied Sciences and Dresden University of Technology (see [Hamke/Huss] Hebezeuge Fördermittel, Berlin 51 (2011) 9, ISSN: 0017-9442 A 06792).

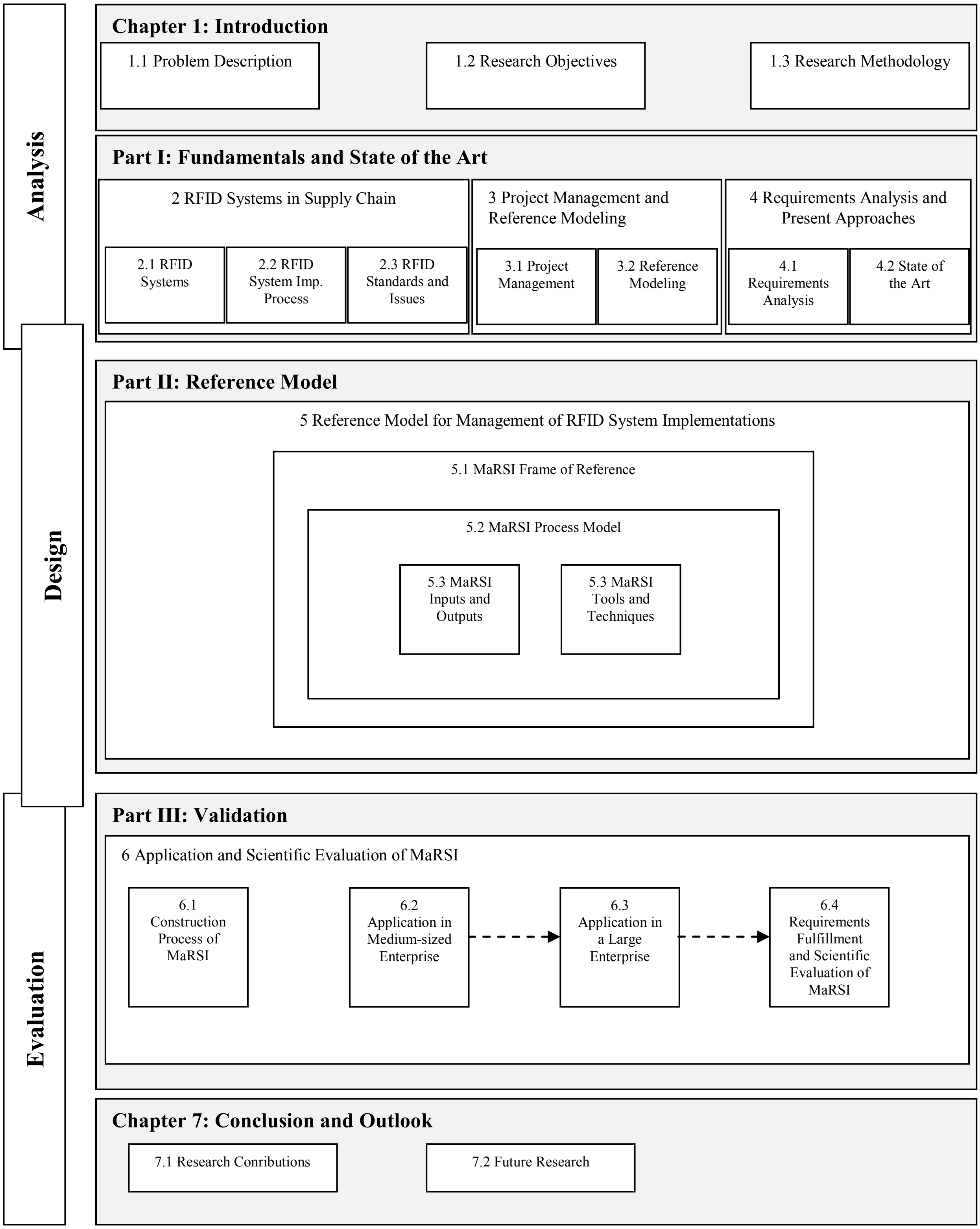
of RFID in supply chain and related issues of the food manufacturing enterprises. Subsequently, research objectives and methodology are described.

The first part covers chapters two, three, and four. The chapter two involves fundamentals and state of the art of RFID systems in supply chain involving discussion of various RFID systems components and variation in RFID system implementation processes by examples. The chapter closes by providing an overview of current standards and the issues during RFID system implementation (i.e. supply chain, management, technological, and security issues). In view of RFID system implementation issues, chapter three makes the foundation to describe management of RFID system implementation by providing outline of project management and reference modeling with standards and methodologies of project management and reasons for appropriateness of reference modeling for the purpose. The chapter four discusses requirements of management of RFID system implementations for respective domain and evaluates current approaches for the purpose.

The second part consists of chapter five. In chapter five, the reference model for management of RFID system implementation (MaRSI) is presented. The MaRSI model focuses on planning, organization, and realization of RFID system implementation activities by delivering appropriate knowledge in respect of specific requirements and explicit concerns in order to increase understanding and ease decision making of RFID technology deployment.

The third part of the dissertation covers chapter six and seven. The chapter six involves validation of the model that is occurred during and at the end of the construction process satisfying specific requirements of the food manufacturing industries (i.e. application in enterprises) and scientific rigor (i.e. compliance with rigorous requirements). The last chapter, chapter seven, concludes the dissertation and provide future outlook. The structure of the dissertation is visualized in the following figure.

Figure 2: Structure of the Dissertation



Part I: Fundamentals and State of the Art

2 RFID Systems in Supply Chain

Radio frequency identification (RFID) is an Auto-ID technology. RFID uses radio frequency or magnetic field technology for identification of tag carrying items with real-time data transfers and without physical and visual contact. It possesses high potential for optimization of business and logistics processes. The technology facilitates bulk identification, usability in harsh environment, storage of larger data volume, reading without line of sight, longer read range, real-time data transfers, and reprogramming [Glover/Bhaṭṭ 2006, 10–16; Schuster et al. 2007, 49; Blecker/Huang 2008, 3; Franke/Dangelmaier 2006; Hedgepeth 2007, 4–9].

A simple RFID system consists of a tag, a reader, a middleware and a backend system. The communication between tag and reader occurs via radio frequency (e.g. UHF 868 MHz), between reader and middleware via protocols (e.g. IP), and between middleware and backend information system via LAN or WLAN (e.g. RS232 or 802.11b/g) [Thornton et al. 2006, 13; Glover/Bhaṭṭ 2006, 1–4; Banks et al. 2007, 6-18, 61, 79; Tamm/Tribowski 2010, 13].

An RFID system in supply chain also involves logistics units (e.g. pallets) and application logic (e.g. warehousing). In supply chain management, RFID systems are applied for various purposes and in different application areas. For instance, RFID is applied for [Glover/Bhaṭṭ 2006, 10–17] access control (e.g. access of a vehicle to certain area), tag and ship (e.g. tagging of an item only for identification), pallet and carton (e.g. for bulk identification and tracking), track and trace (e.g. during transport and warehousing), and smart shelf (e.g. to track single items in retail shelves).

Typically, the compositions of RFID systems vary depending on business objectives and application area. RFID systems operate at different frequencies ranging from LF 125 kHz, HF 13.56 MHz, and UHF 868 MHz to microwave 2.5 GHz and with different functionalities involving reading range, coupling mechanisms, data transfer rate, and access techniques [Schuster et al. 2007, 27; Banks et al. 2007, 126; Curty et al. 2007, 38–46]. Based on energy supply, RFID tags are differentiated between active and passive tags. Active tags possess batteries. In case of passive tags, RFID reader is responsible for power supply [Curty et al. 2007, 37, 117; Glover/Bhaṭṭ 2006, 32; Tamm/Tribowski 2010, 13]. Physically, RFID tags' material varies from paper to PVC and glass [Glover/Bhaṭṭ 2006, 58]. RFID readers differentiate on the basis of application requirements such as management console, application and hardware interfaces, tag densities and reader mobility [Banks et al. 2007, 79]. The functionality of an RFID middleware varies from simple integration in information system (e.g. ERP, WMS), to unnecessary and faulty data filter, and readers management and control [Meiß/Hossain 2006].

Historically, the birth of radio detection and radar (ranging) systems is seen as the birth of radio frequency technologies. The concept of automatic identification using radio transponder was invented and first used in World War II. It was named as Identification of Friend or Foe (IFF) for differentiation of enemy aircraft. The basic principle behind IFF and RFID is the same i.e. using radio frequency or magnetic field technology for identification [Glover/Bhaṭṭ 2006, 10–16; Thornton et al. 2006, 8].

Commercially, RFID technology implementations began in 1980s, whereas RFID systems development for supply chain management, asset management, and formation of standards for RFID technology continued until late 1990s [Hedgepeth 2007, 3–4; Hunt et al. 2007, 27–29]. In 1999, the Auto-ID center at Massachusetts Institute of Technology (MIT) in Cambridge (USA) was founded with the aim to develop standards for the global supply chain. This initiative was undertaken in cooperation with a non-profit organization (i.e. Universal Code Council) and two commercial organizations (i.e. Procter & Gamble and Gillette). In 2003, the activities of Auto-ID center were taken over by EPCglobal Inc. and Auto-ID Labs. In the same year, Global Standard 1 (GS1) International came into being by the merger of Universal Code Council and EAN International. Soon after, EPCglobal Inc. and Auto-ID Labs were incorporated in GS1 International. The adoption of RFID technology in supply chain was initiated by the Wal-Mart in USA and US Department of Defense (DOD), which was followed by the Metro Group in Germany and Tesco public limited company (PLC) in UK in 2004 [Gillert/Hansen 2007, 25–29; Hunt et al. 2007, 3].

Thereafter, RFID technology is becoming a standard technology in supply chain management [Gillert/Hansen 2007, 10; Tamm/Tribowski 2010] and is a building block for internet of things (IoT) and the backbone for Industry 4.0 or industrial internet of things (IIoT) [Nair et al. 2015; Purdy/Davarzani 2015; Lasi et al. 2014; RFIDimBlick 2015]. RFID systems in supply chain are discussed in detail in the following subsections.

2.1 RFID Systems

RFID technology is used for various purposes in supply chain such as bulk identification, usability in harsh environment, storage of larger data volume, reading without line of sight, longer read range, real-time data transfers, and reprogramming [Glover/Bhaṭṭ 2006, 10–16; Schuster et al. 2007, 49; Blecker/Huang 2008, 3; Franke/Dangelmaier 2006; Hedgepeth 2007, 4–9]. RFID systems differ depending on application contexts involving different frequencies, different types and functionalities of tags and readers, and different functionalities of middleware [Schuster et al. 2007, 27; Banks et al. 2007, 79, 126; Curty et al. 2007, 37-46, 117; Glover/Bhaṭṭ 2006, 32, 58; Tamm/Tribowski 2010, 13; Meiß/Hossain 2006]. An RFID system in a warehouse, for example, can consist of moving items (e.g. pallets) tagged with RFID tags that communicate with RFID readers while handling via radio frequency in order to transfer the tags data to RFID middleware via IP network, which is further connected via IP network to backend information system (e.g. ERP) [Hansen/Gillert 2008, 121, 133–137].

In order to structure RFID systems, [Thiesse/Gross 2006] based on [Alt et al. 2004] describe RFID architecture with the help of three levels i.e. infrastructure level, integration level, and application level. The infrastructure level comprises RFID hardware components (i.e. tags, readers) for identification of physical objects of processes (e.g. supply chain processes). The integration level consists of middleware components for connection of readers to application system of an enterprise and for processing of RFID data (e.g. filtering, correction of false reads, and transformation of format). The application level covers application components (e.g. enterprise information systems) that process received RFID information upon occurrence of events in physical processes and exchange RFID related information with further information systems i.e. internal as well as external to enterprise [Thiesse/Gross 2006, 181]. [Liu et al. 2010] provide a detailed view of RFID systems in supply chain management involving logistics environment (e.g. warehouse), infrastructure (i.e. RFID devices, computer, OS and network), RFID middleware, logistics data (i.e. real-time logistics management system), logistics management (e.g. procurement, distribution), business data (e.g. relational database), information system (e.g. ERP), and application enterprise (e.g. manufacturer) [Liu et al. 2010, 3280]. In view of this, an RFID system involves application context (e.g. supply chain management), RFID hardware components, RFID middleware components, and application system components. In the following, these aspects are discussed in detail from implementation point of view.

2.1.1 Supply Chain Management

In the context of RFID implementation, supply chain management belongs to physical infrastructural level (i.e. supply chain level) covering application logic, logistic entities and storage systems. In general, the definition of supply chain management diversifies significantly with the focus of enterprise activities [Cohen/Roussel 2005, 67; Cordon et al. 2012, 5]. The terms supply chain management and logistics are used as synonyms on one hand [Baumgarten 2008; BVL e.V.]. On the other hand, a differentiation is made between these two terms [Werner 2000, 5, 10; Arndt 2008, 37, 47]. According to Werner (2000), logistics deal only with physical flow of materials within an enterprise or between enterprises, whereas supply chain management involves also external information and financial flows [Werner 2000, 5, 10–11]. Arndt (2008), however, describes logistics as the flow of information, materials and products involving internal or internal and external logistics [Arndt 2008, 37, 47]. Stadtler and Kilger (2005) provide a process oriented definition of supply chain management that is "*the task of integrating organizational units along a supply chain and coordinating material, information and financial flows in order to fulfill (ultimate) customer demands […]*" [Stadtler/Kilger 2005, 10–11]. Baumgarten (2008) uses supply chain management and logistics synonymously and includes integral planning, execution, controlling and coordination of enterprise internal as well as external flows of goods and information in the definition [Baumgarten 2008, 11–19]. Nevertheless, the objective of the supply chain management or logistics remains achievement of competitiveness, effectiveness and efficiency by integration and coordination of flows [Stadtler/Kilger 2005, 10–11; Werner 2000, 7–11; Arndt 2008, 151–212; Cordon et al. 2012, 7–9; Baumgarten 2008, 11–19].

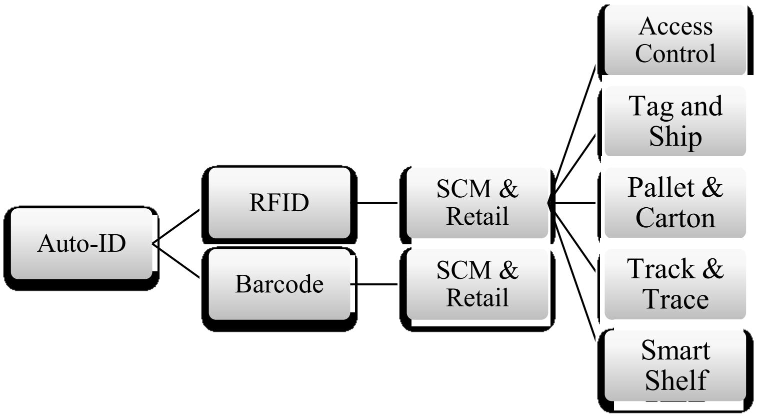
In view of that, it is necessary to specify supply chain management in the context of this dissertation. The terms supply chain management and logistics are used synonymously in this work. For RFID implementation, it involves enterprise internal (i.e. intralogistics[26]) as well as external (i.e. between enterprises) flows of goods and information. An internal supply chain covers goods and information flows from arrival to dispatch of an enterprise (e.g. internal transport, warehousing).

An effective and efficient supply chain management requires development of collaborations (i.e. internal and external integration), deployment of information and communication technologies, and management of change among others in order to be competitive [Arndt 2008, 151–212; Stadtler/Kilger 2005, 10–11; Werner 2000, 7–9]. RFID technology possesses high potential for optimization of business and supply chain processes. It facilitates bulk identification, usability in harsh environment, storage of larger data volume, reading without line of sight, longer read range, real-time data transfers, and reprogramming [Glover/Bhaṭṭ 2006, 10–16; Schuster et al. 2007, 49; Blecker/Huang 2008, 3; Franke/Dangelmaier 2006; Hedgepeth 2007, 4–9]. In practice, RFID is applied for various purposes such as access control (e.g. access of a vehicle to certain area), tag and ship (e.g. tagging of an item only for identification), pallet and carton (e.g. for bulk

[26] Intralogistics involves internal material and information flows of an enterprise see https://www.logistics-journal.de/about/intralogistics (last accessed 05.06. 2016).

identification and tracking), track and trace (e.g. during transport and warehousing), and smart shelf (e.g. to track single items in retail shelves) [Glover/Bhaṭṭ 2006, 10; Finkenzeller 2008, 1–9] as illustrated in figure 3.

Figure 3: Example of Auto-ID Technologies and SCM Applications



Source: Adapted from Glover/Bhatt 2006, 4-9, Finkenzeller 2008, 1-9.

Analysis of the author reveals that the reasons for this variation are different business objectives, business problems and application logics as well as the use of various logistic entities and storage systems. The following examples highlight these aspects of RFID implementation.

2.1.1.1 Implementation Objectives and Application Logics

RFID technology was applied by Manor AG for product safety and monitoring in order to avoid spoilage of food products. The company was facing problems in prevention of using expired raw materials in food manufacturing as well as spoilt food products in retail [RFIDatlas-Manor 2006]. Spar AG applied RFID in retail for traceability of food in warehouse according to European regulation (EC No. 178/2002)[27] by allotting food products to transport units (i.e. roll cases) [Spar Smart Warehouse]. The technology is also used for dry milk products by Sachsenmilch AG that focused on tracking and tracing container, transparency in material and container flow, back flow of special containers in due time, realization of saving potentials, reduction of cost in container loss, automation of positioning of container, and optimal usage of special container for capacity increment or new products [RFIDatlas-Sachsenmilch 2006]. Some enterprises see inventory optimization as an important aspect for RFID implementation in internal supply chain [InformationsforumRFID 2006; RFIDatlas-BLG Logistics 2006], while others apply RFID technology only for external supply chain activities [InformationsforumRFID 2006]. Many companies use RFID along with barcode technology either because of granularity of

[27] See Regulation (EC) No 178/2002.

implementation such as pallet or container level tagging [RFIDatlas-Internom 2006] or because of physical environmental factors such as potentially explosive materials or both in the case of Berliner Wasserbetriebe [Wessel 2007].

2.1.1.2 Logistic Entities and Storage Systems

From implementation point of view, an RFID system in supply chain at physical level encompasses logistics entities and storage systems along with RFID tags and readers. Logistic entities include transport vehicles and transport units such as conveyor belts, forklifts, pallets and boxes. Storage systems involve pallet racks and other warehousing facilities. The appearance of logistic entities and storage systems is relevant for RFID hardware (i.e. tags and readers) installation, for example, in respect of tag reading and environmental influences [Pfohl 1996, 148–149; Martin 2014, 74–83].

2.1.2 RFID Hardware

RFID hardware components consist of tags and readers that belong to physical infrastructure level of RFID architecture. In general, RFID systems operate at different frequencies ranging from LF 125 kHz, HF 13.56 MHz, and UHF 868 MHz to microwave 2.5 GHz, and work with different functionalities such as reading range, coupling mechanisms, data transfer rate, and access techniques [Schuster et al. 2007, 27; Banks et al. 2007, 126; Curty et al. 2007, 38–46]. RFID tags are either with or without internal battery [Finkenzeller 2002, 23–25; Hansen/Gillert 2008, 168–169; Tamm/Tribowski 2010, 15; Glover/Bhaṭṭ 2006, 35; Banks et al. 2007, 62–65]. RFID tags and readers possess various storage capacities and physical forms [Finkenzeller 2002, 14-22, 28; Hansen/Gillert 2008, 165–166; Glover/Bhaṭṭ 2006, 36, 58]. The following subsections provide details of RFID hardware components.

2.1.2.1 RFID Tags

RFID tags consist of an integrated circuit (IC) and antenna and possess different operating frequencies, coupling mechanisms, power supplies, storage capacities, sizes, shapes and standard compliances [Glover/Bhaṭṭ 2006, 32–34; Thornton et al. 2006, 13–26; Banks et al. 2007, 61–78; Hansen/Gillert 2008, 163–169; Tamm/Tribowski 2010, 15–17]. These differences affect functionality and cost of RFID tags.

Frequencies

RFID systems operate at different frequencies. These frequencies range from low frequency or LF 125 kHz, high frequency or HF 13.56 MHz, and ultra high frequency or UHF 868 MHz to microwave 2.5 GHz as shown in table 1. The frequency of a system has an effect on tag antenna form and reading range. For instance, high and ultra high frequencies are used in supply chain for identification of single items and bulk identification delivering different performances. HF RFID tags consist of coiled antenna and use magnetic fields for signal transfer, whereas UHF RFID tags possess dipole antenna and use electromagnetic waves for communication. The performance of RFID tags is measured on the basis of reading range, data transfer rate, bulk reading and sensitivity to environment that is typically influenced by frequency, field strength or power of reader antenna, tag orientation, and shape and size of tag antenna [Finkenzeller 2002, 22–23; Hansen/Gillert 2008, 163–165]. The following table provides a summary of typical applications of RFID frequencies.

Table 1: Typical Applications of RFID Frequencies

Frequency	Operating Range	Typical Applications	Benefits	Drawbacks
LF-125 kHz	< 0.5M or 1.5ft.	• access control • animal tracking • lot identification • chemical process use • vehicle immobilizers / distribution • product authentication • POS applications	works well around water and metal products	short read range and slower read rates
HF-13.56 MHz	< 1M or 3ft.	• smart cards • retail / smart shelve tags for item level tracking • library books • airline baggage • maintenance data logging • logistic warehouse management • automotive manufacturing and tracking • hospitals • security • parcel tracking	low cost of tags	slower read rate than UHF
UHF-868 MHz	***Passive:*** < 3m or 9ft. ***Active:*** < 100 m and unlimited	• retail • tool road • logistics – in factory and throughout SC • pallet tracking • carton tracking • electronic toll collection • parking lot access • long range applications	same cost as HF systems, EPC standard built around this frequency	does not work well around items of high water or metal content
GHz-2.5 GHz	1m or3 ft.	• airline baggage • electronic toll collection • long range applications • item tracking	most expensive	fastest read rates

Source: Adapted from Banks et al. 2007, 126-141, Hansen/Gillert 2008, 163-165.

Physical Forms

RFID tags are applied on transport units (e.g. pallets, containers) of varying size and shapes and in diverse application scenarios. Therefore, there a variety of shapes, sizes and materials of tags are available. Typically, RFID tags consist of an inlay (i.e. a chip and antenna) and material. The form (e.g. label, capsules) and material (e.g. paper, PVC, glass) types differ for various purposes. For instance, labels are made of paper and might be used instead of barcodes, whereas capsule form of tags are of glass and can be used in liquids and concretes [Finkenzeller 2002, 14–22; Hansen/Gillert 2008, 165; Glover/Bhaṭṭ 2006, 58].

Storage Capacities and Data Modification

On the basis of storage capacity and data modification, RFID tags are classified in single-bit read-only tags, unique item identifier (UII) read-only tags, write-once read many tags, and read-write tags. The single-bit read-only tags store only one bit without chip and are usually used in retail against shoplifting. The UII read-only tags contain a unique multi-bit serial number. For application, these tags are identified by serial numbers that are further associated with item numbers in a database. The write-once read many tags can be coded with not modifiable data such as item numbers and serial numbers for various reads. The read-write tags possess writeable and modifiable storage area for data such as item and process data [Finkenzeller 2002, 28; Hansen/Gillert 2008, 165–166; Glover/Bhaṭṭ 2006, 36].

Power Supply

On the basis of power supply, RFID tags are classified in active, semi-active and passive tags possessing different sources of energies and functionalities with specific application and cost. Active tags have internal battery and are able to generate radio signals (i.e. EPCglobal class 4) or communicate with passive tags (i.e. EPCglobal class 5). They can have a read range of more than 100 meter with the ability to buffer (e.g. sensor data) and transmit data, for example, for monitoring temperature history in a cold chain. Active tags can store instructions and response to various conditions. Typically, they are read-write tags and are used many times [Finkenzeller 2002, 23–25; Hansen/Gillert 2008, 168–169; Tamm/Tribowski 2010, 15; Glover/Bhaṭṭ 2006, 35; Banks et al. 2007, 62–65].

Passive tags are without batteries. The reader is responsible for energy supply. They draw energy and transmit data using the electromagnetic field of the reader antenna. Passive tags possess shorter read range, smaller size and longer life-cycles. They are less expensive than active and semi-active tags. Passive tags can be read-only (i.e. EPCglobal class 0), write-once (i.e. EPCglobal class 1) or rewritable (i.e. EPCglobal class 2). Typically, passive tags are used in supply chain applications, for example, for pallets tracking. They are also used in combination of barcode and for lifetime identification of industrial parts [Finkenzeller 2002, 23–25; Hansen/Gillert 2008, 168–169; Curty et al. 2007, 117; Tamm/Tribowski 2010, 15; Glover/Bhaṭṭ 2006, 35–36; Banks et al. 2007, 66–68].

Semi-active (i.e. EPCglobal class 3) tags possess battery but become active only on entering reader antenna field to amplify the transmitted signal. They are useful for applications that require long reading ranges [Hansen/Gillert 2008, 169; Tamm/Tribowski 2010, 15; Banks et al. 2007, 65–66].

2.1.2.2 RFID Readers

RFID readers are hardware devices that consist of antennas and control system. The readers communicate through antennas with nearby tags with the help of electromagnetic fields. The control system of readers (i.e. software) control antennas of readers and transfer tags data to a higher level of IT system, for example, by LANs or WLANs [Finkenzeller 2002, 318–319; Glover/Bhaṭṭ 2006, 36; Hansen/Gillert 2008, 169].

RFID readers facilitate functionality such as read data from tags, write data on tags, deactivate tags, and anti-collision. RFID Readers are basically similar in operating and design apart from type of coupling (e.g. inductive), communication sequence (e.g. FDX, HDX, SEQ), data transmission procedure i.e. tag to reader (e.g. backscatter, subharmonic), and frequency range [Finkenzeller 2002, 320–321]. They are differentiated on the basis of application requirements such as management console (e.g. central for cross-enterprise solution), application interface (e.g. APIs), hardware interface (e.g. RS232, WLAN), tag densities (i.e. number of tags' reading per second) and reader mobility (e.g. handhelds) [Banks et al. 2007, 79–81; Tamm/Tribowski 2010, 17]. On the basis of reader mobility, RFID readers are classified as stationary and mobile readers [Hansen/Gillert 2008, 169–170; Finkenzeller 2002, 338–339; Scholz-Reiter et al. 2008] as shown in table 2.

Table 2: Types of Stationary and Mobile Readers

Stationary Readers	
Gate Reader	It consists of a reader and antennas that are installed at doors (e.g. warehouse). Stationary reader is designed to ensure reliable identification at large distances with various tag positions and orientations.
Compact Reader	It combines reader and antenna in single housing and is suitable for short distance reads, for example, at warehouse gates.
Mobile Readers	
Vehicle-mounted Reader	It is mounted on vehicles such as forklift and is suitable, for example, for pallet movement in warehouse.
Handheld Reader	Handhelds are easy to handle and suitable for mobile use. They either store data in built-in memory and transfer it after docking or transmit the data via wireless such as WAN.
RFID-enabled Mobile Phones	Mobile phones with near field communication (NFC) can act as RFID reader or tag. NFC-enabled phones can be used in consumer applications such as payment in public transportation as well as industrial applications such as individual parts identification.

Source: Hansen/Gillert 2008, 169-170, Finkenzeller 2002, 338-339, Scholz-Reiter et al. 2008.

The selection of a reader is constrained by selected tag type and its standard compliance. It also requires consideration of the physical environment of operation and compatibility with enterprise IT system [Glover/Bhaṭṭ 2006, 38; Banks et al. 2007, 80; Hansen/Gillert 2008, 170]. The cost of RFID readers varies depending on the type of readers [Tamm/Tribowski 2010, 18].

Coupling Mechanism and Read Ranges

Coupling mechanism is the mean by which a reader and a tag communicate. RFID readers and tags communicate at different frequencies that result in various reading ranges. Consequently, RFID systems are differentiated on the basis of communication frequencies in low frequency (LF, 30-300 KHz), high frequency (HF, 3-30 MHz), ultra high frequency systems (UHF, 300 MHz-3 GHz), and microware (>3 GHz). RFID systems can be classified on the basis of read ranges in close-coupling (LF and HF, 0-1 cm), remote-coupling (LF and HF, 0-1 m), and long-range (UHF, > 1 m) systems. Furthermore, read ranges are affected by energy sources of tags (e.g. with or without battery). Active RFID tags possess internal battery and are not dependent on reader to generate radio signals (range < 100 m and more). Passive RFID tags, however, are dependent on energy provided by the reader (range < 3 m). Accordingly, specific coupling mechanisms are used for different frequencies and tag types with various reading ranges [Finkenzeller 2002, 13, 22–25; Banks et al. 2007, 62-65, 95-101].

For instance, beacons (i.e. transmitter) are used for communication between reader and active tags in real-time location systems (e.g. tracking of automotive parts in large manufacturing facilities) [Banks et al. 2007, 100]. Usually, coupling mechanisms such as backscatter, inductive, magnetic and capacitive are used for communication between reader and passive RFID tags. Backscatter coupling is suitable for higher frequencies such as UHF tags. Inductive coupling is typically used for low and high frequency tags (e.g. 13.56 MHz). Magnetic and capacitive coupling are efficient between 1 to 10 MHz [Glover/Bhaṭṭ 2006, 35, 63]. The physical environment has also effect on reading range. It can cause reflection in case of metals (e.g. aluminum) and absorption in case of liquids (e.g. milk). Electrically conductive surfaces such as iron scatter energy of electromagnetic waves. The read ranges can, however, be enlarged by using reader antennas on metals (e.g. conveyor belt). Liquids such as water and milk absorb energy particularly at high frequencies. The effects of physical environment can result in ineffective reads, reads outside desired reading area, and no reads in desired reading area [Hansen/Gillert 2008, 181]. In addition to this, orientation of tag's antenna and tag movement affect reading range [Finkenzeller 2002, 22–23; Hansen/Gillert 2008, 163–165].

Read Rates

The data volume between reader and tag is measured as read or transmission rates of an RFID system. Higher frequencies of RFID systems facilitate high read rates

[Hansen/Gillert 2008, 181]. According to ISO, the read rates for LF and HF RFID systems are about 5 kbit/s, whereas UHF RFID systems achieve read rates from 50 to 100 kbit/s [Lampe et al. 2005; ISO][28]. Read rates are also significant, for example, for bulk reading. Bulk reading refers to simultaneous reading of two or more tags by an RFID reader [Hansen/Gillert 2008, 181; Banks et al. 2007, 104–107; Lampe et al. 2005]. Anti-collision methods[29] are used to avoid tag collision during communication of RFID reader with two or more tags at a time [Banks et al. 2007, 104–107].

Environmental Influences (on reading)

The communication between RFID tags and readers is realized with the help of magnetic (i.e. below 13.56 MHz) or electromagnetic (i.e. 433, 860-960 MHz or 2.45 GHz) waves. It is influenced negatively, for example, in the presence of liquids, metals or high temperature in physical environment or in the presence of liquid containing material and products or metal containing packaging. In general, the disturbance of radio waves effects identification, read ranges, and transmission/read rates. A summary of environmental influences on RFID systems is provided in table 3 [Hansen/Gillert 2008, 180–183].

Table 3: Potential Environmental Influences on RFID Systems

Electromagnetic Fields	Mechanical	Chemical	Thermal	Weather
Reflective or electrically conductive surfaces, absorbent materials, total RF spectrum (interference frequencies), electrostatic discharge, etc.	Shocks, vibrations, pressure, friction, shear forces, etc.	Oils, cleaning products, lubricants, acids, alkalis, surfactants, solvents, etc.	Operating and storage temperatures (minimum and maximum)	Rain, fog, atmospheric humidity in general, frost, ice, solar irradiation, salty sea air, etc.

Source: Hansen and Gillert 2008, 180-183.

For instance, the tagging objects can cause reflection in case of metals (e.g. aluminum) and absorption in case of liquids (e.g. milk) [Hansen/Gillert 2008, 181] or high densities (e.g. sugar, flour) [Lampe et al. 2005]. These can result in ineffective reads, reads outside desired reading area, and no reads in desired reading area [Hansen/Gillert 2008, 181]. Metal containing logistics units and storage systems disturb electromagnetic waves and

[28] See ISO Standards 15693, 14223, 18000.

[29] Reader anti-collision algorithms (e.g. space division multiple access (SDMA), frequency division multiple access (FDMA), and time division multiple access (TDMA)) and tag anti-collision algorithms (e.g. ALOHA typically for 13.56 MHz and tree-walking for UHF 860-915 MHz) see Banks et al. 2007, 104-107.

weaken coupling between tags and reader that result in no reads or reduced or increased read range. The use of lower frequencies, antenna adjustment or ferrite can help to avoid or reduce these disturbances [Hansen/Gillert 2008, 181; Lampe et al. 2005]. The presence of noise (e.g. by welding plant) and other frequencies (e.g. similar frequencies as RFID system, WLAN, Bluetooth) can also affect the communication between tags and readers negatively [Lampe et al. 2005].

2.1.3 RFID Middleware

RFID middleware components cover software for connection of RFID readers with enterprise information system. RFID middleware belongs to integration level of RFID architecture. The need for RFID middleware is imposed by the large amount of data that is generated by RFID systems and that require real time processing. A main characteristic of RFID middleware is preparation of RFID data according to application requirements in a reliable and secure manner [Ahmed/Ramachandran 2011; Hansen/Gillert 2008, 39, 133–135].

RFID middleware components basically include application-level interface, event manager, and reader adapter [Glover/Bhaṭṭ 2006, 137] that are sometimes designed as edgeware and event middleware [Hansen/Gillert 2008, 121, 133–137]. Depending on perspective, RFID middleware is seen as component or layer in software system. As software component, the functionality of the middleware is to provide transformation of RFID data [Banks et al. 2007, 15–17]. It facilitates communication between decoupled software components as service provider forming an integration level [Thiesse/Gross 2006, 181]. As a layer in software system, an RFID middleware provides abstraction and hides RFID hardware complexity (i.e. technical details) [Ahmed/Ramachandran 2011].

RFID middleware are generally classified on the basis of functionality [Ahmed/Ramachandran 2011]. They provide basic functionalities of data filter, data aggregation, data transformation, and system scalability, whereas control of large data volume as well as RFID readers, and coordination of heterogenic systems are considered as advance functions of RFID middleware [Ahmed/Ramachandran 2011; Melski et al. 2008, 471].

RFID software integration (i.e. middleware and database) requires greater understanding of application scenario and usage environment in comparison to RFID hardware (i.e. reader) in order to ensure business value [Banks et al. 2007, 141; Hansen/Gillert 2008, 133–135]. In this regard, aspects of data storage, retrieval and real-time availability [Banks et al. 2007, 141], buffer functionality for event data, and real-time processing of event data

[Hansen/Gillert 2008, 133–135] require proper consideration during RFID system implementation. RFID middleware requirements are shortly described in table 4.

Table 4: RFID Middleware Requirements

Requirements	Description
Data filter	The middleware must be able to filter rough RFID data in order to avoid multiple reads.
Data aggregation	The middleware must be able to aggregate rough RFID data in order to forward to a higher application level.
Data transformation	The middleware must be able to transform protocols and data formats in order to make them compatible according to application systems.
Data distribution	The middleware must be able to distribute RFID data to application system. This must also be possible in real time.
Data storage	The middleware must provide functionality to buffer RFID data temporary or store permanently for the purpose of analysis.
Reader integration	The middleware must provide integration of readers for reading and writing of RFID tags.
Management and Scalability	The middleware must provide functionality to manage RFID readers, add new RFID readers, or remove RFID readers.
Robustness	The middleware must be able to react in order to correct mistakes or to forward them to higher level application systems automatically and at any time.
Security	The middleware must be capable of data protection in terms of access or modification and misuse of services.

Source: Ahmed/Ramachandran 2011, Melski et al. 2008, 471, Glover/Bhatt 2006, 48-51, Banks et al. 2007, 224-226, Thiesse 2005, 101-117.

2.1.4 Application Systems

Application system components encompass enterprise information systems such as enterprise resource planning (ERP)[30]. Application systems belong to application level of RFID architecture. Enterprise information systems, in general, provide standardized methods for data collection, definition of business rules, integration with other business processes, and integration with other business. However, these systems are applied for specific business needs such as supply chain management. Application systems store RFID data according to business logic [Banks et al. 2007, 252–253].

RFID technology is applied either to replace barcode or to introduce new processes. In case of replacement of barcode, the process logic in application systems may remain unchanged. However, process innovation with the help of RFID (e.g. tracking of pallets) changes the process logic as well as data models in application systems. Application systems process RFID data according to application logic at physical level and forward it to further internal or external application systems in the supply chain [Thiesse/Gross 2006, 184–185].

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[30] including supply chain management (SCM), customer relationship management (CRM), warehouse management system (WMS), product life cycle management (PLM), and logistic execution system (LES).

2.2 RFID System Implementation Process

RFID system implementation process, according to the author, can be defined as a process that serves to design an RFID system for and implement an RFID system in a particular enterprise.[31] An RFID system in supply chain consists of RFID transponders/tags and interrogators/readers installed according to the supply chain management logic, a middleware, and backend enterprise systems.[32] The activities of an RFID system implementation vary because of the differences in focus and objectives of implementations and approaches for implementation. These activities, in general, aim problem definition, requirements formulation, solution concept, solution realization, and continuous operation of the solution.[33]

The studies of the author reveal that an RFID system implementation process is a multi-facet process including, for example, facets of project management, economic analysis, system design, technical implementation, enterprise size, and business domain. The current approaches focusing on RFID system implementation address one or two of these facets, whereas other facets are either excluded intentionally or referred indirectly [Khan 2015]. For example, the methodology by [Borea et al. 2011] focuses on economic analysis of RFID systems in healthcare domain. This methodology addresses two facets of an RFID implementation, namely economic analysis and application domain. Similarly, there are approaches that focus either on special issues such as anti-counterfeiting [Lehtonen et al. 2009] or mathematical models [Decker et al. 2008].

According to the author [Khan 2015], there are several approaches that refer RFID system development and deployment (i.e. [Pigni et al. 2006; Vogeler 2009; Donath 2010]) and economic analysis (i.e. [Vilkov 2007; Bardaki et al. 2008; Rhensius/Dünnebacke 2009]). These are either domain specific or domain independent and involve aspects of enterprise size. There are two approaches that address aspects of project management of RFID system implementations explicitly (i.e. [Gross/Thiesse 2005; Gillert 2008]). The following subsections describe these approaches in order to highlight different facets of an implementation and differences in activities of implementation processes. The discussion focuses primarily on the applicability characteristic of the approaches. The approaches on project management are excluded from the discussion and will be analyzed in detail in chapter 4.

[31] See Chapter 5, Section 5.2.4.

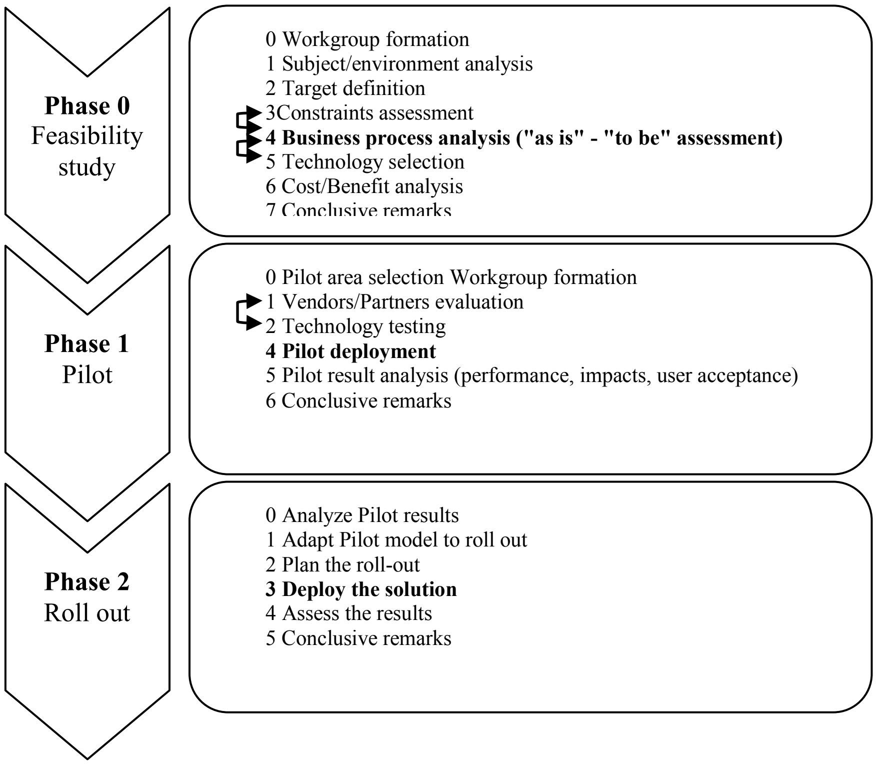
[32] See Chapter 2.

[33] See Sections 2.2.1 to 2.2.6.

2.2.1 Pigni-2006

The guideline by [Pigni et al. 2006] for RFID application in supply chains covers introduction to RFID technology, its applications and its role in supply chains. It suggests a roadmap for RFID implementation as shown in figure 4. The roadmap focuses on supply chains between different business partners. It is intended to evaluate impacts of RFID implementation on business processes, organization, and information systems. The guideline divides an RFID implementation in feasibility study, pilot, and roll out phases. The feasibility study is aimed to address business and economic aspects. The pilot phase covers technological aspects focusing on gradual implementation (i.e. partial solution). The roll out phase involves adaptation of pilot results and deployment of RFID solution.

Figure 4: A Guideline by Pigni-2006



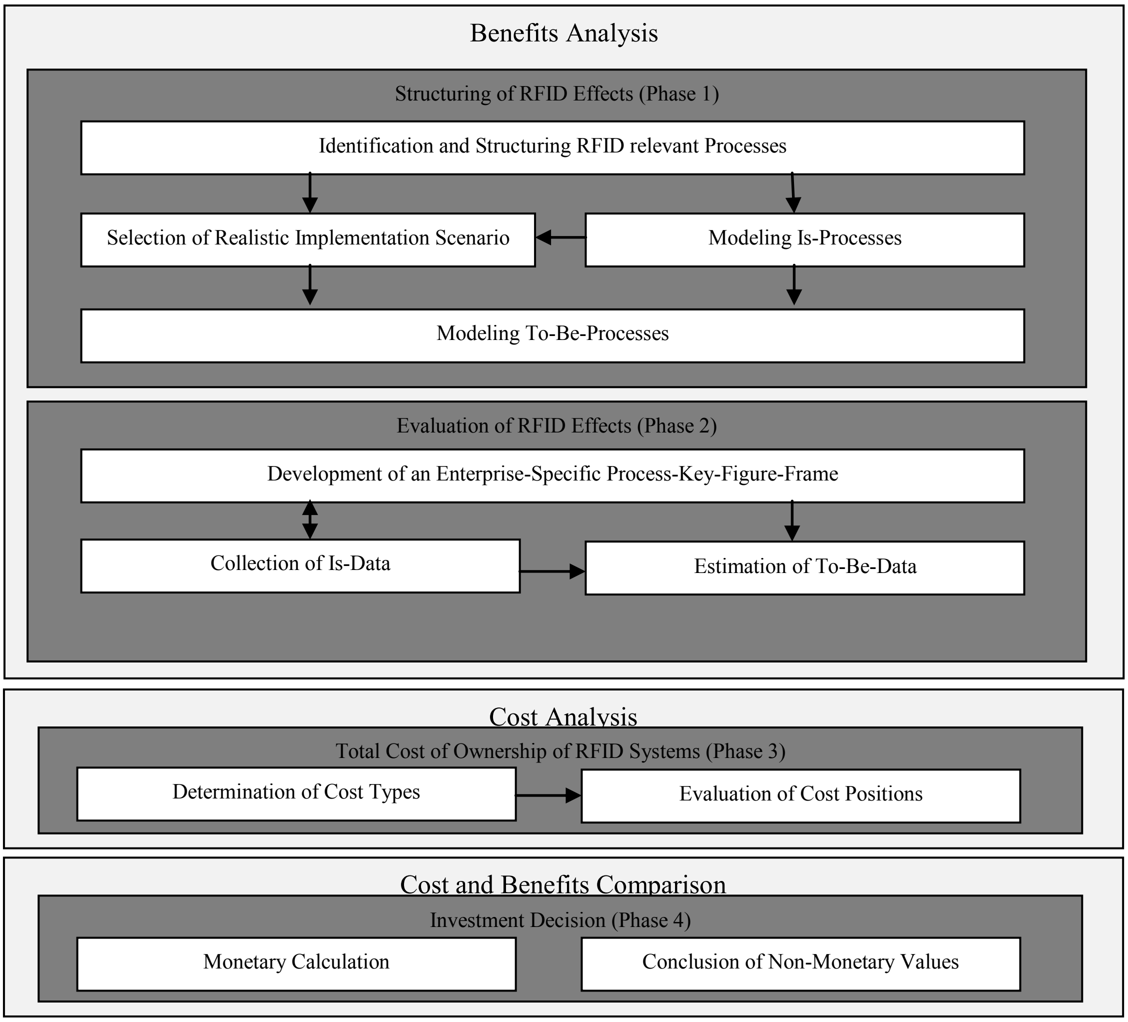
Source: Pigni et al. 2006, 66-86.

The guideline primarily aims to provide support in evaluation of the opportunity to start an RFID project. It provides general guidelines and is industry independent. The roadmap focuses on cost and benefits analysis in the feasibility study phase. It is suggest that cost and benefits analysis should be carried out for each business partner in the supply chain in order to make the decision for “go” or “no go” to pilot implementation. The assumptions made during feasibility study phase are suggested to be tested, for example, for single product in order to facilitate gradual adaptation. For large scale implementation, adjustments of the pilot results are suggested in a general manner. The guideline mentions the facts that RFID hardware and software are easily available “on shelves”, however putting an RFID system together according to application logic is hard. It advises to involve all stakeholders from project initiator to supply chain roles. In terms of applicability, the approach is realizable only with additional knowledge of RFID technology and additional approaches for implementation management and economic analysis.

2.2.2 Vilkov-2007

The approach by [Vilkov 2007] focuses on a process-oriented economic analysis of RFID systems in logistics. It suggests a model that consists of a reference-effect-model and a reference-process-model for the purpose. The reference-effect-model provides a generic database for referential RFID effects on supply chain in order to structure and evaluate benefits. The reference-process-model describes the logical sequence of steps to perform economic analysis of RFID implementations.

Figure 5: The Model by Vilkov-2007



Source: Vilkov 2007, 182.

The reference-process-model consists of four phases, namely structuring of RFID effects, evaluation of RFID effects, total cost of ownership of RFID systems, and investment decision as shown in figure 5. Each phase contain further activities. The approach is designed as universal and operational and requires high technical and methodical skills for the use. As it intends economic analysis, activities of analysis and design of RFID system are not part of the models. In order to be applicable, the approach requires additional approaches for RFID system development and project management.

2.2.3 Bardaki-2008

The approach by [Bardaki et al. 2008] is a preliminary approach that focuses on economic analysis of an RFID implementation. The approach is intended to help design realistic RFID-enabled application scenarios and services in supply chain. It involves two decision variables, namely technical feasibility and economic feasibility. The approach illustrates generic steps of cost specification for RFID system implementation and is applicable only for economic analysis of specific scenarios in supply chain management.

Figure 6: The Approach by Bardaki-2008

A) Mapping of Business Process →
B) Picture of RFID-enabled Business Processes →
C) Identification of Decision Points →
D) Identification of Technical Feasibility →
E) Cost-benefit Assessment of Solution Alternatives →
F) Recommendation of RFID Solution

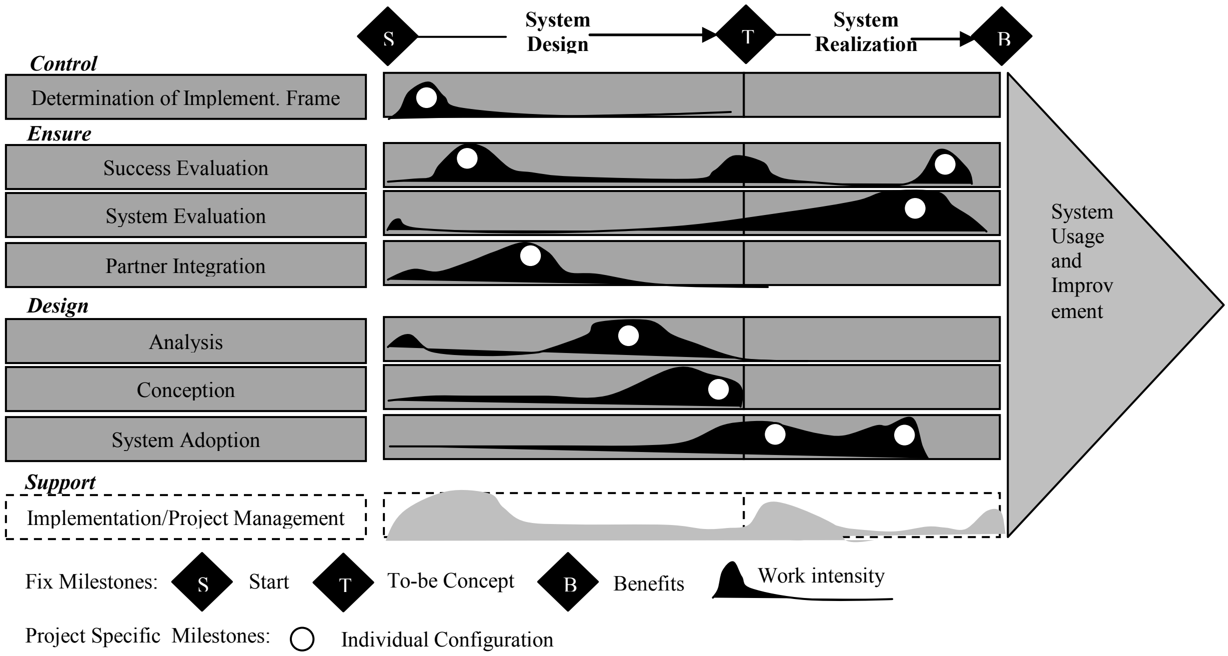
Source: Bardaki et al. 2008, 245-246.

2.2.4 Vogeler-2009

The approach by [Vogeler 2009] specifically focuses on design of a process model for implementation of RFID in logistics of textile retails. The approach suggests seven different activities listed vertically as shown in figure 7. These include determination of implementation frame, evaluation of success, evaluation of system, integration of partner, analysis, conception, and system implementation. The effort of system design and realization is exemplified horizontally. The implementation frame possesses control aspects and covers logistic strategy as well as implementation objectives that are relevant for definition of implementation strategy. The assurance is seen as extension of control providing success evaluation as economic analysis, system evaluation as system tests, and partner integration involving supply chain and system partners as well as relevant departments.

The analysis activity involves understanding of logistics covering weaknesses and potentials. The activities of conception include design of RFID processes (i.e. supply chain) and RFID systems covering infrastructure, integration and application levels. The system adoption involves rollout and operation activities but also personnel training activities. The process model refers to project management activities as supporting activities that are not part of the approach.

Figure 7: The Process Model by Vogeler-2009



Source: Vogeler 2009, 106.

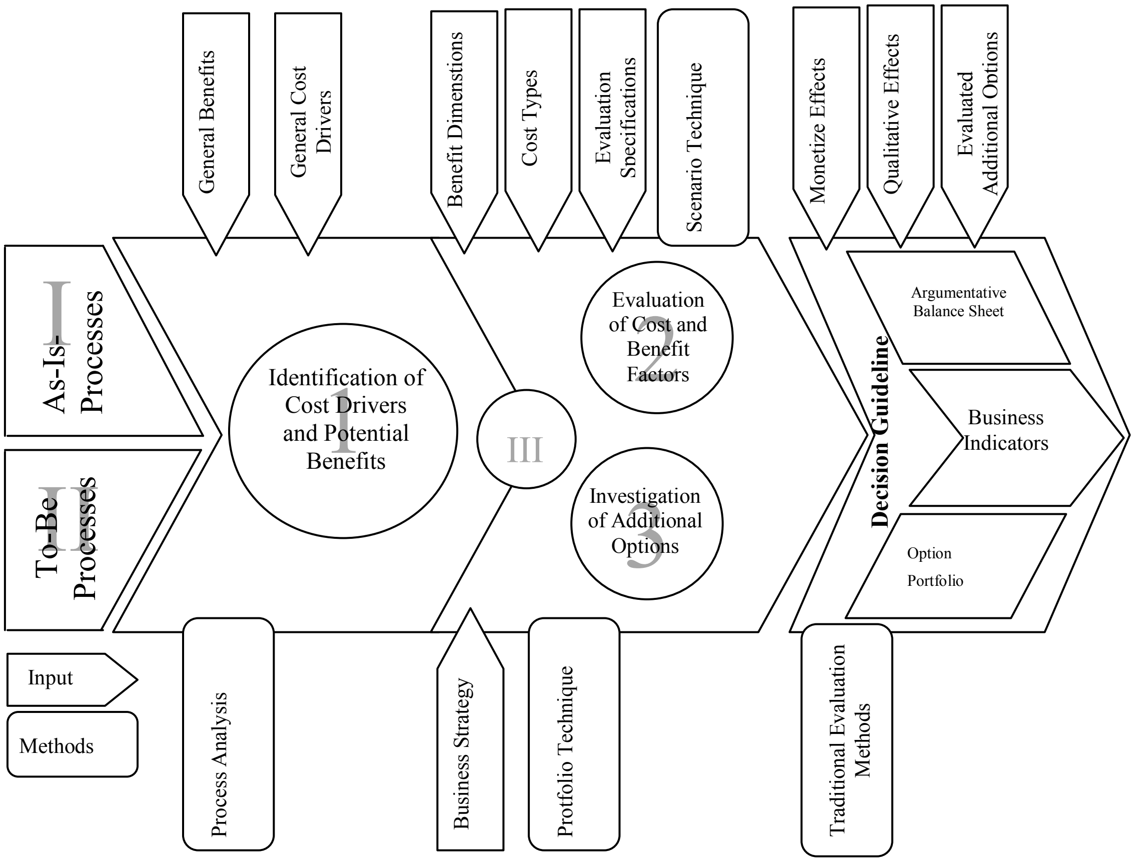
The approach is designed for textile retail and further research is suggested for application of the process model for other domains such as textile manufacturer. The process model is illustrated with the help of case studies without providing tools and procedures for RFID system implementation. In order to be applicable, the approach requires adjustment in terms of activities and procedures as well as addition of further activities of project or implementation management.

2.2.5 Rhensius-2009

The method by [Rhensius/Dünnebacke 2009] is designed as business case that provides a three step approach for planning and evaluation of RFID implementation focusing on cost and benefit as shown in figure 8.

These steps include identification of cost drivers and potential benefits, evaluation of cost and benefit factors, and investigation of additional options. The cost and benefit factors are identified by comparison of As-Is processes with To-Be processes. In order to support the identification and evaluation of these factors, general effects of RFID are analyzed and structured. By this, individual factors are evaluated either monetarily using calculation procedures or qualitatively. According to the method, the analyzed and evaluated effects make the foundation for an RFID investment combined with additional options of RFID implementation.

Figure 8: The Method by Rhensius-2009



Source: Rhensius and Dünnebacke 2009, 69.

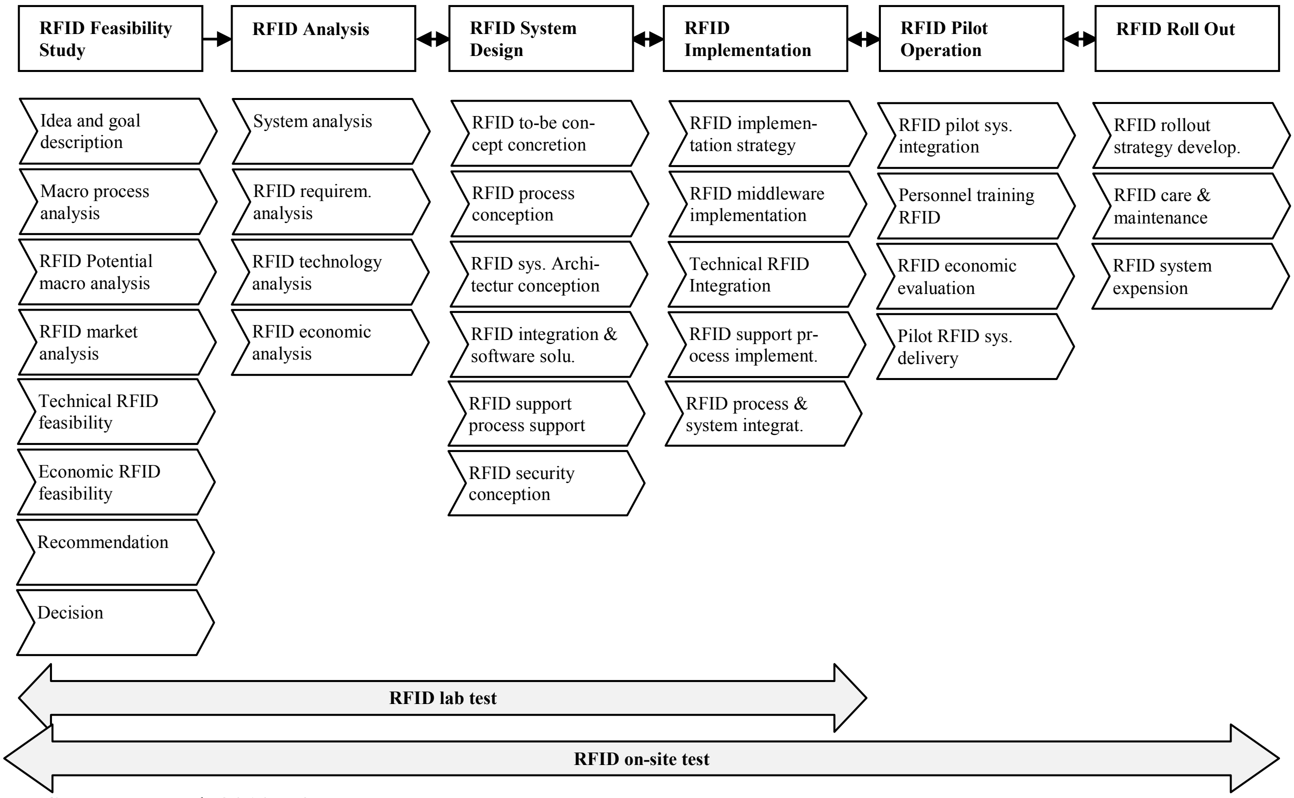
The method is properly documented and supported by online calculator. It considers direct as well as indirect effects and costs of RFID implementation. The method is domain independent addressing small and medium-sized enterprises specifically. The approach is considered to be developed further in terms of evaluation factors, performance measurements, and evaluation logic. In order to be applicable in practice, the approach needs additional approaches for RFID implementation and project management.

2.2.6 Donath-2010

The method by [Donath 2010] aims implementation of RFID technology in SMEs. It consists of a meta-model, process model, and results, techniques and role models. The process model includes RFID feasibility, analysis, system design, implementation, pilot operation, and rollout phases as shown in figure 9. Each phase consists of further activities that are sometime overlapping. The approach emphasizes on activities of system tests throughout the project. The process model supports iterative and incremental RFID system development and is detailed in order to facilitate comprehensiveness for SMEs.

It highlights interdisciplinarity of RFID projects and suggests consideration of technological, software relevant, business, and domain specific aspects in parallel. The approach recommends intensive analysis and RFID system design prior to RFID implementation and provides decision making point after RFID feasibility study in the first phase. The intensity of work is seen higher in earlier phase in comparison to the later phases.

Figure 9: The Process Model by Donath-2010



Source: Donath 2010, 79.

The process model is designed as domain independent approach. It refers to project management but without involving these activities. The approach lacks procedures for economic analysis. In order to be applicable in practice, the method requires additional approaches for economic analysis and project management.

2.2.7 Conclusion

Business managers are often confronted with questions of compatibility, capability, and applicability of the technology in general[34] and also in the context of RFID[35] implementations.[36] It can be seen in above examples that practitioners are mainly confronted with issues of management of implementation, analysis of supply chain process, design of RFID system, deployment of RFID system, and feasibility of RFID

[34] See Leonard-Barton/Kraus 1985, Dietrich/Schirra 2005, 21-22.

[35] See Bank et al. 2007, 18.

[36] See Sections 6.2 and 6.3.

technology. Furthermore, it is noticeable that the activities of RFID system implementation vary with focus and objectives of implementation.

The study of above approaches shows that RFID system implementations are business or technology driven involving issues of management and technology. From management point of view, RFID system implementation projects involve intensive stakeholder communication and change management for successful completion. In addition to this, RFID system implementations are innovative projects and require consideration of compatibility, applicability and profitability of RFID technology as well as RFID implementation approaches, and capability of information technology in place. Furthermore, an RFID system implementation cause logistics process change that may imposes redesign or reengineering of supply chain processes. From technological point of view, RFID systems need proper consideration of characteristics and functionalities of, and environmental effects on RFID system components while defining physical infrastructure. It also obliges consideration of middleware characteristics, data processing, data management, and data storage for information management. Similarly, consideration of socio-political aspects such as standards, privacy, and security are crucial.

The study of RFID system implementation approach shows that there are different factors that contribute to the complexity of implementation process. These include management concerns (e.g. large number of stakeholder, intensive communication), technology concerns (e.g. technology characteristics at physical and information levels), varying business objectives (e.g. system development or economic analysis), and multifaceted RFID implementation process (e.g. enterprise size, business domain). Few of the discussed approaches refer to project management aspects of RFID implementations, while others describe project nature of RFID implementations referring to management issues in the context of economic feasibility or technical implementation process. The issues related to RFID system implementations are discussed in the following section.

2.3 RFID Standards and Issues

This section provides an overview of present RFID standards and various issues related to RFID system implementations in supply chain.

2.3.1 RFID Standards

RFID system components and thus RFID systems are developed in accordance with specifications provided by underlying standards [Hansen/Gillert 2008, 104]. There are several standards for RFID systems that can be categorized as animal identification, contactless smart cards, tools and clamping devices, container identification, anti-theft, and item management as shown in table 5.

Table 5: Overview of RFID Standards

Institute	Standard	Description
Animal Identification		
ISO/IEC	11784	Code structure
	11785	Technical concept
	14223	Advanced transponders
Contactless Smart Cards		
ISO/IEC	10536	Close-Coupling Smart Cards
	14443	Proximity-Coupling Smart Cards
	15693	Vicinity-Coupling Smart Cards
	10373	Test Methods for Smart Cards
Tools and Clamping Devices		
ISO/IEC	69873	Data Carriers for Tools and Clamping Devices
Container Identification		
ISO/IEC	10374	Container Identification
Anti-theft		
VDI	4470	Anti-theft Systems for Goods: Part 1 – Detection Gates – Inspection Guidelines for Customers Part 2 – Deactivation Devices – Inspection Guidelines for Customers
Item Management		
ISO/IEC	see table 6	Several standards for tag data, air interface, reader integration, middleware integration, and tests methods
EPCglobal	see table 6	Several standards for tag data, air interface, reader integration, middleware integration, and EPCglobal Network

Source: Adopted from Finkenzeller 2002, 233-280, Hansen/Gillert 2008,102-108, GS1, ISO.

RFID standards for item management are primarily defined by EPCglobal that is a GS1 initiative and International Standards Organization (ISO) [GS1; ISO]. These standards cover aspects such as unique identification, data syntax, air interface, reader protocol, application interface, and test methods [Finkenzeller 2002, 233–280; Glover/Bhaṭṭ 2006, 36; Banks et al. 2007, 75–78; Hansen/Gillert 2008, 102–108; GS1; ISO]. In general, RFID systems require compliance with national or international standards. For instance, the operating frequency for UHF RFID systems in Europe is 868 MHz, whereas 915 MHz frequency is used in America. Similarly, the usage of reader power is limited to 2 Watt in Europe and 4 Watt in America. Aspects such as data on tag differ also regionally [GS1; Finkenzeller 2002, 233–280]. A detail discussion of RFID standards is not the aim of this section. It only provides an overview of present standards related for integration of different levels of RFID systems during implementation in supply chain. Item management standards are of relevance for supply chain management and described briefly in the following table.

Table 6: Overview of RFID Standards for Item Management

Institute	Standard	Description
ISO/IEC	Tag Data	
	15963	Unique Identification for RF tags describing numbering systems, (rev. 2009)
	Air Interface	

	18000	Air Interface Part 1: Generic Parameter for Air Interface Communication for Globally Accepted Frequencies Part 2: Parameters for Air Interface Communication below 135 kHz, (2009) Part 3: Parameters for Air Interface Communication at 13.56MHz, (2010) Part 4: Parameters for Air Interface Communication at 2.45 GHz, (2015) Part 5: Parameters for Air Interface Communication at 5.8 GHz Part 6: Parameters for Air Interface Communication – UHF Frequency Band, (2013) Part 7: Parameters for Air Interface Communication at 433MHz, (2014)
	Reader Integration	
	15961	addresses the abstract interface between an application and the data processor (i.e. data protocol – Application interface), (rev. part 1, 2013)
	15962	focuses on encoding of transfer syntax (i.e. data protocol: data encoding rules and logical memory functions), (rev. 2013)
	Middleware Integration	
	24791	Part 1:defines Software System Infrastructure for RFID system operations between business application and RFID readers, (i.e. Architecture), (2010) Part 2: defines interface for operations on RFID tag data e.g. reading, writing, collection, filtering, grouping, and event subscription (i.e. data management), (2011) Part 3: defines interfaces for device management of RFID systems (EPC DCI and OASIS), (i.e. device management), (2014) Part 5: defines interface within the Software System Infrastructure (i.e. low-level access to RFID interrogators) for RFID data access and control operations (device interface), (2012)
	Test Methods	
	TR 18047	Technical Report - RFID Conformance Test Methods for air interface Part 2: Test methods for air interface communications below 135 kHz Part 3: Test methods for air interface communications at 13,56 MHz Part 4: Test methods for air interface communications at 2,45 GHz Part 6: Test methods for air interface communications at 860 MHz to 960 MHz Part 7: Test methods for active air interface communications at 433 MHz
	18046	Part 1:Test methods for RFID system performance, (2011) Part 2:Test methods for RFID interrogator performance, (2011) Part 3:Test methods for RFID tag performance, (2012)
EPCglobal	Tag Data	
	EPC Tag Data Standard (TDS)	TDS version 1.9 defines the Electronic Product Code, a universal identifier, and specifies the memory contents of Gen 2 RFID Tags (ratified November 2014). EPC embeds existing coding systems such as the GS1 (formerly EAN.UCC) family of codes (GTIN, GLN, SSCC, GRAI, GIAI, GSRN, GDTI) and other identifier
	EPC Tag Data Translation (TDT)	TDT standard defines rules for formatting and translation of EPC identifiers (i.e. machine-readable) aiming to future-proof the EPC Network (version 1.6 issue 2)
	Air Interface	
	13.56MHz ISM Band Class 1	communication interface and the protocol for Class 1 HF transponders, passive-backscatter, interrogator-talks-first, version 2.0.3
	900MHz Class 0	*communication interface and the protocol for Class 0 transponders (Read-only, passive (no internal power source)), replaced by UHF Gen 2*
	860–930MHz Class 1	*communication interface and the protocol for Class 1 transponders (Write-once, passive), replaced by UHF Gen 2*
	EPC UHF Generation 2	Air Interface Protocol Class 1: passive-backscatter (interrogator-talks-first), 860-960 MHz, version 2.0 Class 2: Passive tags with supplementary functions, such as data storage for encryption, 860–930 MHz Class 3: Semipassive tags, 860–930 MHz

		Class 4: Active tags (with internal power sources), 860–930 MHz Class 5: Active readers that can communicate with all classes and with each other, 860–930 MHz
	Reader Integration	
	LLRP	Low Level Reader Protocol (LLRP) specifies interface between readers and clients (i.e. end-user-applications) providing control of RFID air protocol operation timing and access to air protocol command parameters
	DCI	Discovery Configuration and Initialization (DCI) specifies Access Controller (new device) aiming identification of the ability of the Reader "to discover one or more Clients, the Client to discover one or more Readers, and for the Reader to obtain configuration information, download firmware, and initialize operations to allow other Reader Operation protocols to operate"
	RM	Reader Management (RM) defines wire protocol used by management software to monitor the operating status and health of EPCglobal complaint readers. It complements Reader Protocol (RP) used for control of readers.
	Middleware Integration	
	ALE	Application Level Event (ALE) Specification Version 1.1.1 specifies an interface (between RFID readers and application system) for prompting filtered and consolidated Electronic Product Code data, and related data from different sources Part I: Core Specification Part II: XML and SOAP Bindings
	EPCIS	EPC Information Services aims to enable disparate applications to create and share visibility event data, both within and across enterprises (a middleware component for access to EPCglobal Network)
	EPCglobal Network	
	Architecture Framework	defines and describes the basic architecture of the EPCglobal Network
	ONS	Object Naming Service (ONS) Specification describes the use of a DNS (domain name system) for localizing authoritative metadata and services associated with an EPC (a core component of EPCglobal Network)

Source: Adopted from Finkenzeller 2002, 233-280, Hansen/Gillert 2008, 102-108, GS1, ISO.

2.3.1.1 Standards for Tag Data and Air Interface

Standards for tag data and air interface, as described in table 6, primarily address tag and reader communication. International Standards Organization and International Electrotechnical Commission (ISO/IEC) specifies ISO/IEC 15963 and 18000 series for data on tag and air interface between tags and readers, whereas EPCglobal provides EPC Tag Data Standard (TDS), and ISM 13.56 MHz and UHF Generation 2 classes respectively. For instance, EPC Tag Data Standard (EPC TDS) defines the Electronic Product Code (EPC) and specifies the memory contents of Gen 2 RFID Tags.

The EPC "*is a universal identifier*" for tracking physical objects in information systems. It includes representation at various levels of the EPCglobal Architecture and correspondence to GS1 keys and other existing codes. The memory contents cover the EPC, "*user memory*" data, control information, and tag manufacture information [GS1-TDS 2014]. The Tag Data Translation (TDT) standard defines rules for formatting and translation of EPC identifiers (i.e. machine-readable). It "*is designed to help to future-proof the EPC Network*" reducing the disruption in supporting additional EPC identifier schemes [GS1-

TDT 2011]. In the same way, EPC UHF Generation 2 Class 1 represents an RFID system that operate between 860 and 960 MHz frequencies with passive backscattering, where the reader (i.e. interrogator) is responsible for communication and energy supply (i.e. interrogator-talk-first).

2.3.1.2 Standards for Reader Integration

Standards for reader integration cover RFID standards that focus on reader protocols and middleware interfaces as shown in table 6. ISO/IEC provides 15961 and 15962 standards that address these aspects. Similarly, EPCglobal defines Low Level Reader Protocol (LLRP), Discovery Configuration and Initialization (DCI), and Reader Management (RM) addressing reader interface, access control, and reader monitoring respectively.

2.3.1.3 Standards for Middleware Integration

The standards refereeing aspects of middleware components integration in application systems are grouped as standards for middleware integration in table 6. These aspects are addressed by ISO/IEC 24791 standard. This standard consists of four different parts covering software architecture between RFID readers and application system (e.g. middleware, information system), interface for operations on RFID tag data (e.g. reading, writing, and filtering), interface for device management, and interface for RFID data access and control.

The EPCglobal, similarly, specifies Application Level Event (ALE) that focuses on interface between RFID readers and application system components for prompting filtered and consolidated EPC data and other related data from different sources. The EPCglobal also specifies EPC Information Services (EPCIS), a middleware component for acess to EPCglobal Network.

2.3.1.4 Standards for Tests Methods

The tests methods are address by ISO/IEC in TR 18047 and 18046 standards as summarized in table 6. The ISO/IEC TR 18047 consists of six parts involving test methods for air interfaces of various frequencies. The ISO/IEC 18046, however, covers three parts of tests methods for system, interrogator (i.e. reader), and tag performances.

2.3.1.5 Standards for EPCglobal Network

The standards for EPCglobal Network in table 6 comprise standards related to EPCglobal Netowrk technology. The EPCglobal Netowrk technology aims standardization of components for cross-enterprise exchange of RFID data (in near real time) covering both tags and readers communication as well as information architecture for internet of things

(IoT). Standards and components that are used as services include an architecture framework for EPCglobal Network and EPC Object Naming Service (ONS). The ONS is a specification and core component of EPCglobal Network that describes the use of Domain Name System (DNS) for localization of authoritative metadata and services associated with an EPC. Basic services (components) of EPCglobal Network include [GS1-EPCglobal; Finkenzeller 2002, 274–275; Glover/Bhaṭṭ 2006, 176–177]:

- Identification by electronic product code (EPC)
- Read out of tag by reader
- Storage i.e. administer by middleware
- Query and find i.e. discovery services (DS) and object naming services (ONS)
- Exchange by EPC information services (EPCIS)

2.3.2 Implementation Issues

RFID systems are not standardized fully at present as the discussion above shows. This is one of the main issues of RFID implementation for many domains. Despite of this, there are several supply chain, technical, and security issues that require consideration during RFID implementation.

2.3.2.1 Supply Chain Issues

RFID system implementations in supply chains are, in general, aimed to optimize and rationalize supply chain processes. The decision for an RFID implementation and the design of an RFID system are, however, constrained by specific issues. Accordingly, the cost[37] of RFID technology and inappropriate knowledge of RFID technology as well as approaches[38] are the primary concerns for many businesses [Khan 2015].[39] High cost and inappropriate knowledge of RFID systems may result in isolated solutions of RFID for particular products or areas. These isolated solutions come into being without consideration of overall supply chain requirements (either internal or external) and RFID optimization potentials.[40]

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[37] See Vilkov 2007, Bardaki et al. 2008, Rhensius/Dünnebacke 2010, Donath 2010, Gross/Thiesse 2005, Gillert 2008, Decker et al. 2008 addressing cost as a key success factor along technical feasibility.

[38] See Vilkov 2007, Rhensius/Dünnebacke 2010, Faupel 2009, Donath 2010, Tamm/Tribowski 2010 addressing issues of comprehensiveness, granularity, structure, and applicability.

[39] See also Section 2.2.

[40] Based on observations of the author during practice-oriented research (see Section 6.3).

There are also domain specific issues[41] that affect the decision of RFID implementation. Specific domains characteristics may involve supply chain nature (e.g. position in a supply chain[42]) or application area characteristics[43] (e.g. use of liquids or metals) [Khan 2015]. Business domains such as food industries[44] possess low price products with specific supply chain hierarchies and influences. The price of products has an effect on RFID implementation, for example, in respect of level of tag implementation (i.e. pallet or product level). Generally, food industries are in less power position to influence adoption of new technologies in comparison to retail. Therefore, according to the author, preparation for a potential demand by retail is of great importance for both in time reaction on demand and rationalization of internal enterprise supply chain processes.

The practice-oriented research of the author reveals that documentation and automation level of existing supply chain processes affect the intensity of project work and duration.[45] For instance, less documented supply chain processes require detailed analysis[46] activities in order to define strategies of optimization. Furthermore, existing information technologies are crucial for RFID system and data integration [Thiesse/Gross 2006]. Along with technical integration of RFID system (e.g. middleware integration), the use of RFID data to generate business value needs proper consideration, for example, in terms of data modeling.[47]

2.3.2.2 Management Issues

The study of RFID system implementation of the author shows that there are different factors that contribute to the complexity of implementation process [Khan 2015]. These involve management and technical concerns. From management point of view, RFID

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[41] See Gampl et al. 2008, Bardaki et al. 2008, Vogeler 2009 addressing specific domains.

[42] Based on observations and analysis of the author during practice-oriented research (see Sections 6.2 and 6.3).

[43] See Vilkov 2007, Rhensius/Dünnebacke 2010, Faupel 2009, Vogeler 2009, Donath 2010, Gross/Thiesse 2005, Inormationsforum RFID, Ngai et al. addressing detailed analysis of supply chain.

[44] See Sections 6.2 and 6.3.

[45] Based on the observations in projects involving pallet management studies (i.e. four enterprises) and projects from sections 6.2 and 6.3.

[46] For detailed supply chain analysis see Vilkov 2007, Rhensius/Dünnebacke 2010, Faupel 2009, Vogeler 2009, Donath 2010, Gross/Thiesse 2005, Inormationsforum RFID, Ngai et al. 2010.

[47] For aspects of integration see sections 2.1.3 and 2.1.4.

system implementation projects involve intensive stakeholder communication[48] and change management[49] for successful completion. RFID initiatives have different objectives and may focus on only system design or economic analysis.[50] Furthermore, RFID system implementations are innovative projects and require consideration of compatibility, applicability and profitability of RFID technology as well as RFID implementation approaches, and capability of information technology in place.[51] In addition to that, an RFID system implementation cause logistics process change[52] that may imposes redesign or reengineering of supply chain processes.

The project nature or project management of RFID system implementation is referred directly or indirectly by many approaches as discussed in section 2.2. However, because of the complexity of RFID implementations and importance of management concerns[53], the project management facets of RFID implementation require proper study and consideration along with economic feasibility and technical implementation.[54]

2.3.2.3 *Technological Issues*

The technological issues of an RFID implementation stem from the maturity level and the nature of the technology [Hodel/Jacobs 2008]. The overview of available standards in section 2.3.1 also provides indications of the maturity of RFID technology at present. This is an issue for many businesses in order to adopt RFID technology in supply chain.[55] RFID systems operate using magnetic and electromagnetic waves.[56] Therefore, the performance

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[48] For stakeholder orientation see Gampl et al. 2008, Faupel 2009, Vogeler 2009, Donath 2010, Gross/Thiesse 2005, Gillert 2008, AIM-Germany 2006, Decker et al. 2008, Ngai et al. 2010.

[49] For consideration of change management see Gross/Thiesse 2005, InformationsforumRFID 2006, Decker et al. 2008, Ngai et al. 2010.

[50] For differences in objectives see sections 2.1.1.1, 6.2, and 6.3.

[51] For technical feasibility see Bardaki et al. 2008, Rhensius/Dünnebacke 2010, Faupel 2009, Vogeler 2009, Donath 2010, Gross/Thiesse 2005, Gillert 2008, InformationsforumRFID 2006, Ngai et al. 2010.

[52] For potential changes in supply chain processes see Glover/Bhatt 2006, Vilkov 2007, Bardaki et al. 2008, Rhensius/Dünnebacke 2010, Faupel 2009, Vogeler 2009, Gillert 2008.

[53] For business needs and strategy (e.g. partial solutions, system design or economic analysis) see Glover/Bhatt 2006, Vilkov 2007, Rhensius/Dünnebacke 2010, Faupel 2009, Vogeler 2009, Donath 2010, Gross/Thiesse 2005, Gillert 2008, InformationsforumRFID 2006, Ngai et al. 2010.

[54] See Sections 4.2, 6.2 and 6.3.

[55] For technical feasibility see Bardaki et al. 2008, Rhensius/Dünnebacke 2010, Faupel 2009, Vogeler 2009, Donath 2010, Gross/Thiesse 2005, Gillert 2008, InformationsforumRFID 2006, Ngai et al. 2010.

[56] See Section 2.1.

of RFID systems such as identification, read ranges, and transmission rates is influences in the presence of liquids, metals or high temperature in physical environment or in the presence of liquid containing material and products or metal containing packaging.[57] For instance, the tagging objects can cause reflection in case of metals (e.g. aluminum) and absorption in case of liquids (e.g. milk) [Hansen/Gillert 2008, 180–183]. Such technical issues[58] at physical level require proper consideration from the very beginning.

At information level, aspects of change in application logic and data integration are vital during RFID system implementations. The application logic in supply chain is changed, for example, if the enterprise intends to trace products or pallets, which consequently causes changes in data models. Furthermore, the enterprise must be capable of dealing with RFID data to avoid information overflow [Thiesse/Gross 2006]. The enterprise must also consider integration or co-existence of barcode and RFID technologies.[59] Proper consideration of these issues is necessary, for example, for the purpose of validation.[60]

2.3.2.4 Security Issues

RFID systems use magnetic and electromagnetic waves for communication between tags and readers, intranet for connection of reader and middleware and internet for communication with other information system (i.e. internal to enterprise) and supply chain partners (i.e. external to enterprise).[61] Accordingly, security concerns arise at different levels in RFID system. Figure 10 illustrates examples of vulnerabilities at different stages.

A system's security is build around its requirements of availability, integrity, and confidentiality. Availability requirements of a system refer accessibility and usability of a system by individuals or entities at required performance and scalability. A common threat in this regard is the Denial-of-Service (DoS) attack, where the communication between RFID reader and tags are blocked using a blocker tag. Integrity requirements of a system address accuracy and completeness assurance of transmitted information by preventing

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[57] See Section 2.1.2.

[58] See also Glover/Bhatt 2006, Schuster et al. 2007, Thornton et al. 2006, Banks 2007, Vilkov 2007, Bardaki et al. 2008, Rhensius/Dünnebacke 2010, Faupel 2009, Vogeler 2009, Donath 2010, Gross/Thiesse 2005, Gillert 2008, AIM-Germany 2006, InformationsforumRFID 2006, Decker et al. 2008 for technology characteristics.

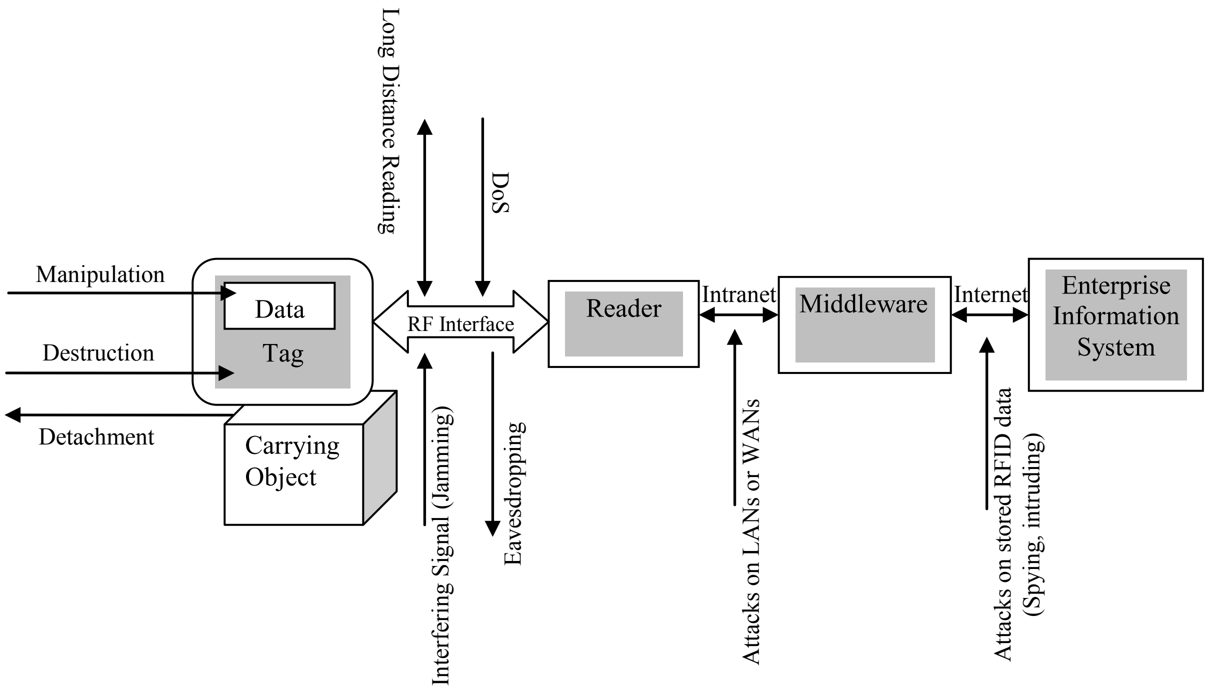
[59] For aspects of co-existence of RFID with other Auto-ID technologies see Glover/Bhatt 2006, Donath 2010.

[60] For test and validation of RFID system see Rhensius/Dünnebacke 2010, Faupel 2009, Donath 2010, Gross/Thiesse 2005, Gillert 2008, InformationsforumRFID 2006, Ngai et al. 2010.

[61] See Section 2.1.

modification (i.e. accidental or malicious). An example of integrity threat is spoofing, where a tag is impersonated by emulating devices. Confidentiality requirements of a system involve limitation of access to information only by authorized individuals, entities, or processes. For instance, details of inventory and goods movement are confidential data and need to be protected, for example, by encrypted data transfer between RFID tag and reader, reader and middleware, or middleware and other information systems [BSI 2004; Glover/Bhaṭṭ 2006, 197–214; Finkenzeller 2008, 214].

Figure 10: Potential Attacks on RFID Systems



Source: According to BSI 2004, Glover/Bhatt 2006, 197-214, Finkenzeller 2010, 214.

In table 7, an overview of potential threats to an RFID system involving physical components of RFID system is provided. Attacks on tags might involve mechanical or chemical destruction, shielding by metal, spoofing aiming impersonation, cloning of tag data, and tracking of tag to individuals. The threats at the RF interface level include, for example, eavesdropping, jamming, denial of service, and relay attack. Risks at middleware and application level of an RFID system (i.e. communication via intranet or internet) are similar to any other telecommunication and information system [Finkenzeller 2008, 213] and are not discussed here.

Table 7: Overview of Potential Threats

Threat	**Description**
Attacks on Tags	
Destruction	It is the mechanical or chemical destruction of the tag.
Shielding	It aims to shield a tag from reader e.g. using metal such as foil.
Spoofing	It is an attack on tags and reader communication aiming impersonation of tag by emulating devices that prerequisites knowledge of protocols and authentication applied.
Cloning	It is transferring tag data onto new tag to form a copy e.g. to alter the tag data for an

	attack.
Tracking	It is the association of tag ID code to individuals or consumer.
Attacks on RF Interface	
Eavesdropping	It is an attack on tags and reader communication aiming unauthorized listening of tag and reader communication (i.e. reading of data).
Jamming	It is interruption of transmission between tag and reader by interfering signal using a jamming device.
Denial of Service	It is an attack on tags and reader communication aiming disruption of communication e.g. by overwhelming capacity of reader with requests by designed blocker tags or random noise.
Relay	It is an attack on tags and reader communication aiming to extend the read range by interposing a transmission device (relay), which simulate the presence of tag in read range.

Source: BSI 2004, Finkenzeller 2008, 216-226.

In order to cope with these security issues, there are several non-cryptographic schemes and cryptographic algorithms available as shown in table 8. The non-cryptographic schemes involve tag killing, tag locking, faraday cage, blocker tag, and the RFID guardian. As cryptographic algorithms, there are mutual symmetrical authentication, derived keys, encrypted data transfer, public key encryption, hash lock, randomized hash lock, hash chain scheme, pseudonym throttling, and delegation tree authentication measures to protect RFID systems at different levels.

Table 8: Overview of Protection Measures

Protection	**Description**
Non-Cryptographic Schemes	
Tag Killing	It is a feature to disable a tag usually at the point of sale in retail.
Tag Locking	It refers to the lock mode of a tag by a PIN number, where tag is readable with ID number and without the stored data.
Faraday Cage	It is the use of metal mesh such as aluminum foil to prevent communication.
Blocker Tag	This scheme is used to stop communication between other tags and RFID readers by blocker tag e.g. for consumer privacy.
RFID Guardian	It is a battery powered device that searches, records, and displays tags in reading range, manage keys, authenticates readers, and block unauthorized access attempts.
Cryptographic Algorithms	
Mutual Symmetrical Authentication	An authentication between tag and reader by checking the others knowledge of a secret cryptographic key.
Derived Keys	It refers to the keys that are calculated during production of tags using a cryptographic algorithm and a master key.
Encrypted Data Transfer	It refers to the encryption of data prior to transmission from plain text to encrypted text (e.g. stream ciphers algorithms).
Public Key Encryption	It uses public and private keys with set of associated operations for cryptographic operations and consequent re-encryption.
Hash Lock	It use hash encrypted ID that operates in locked and unlocked stages to protect tag data. It is usually applied on tags with little memory in supply chain management.
Randomized Hash Lock	It is the hash lock functionality with pseudo-random number generator to prevent tracking of tag (i.e. by variation of ID in transmission).
Hash Chain Scheme	It operates as key-updating by using two hash functions, where the tag computes a new key from the old hash value of the key after each authentication.
Pseudonym Throttling	It is an authentication with short list of pseudonyms on tag and the list know to reader.
Delegation Tree Authentication	It is an algorithm based on shared secret (i.e. mutual symmetrical authentication) and pseudo-random function using Trusted Center for providing keys to new tags and control of reader.

Source: BSI 2004, Finkenzeller 2010, 226-232.

The table 8 highlights examples of protection schemes. The presence of threats and use of protection measures in practice depends on application scenario. Furthermore, every protection measure possesses strengths and weaknesses. Therefore, each application scenario requires proper consideration of security issues in a given context.

3 Project Management and Reference Modeling

In view of the implementation issues in section 2.3, this chapter provides an overview of the project management field, project requirements, and project management standards and methodologies. By this, a foundation is made to understand approaches that refer management of RFID system implementation.

This chapter also aims to provide basics of reference modeling. The method reference modeling is applied to create the resulting model of this dissertation. Furthermore, reference modeling is suggested for the adaptation of the resulting model of this research according to the needs of a project or enterprise. The reasons for the use of reference modeling as a research method include:

- There is significant amount of work done on project management during last decades.
- There are several standards and methodologies available for project management and IT project management.
- The knowledge provided by available standards can be used to develop a reference model for management of RFID system implementations.

Historically, the development of quality and rigor of research in project management is not longer than twenty years. In 1970s, the research in project management was dominated by practitioners, whereas in 1980s professional associations led the research activities. Consequently, there was a lack of methodologies, theory development, and research [Turner 2010; Lundin 2011]. In this regard, the practice oriented research (i.e. mutual interest by companies and researchers) is one of the examples of research development in recent project management [Lundin 2011].

3.1 Project Management

Project management is performed to plan, organize, execute, and control project activities. This interpretation is followed by project management standards such as PMBOK, methodologies such as PRINCE2, and process model for IT project management such as V-Modell-XT.[62] According to PMI, projects are specific in objectives and aimed to be completed in given time with defined scope and resources (i.e. human and nonhuman). A project is a temporary undertaking with definite start and end in order to create a unique product, service or result, whereas project management is "*the application of knowledge, skills, tools, and techniques to project activities*" [PMI 2008, 5–6]. Project management

[62] See Sections 3.1.2.1, 3.1.2.2, and 3.1.2.4.

requires consideration of project requirements and constrains as well as stakeholder needs and expectations [Kerzner 1995; Kerzner 2003, 2–3, 56; PMI 2008; Kuster et al. 2011]. Project management involves planning, organization, execution, monitoring, and control **activities** [PMI 2008, 5–6]. IT project management, additionally, covers also methods of requirement engineering, organizational and technical change management, and configuration management [Pietsch 2012].

There are three different **views** on project management, namely functional, organizational, and methodical. The functional view considers project management as task of operational management that requires competencies of leadership. The organizational view sees project management as organizational form for a flexibly adjustable organization. The methodical view on project management describes project management as a guideline for planning, organization, and execution of a project [Pietsch 2012].

In general, the problems to be solved in projects are dissimilar. Also projects of information systems (or Wirtschaftsinformatik) involve different problems. They, for instance, are differentiated in software and information technology (IT) projects. Software projects involve only software components, whereas IT projects are broader in context with specific **requirements** involving software and hardware components (e.g. navigation systems) [Pietsch 2012]. In order to complete a project successfully, project management need to be efficient and effective. Accordingly, **specific** project management approaches are applied to address specific project requirements [Kerzner 1995; Kerzner 2003, 2–3, 56; PMI 2008; Kuster et al. 2011]. These approaches include standards such as PMBOK and ISO 21500, methodologies such as PRINCE2, process models such as V-Modell-XT and Rational Unified Process (RUP), and frameworks such as Scrum. Primarily, these approaches differ in focus, scope, abstraction level, and sometimes in underlying philosophy. These differences are discussed in detail after description of different project requirements in the following.

3.1.1 Project Characteristics

Projects are temporary, unique, and cross-functional undertakings that induce uncertainty [PMI 2008; Pietsch 2012]. In order to ensure management and control, the work of a project is divided horizontally and vertically that results in a phase structure and work breakdown structure (WBS) respectively. Management of IT projects, for instance, requires managerial as well as technical **competencies** in management, communication and interpersonal relations, **knowledge** of enterprise processes including standards and regulations, enterprise behavior, organizational and technical change management, and related technologies [Kerzner 2003, 10–11; Meredith/Mantel Jr 2009, 127–130; Schwalbe 2011, 22–24; Schwalbe 2006]. They require also use of **tools and techniques** such as schedules, milestones, deadlines, critical path method (CPM), program evaluation and review technique (PERT), and Gantt charts [Burke 1999, 24–26; Burke 2003, 28–30]. The work of projects is dictated by several **constraints**. Main project constraints include scope, time and cost. In addition to that, aspects such as specification level (i.e. quality), user acceptance, mutual scope change, corporate culture, and customer relations (i.e. external) direct and restrict projects [Kerzner 2003, 5-6, 141; Meredith/Mantel Jr 2009, 3, 27; Schwalbe 2006; Schwalbe 2011, 8-10, 87]. Project **requirements** are defined by **stakeholder needs and expectations** and influenced by strategic objectives, business context, and involved technologies. For instance, a software project can have different requirements in comparison to an information technology project because of the involvement of software and hardware components of an information system. In general, project requirements are differentiated in functional requirements, service requirements, performance requirements, quality requirements, training requirements, etc. [Kerzner 2003, 5-6, 88, 141; Meredith/Mantel Jr 2009, 3, 27, 37; Schwalbe 2011, 8-10, 87, 182; Pietsch 2012]. Requirements change has a significant influence on project management and project management life cycle. Therefore, the following subsections categorize projects on the basis of requirements change i.e. firm requirements, changing requirements, and rapidly changing requirements.

3.1.1.1 Firm Project Requirements

The requirements of projects remain unchanged or are considered firm in areas with substantial industry practices, co-located teams, and life or **business critical** responsibilities. Accordingly, they require simple and sequential approaches such as waterfall, where project scope, schedules, and cost are determined as early as possible. Following predictive project management approaches, project activities are carried out in sequential and sometime overlapping phases including requirements, design, implementation, test, and operation phases. They involve intensive documentation that stem from traditional engineering disciplines. Predictive approaches support only **formal** change requests. Accordingly, they do not accommodate requirements and scope change and are less flexible in terms of rework and increment. As the project work is predictive and planned, minimal supervision and intermediate skills are required for realization of the project. Projects that follow predictive life cycles, deliver late delivery of system or software in the development process, where any change is expensive. Errors are also recognized later that cause extra cost because of rework. Predictive approaches are suitable for co-located as well as separated project teams, but less suitable for projects with changing requirements [PMI 2008, 20–21; PMI 2013, 44–45; Wysocki 2009, 341–353; Royce 1998].

3.1.1.2 Changing Project Requirements

The requirements of projects change in areas such as information systems. Accordingly, they require iterative and incremental project management life cycles. Iterative and incremental project management life cycles also follow a sequential and sometime overlapping phase structure with intensive documentation. However, they involve intentional repetitions of project activities and addition of functionality to a system or results. A preliminary project plan and system design is developed in the beginning of the project, whereas detailed project planning and system design is carried out during iterations. The length or **duration** of iterations may vary for a set of deliverables and the **project team may change** between or during iterations. By iterations, feedback is provided in order to reduce complexity, improve quality (rework), and manage risk. Incremental development provides partial solutions without affecting the final results of a project. Iterative and incremental approaches follow **scheduling strategies** by prioritizing requirements as well as resources. They are flexible, allow **feedback** with **careful management of change** to project scope (i.e. requirements and work), and are applied to large and complex projects. Accordingly, these approaches are suitable for business personals as they provide intensive documentation with defined activities and scheduling of limited project resources. They are also suitable for separated as well as co-located project teams. On the contrary, iterative and incremental approaches are difficult in terms of early project time and cost estimation, require skilled project teams because of management of change, and possess longer schedules because of iterations. Examples of iterative and incremental approaches are spiral model, V-Model, unified software development process (UP), and rational unified process (RUP). RUP is a specific and detailed instance of UP [PMI 2008, 22; PMI 2013, 45–46; Cockburn 2008; Wysocki 2009, 357–364].

3.1.1.3 Rapidly Changing Project Requirements

The requirements of projects change rapidly in areas with less known final solutions. Accordingly, agile life cycles such as Scrum and extreme programming (XP) are preferred. The focus of agile approaches remains on working system or software, team interaction, customer collaboration, and change responding development instead of comprehensive documentation, processes and tools, contract negotiation, and defined plan. Agile approaches also follow iterative and incremental development, where the overall **scope** of a project is **decomposed** and **requirements** for the iteration are **prioritized** at the beginning. Each cycle of project deliver finished, complete and usable features for **review**. The stakeholders are involved throughout the project to provide **feedback** and ensure **correctness** of requirements in order to reduce **risk**. The scope change requests are made **informally**. Agile approaches are beneficial when small incremental development deliver **business or stakeholders' value** in high risk and changing project environments. They are suitable for small and co-located project teams and provide quality through frequent feedback (i.e. test-driven, reviews, lessons learned). However, they are inappropriate for large as well as separated teams, and large projects because of increased communication and synchronization efforts. Agile approaches require skilled project teams with generalized and specialized skills [Cockburn 2008; Wysocki 2009, 383–481; Brewer/Dittman 2010, 43–45; Hanser 2010, 13–45; PMI 2013, 46].

3.1.2 Project Management Standards and Methodologies

Project management approaches vary depending on project characteristics and requirements resulting from application context, underlying philosophy, abstraction level and involved technologies as described in section 3.1.1. These approaches form different project management standards and methodologies. In general, the work of a project is structured in phases forming a process model or project life cycle (i.e. phases, activities, sub-activities). Project activities are performed either sequentially in overlapping manner or iteratively and incrementally for the purpose of **simplicity** and **ease of management and control**[63] [PMI 2008, 18-22, 39-40; PMI 2013, 41–46; Wysocki 2009, 341–357; Pietsch 2012; Jacobs 2015].

In linear sequential process models, the phases of a project are **linked through outputs** or phase deliverables [PMI 2008, 39–40; PMI 2013, 41]. The work within a phase has a **distinct focus** involving different organizations and stakeholders. Each phase requires extra degree of control[64] and defined boundaries. The **duration or length** of a phase varies depending on objective of the phase [PMI 2008, 18–20; PMI 2013, 41]. The phase structure provides **decision making points** for management [PMI 2013, 41]. The **number, size, and sequence** of phases of project management process model depend on the nature

[63] i.e. in consideration of level of control, effectiveness (i.e. time), and degree of uncertainty.

[64] Controlling is done with the help of project governance method that is part of project plan.

of industry, culture of enterprise, structure of enterprise[65], objectives of the project, subject area expertise of project team, and the selected process model for the technical work realization. Similarly, a feasibility study can be treated as routine pre-project work, first phase of a project, or stand-alone project depending on the organization and management. The sequential process models reduce uncertainties but with increase of overall schedule. The parallel execution of project activities (i.e. schedule compression technique) decreases overall schedule. However, they may increase uncertainties and rework in case of inaccurate results of performed activities [Wysocki 2009, 341–357; PMI 2008, 18–40; PMI 2013, 41–46].[66]

In iterative process models, the selected project work (i.e. activities or system) is revised and improved with specified periods and lengths of rework with the help of rework scheduling strategy. For instance, a rework strategy can involve development of least amount of system possible before evaluation in order to do less rework upon changes in requirements or development of possible system with the intention to carry out minor and quick changes if needed. Iterative development improves system or deliverable quality by rework. The validation is achieved by examination of the system or deliverable from various perspectives. The selected project work for revision and improvement could be, for example, system requirements and design. This may involve three steps, namely plan review (e.g. of requirements), allocate review periods (e.g. one), and allocate revision time (e.g. 1st review 30 percent and 2nd review 15 percent of initial development). Incremental development uses top-down technique involving staging and scheduling strategy or time-boxing to decompose project work or system functionality. It focuses on achievement of specific project objectives or system functionality by division of work in useful slices over time one after the other. The project work can be improved, adjusted and validated at the end of an increment. General steps may involve development of full piece of functionality, addition of functionality, and completion of system [Cockburn 2008; PMI 2008, 20–21; PMI 2013, 44–45; Wysocki 2009, 341–357; Hanser 2010, 5].

In view of that, there are different project management approaches for different purposes resulting in general standards such as PMBOK and ISO 21500, methodologies such as PRINCE2, and process models such as V-Modell-XT and Rational Unified Process (RUP), and frameworks such as Scrum. These are described in the following.

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[65] For variation in project handling see PMI 2008, 19 and up to 27.

[66] For process orientation see PMI 2008, 19

3.1.2.1 PMBOK

The project management body of knowledge (PMBOK) is a general standard for project management that is intended for the use in a wide range of project environments. The standard is maintained by project management institute (PMI). Historically, the PMBOK is emerged from the construction field. There are several standard extensions to the PMBOK in order to support the uniqueness of projects. These extensions include software extension, construction extension, and government extension for project management. For instance, the software extension is developed by PMI and IEEE Computer Society for software development projects supporting both plan-driven and agile approaches. PMBOK was first published in 1987. The standard evolved over time. The fourth edition of the standard was published in 2008. Presently, the fifth edition with slight changes is available since 2013. The standard focuses on team involvement in the decision making processes of defining tasks, and estimating effort, size and duration. It supports project, program, and portfolio management and is suitable for large and complex projects. The PMBOK suggests initiation, planning, execution, monitoring and control, and closure process groups for project management. It furthermore suggests ten knowledge areas such as integration, scope, time, cost, quality, human resource, communication, risk, procurement and stakeholder management for support of project management processes. PMBOK was adopted by American National Standards Institute (ANSI) as national standard for project management in 1999 [PMI 2008; PMI 2013; PMI].

3.1.2.2 ISO 21500:2012

The ISO 21500:2012 is also a general standard for project management by international organization for standardization (ISO). The standard is developed in 2012 for the first time. The initiative for the standard was taken by British Standard Institute (BSI) jointly with the American National Standards Institute (ANSI) in 2006. It is a result of combination of BS 6079, PMI PMBOK, and ISO 10006:2003 standards. The standard suggests project management process groups (i.e. initiation, planning, implementation, controlling, and closing) in accordance with subject groups (e.g. integration, stakeholder, scope, and resources). It describes organizational context as project environment, governance, portfolio management and life cycle, and categorizes project management competences in technical, behavioral, and contextual competencies. The standard is designed as industry and project independent and aimed to be applicable irrespective of complexity, size and duration of project. It addresses senior managers, project sponsors, project managers, and developers of national and organizational standards. The standard supports project, program, and portfolio management [BS ISO; ISO 21500:2012].

3.1.2.3 PRINCE2

The projects in controlled environments version 2 or PRINCE2 is a methodology and de facto standard for information system project management in United Kingdom (UK). The standard was initially introduced in 1989 and fundamentally revised in 2006. The latest version is available since 2009. PRINCE2 is a process-driven methodology that suggests division of a project in management and technical stages. It is based on seven principles, seven themes, and seven processes. The seven principles involve continued business justification, learn from experience, defined roles and responsibilities, manage by stages, manage by exception, focus on products and tailored to suit the project environment. The seven themes include business case, organization, quality, plans, risk, change and progress. The seven processes consist of starting up a project, initiating a project, directing a project, controlling a stage, managing product delivery, managing stage boundaries and closing a project [Bradley 1997; Turley 2010; PRINCE2].

The PRINCE2 methodology focuses on business value and involves **business case** throughout the project. It distinguishes between project manager and team manager. A team manger, for example, possesses personal and soft skills to manage project team. The project board (i.e. project office) is responsible for project plans and decisions, whereas the project manager reports to the project board regarding operational activities of a project. The project board and project manager form management and work/operation layer. The methodology addresses only project management without program and portfolio management. The aspects of portfolio management (e.g. decisions of resource reallocation) are covered by the project board [Bradley 1997; Turley 2010; PRINCE2].

3.1.2.4 V-Modell-XT

The V-Modell-XT is a process model for development of IT systems and the standard for IT projects of public sector in Germany. The model is first published in 2005 and is successor of the V-Modell 97. It covers project management, quality assurance, configuration management, acquirer and supplier, and system development [V-Modell XT; Biffl et al. 2006; Kuhrmann 2015].

For project management, the V-Modell-XT follows the classical project management approach and suggests the role of project leader. The project leader is responsible for leading of project team, planning of project, and management of risks. It furthermore involves the role of project manager seen as project sponsor or owner. Accordingly, the project manager is the first contact person of project leader in case of problems. Project management activities in V-Modell-XT include project initialization, project execution and iteration, and project conclusion. The project initialization covers aspects of project approved, project defined, project objectives, and project organization. The project execution and iteration involve decision points, update of project plan, status reports, quality assurance reports, project progress decision, and adjustments. The project conclusion includes project end report and dissolving of project organization [V-Modell XT].

The basic concept of the V-Modell-XT involves **product orientation**, tailoring, and acquirer/supplier interface. Main project management products include project plan, project status and quality assurance reports, adjustment status list, project and quality handbooks, and final project report. The products are delivered at decision making points and judged qualitatively. The quality assurance is considered as separate discipline and not part of the project management. The tailoring covers project specific adjustments that are seen as eXtreme Tailoring and supported by the tool project assistant. The acquirer/supplier interface is seen for project interaction involving specific products and decision making points (e.g. external products) [V-Modell XT; Biffl et al. 2006; Kuhrmann 2015].

3.1.2.5 RUP

The Rational Unified Process (RUP) is an iterative process model for software engineering and a specific and detailed instance of the unified software development process (UP). It was introduced in 1998. The process focuses on development process, team productivity, creation and maintenance of models, use of unified modeling language (UML), tools, configuration of the development process, and best practices of software development. The development process is described in two dimensions involving organization along time and content. The time dimension consists of phases and iterations, namely cycles of inception, elaboration, construction and transition phases. Each phase has a specific purpose and the completion of each phase provides milestone for decision making. The content dimension describes workers with behavior and responsibilities, activities as units of work, artifacts as piece of information, and workflows as sequenced activities. The workflows are distinguished in core and supporting. The core process workflows involve business modeling, requirements, analysis and design, implementation, test and deployment, whereas the supporting workflows cover project management, configuration and change management, and environment. The project management workflow focuses mainly on iterative development process involving a framework for management, practical guidelines for planning, staffing, executing and monitoring projects, and a framework for management of risk [Rational 1998; Brewer/Dittman 2010, 43–45; Hanser 2010, 13–45; Kruchten 2004].

3.1.2.6 Scrum

Scrum is an iterative and incremental process framework[67] for complex product development (i.e. software). It is developed by Schwaber and Sutherland in 1995. Theoretically, the Scrum is based on empiricism[68]. It focuses on complex problems that can be addressed adaptively in order to deliver early highest possible value products. It presumes that a product development involves environmental and technical variables such as requirements, time frame, resources, and technology. The framework consists of Scrum teams, roles, events, artifacts, and rules components with specific purpose. The Scrum team is a self-organizing and cross-functional involving product owner, development team, and Scrum master. It provides three pillars for empirical process control, namely transparency, inspection, and adaptation. The inspection and adaptation is supported by four formal events i.e. sprint planning, daily scrum, sprint review, and sprint retrospective. The Scrum artifacts represent work or value including product backlog as an ordered requirements list, sprint backlog as a set of product backlog and increment plan, and the increment as completed work [Brewer/Dittman 2010, 43–45; Hanser 2010, 13–45; Schwaber/Sutherland 2013].

3.1.2.7 Conclusion

The analysis of project management approaches covers standards and methodologies PMBOK, ISO 21500:2012, PRINCE2, V-Modell-XT, RUP, and Scrum. It reveals that all approaches primarily aim simplicity and ease of management and control of project work for development of products or results. The type of product or result along with aspects such as industry, culture, and expertise specifies the approach of project management. However, stakeholder needs and expectations are crucial for specification of project requirements. Project requirements may change over time. Accordingly, projects can be **broadly** classified in projects with firm requirements, projects with changing requirements, and project with rapidly changing requirements. The resulting project management approaches are either sequential or iterative and incremental in nature. Aspects such as

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[67] A framework where various processes and techniques can be applied to develop products.

[68] Empiricism asserts that knowledge comes from experience and making decisions based on what is known.

documentation intensity, co-location of teams, formulization, and business value orientation are also relevant for project characteristics. For example, PRINCE2, V-Modell-XT, and RUP involve intensive documentation as compare to Scrum. The V-Modell-XT is **formulized** following strict activity policies and tailoring.

The standards and methodologies PMBOK, ISO 21500, PRINCE2, V-Modell-XT, as discussed above, follow the same interpretation of project management that involves initiation, planning, execution and control activities to conclude a project. The Scrum framework, however, follows a different philosophy but similarities in formal activities (i.e. events) covering planning, doing, review, and demonstration. The discussed approaches provide **guidelines** either specifically for project management (e.g. PMBOK, ISO 21500) or involve **project management as supporting** activities (e.g. RUP, V-Modell-XT). These approaches differ, for example, in focus, scope, abstraction level, and sometimes underlying philosophy. The standards PMBOK and ISO 21500 are general in **focus**, whereas PMBOK possesses different extensions (e.g. software). Both standards support project, program, and portfolio management and are suitable for large and complex projects. The (de facto) standards PRINCE2 and V-Modell-XT, the process model RUP, and the framework Scrum focus mainly and specifically on information systems projects but with varying orientation (i.e. business or product). The discussed approaches differentiate in terms of **scope** i.e. project, program, or portfolio management. For instance, PRINCE2 and V-Modell-XT are only applicable to single projects or project within programs, whereas PMBOK and ISO 21500 include also interfaces for program and portfolio management. Furthermore, arrangement of processes and inclusion or exclusion of behavioral competencies makes a difference. PMBOK involves mainly project management processes, where ISO 21500 covers also project management competencies (i.e. technical, behavioral, and contextual). The standards PMBOK and ISO 21500 provide different **abstraction levels**, for example, in terms of knowledge or subject areas (i.e. ten and four respectively). Similarly, PRINCE2 provides seven principles, seven themes, and seven processes. V-Modell-XT suggests three project management activities project initialization, project execution and iteration, and project conclusion that are further detailed. Scrum suggests transparency, inspection, and adaptation with formal events of planning, daily scrum, review, and retrospective. The management of projects is supported by specific **tools and techniques**. For instance, Scrum provides product backlog, sprint backlog, and increment, whereas V-Modell-XT suggests project plan, project status and quality assurance reports, adjustment status list, project and quality handbooks, and final project report. The standards discussed above are based on profound experiences.

However, the ISO 21500 is first published in 2012 and the use and acceptance of the standard in projects is unclear presently.

3.2 Reference Modeling

In view of the available knowledge on project management as discussed in section 3.1 and the uniqueness of RFID system implementations as described in chapter 2, reference modeling is an appropriate method for development of an approach for management of RFID system implementation. The primary reasons for suitability of reference modeling for the purpose, according to the author, are as follows:

- Because of the use of reference models (e.g. best practices) for management purposes and in early stages of a system development, reference modeling is suitable for project management in the context of this research.
- Because of the available profound knowledge on general and IT specific project management, reference modeling is suitable.
- Because of the techniques of reference modeling for reuse and use i.e. analogy, specialization, instantiation, aggregation and configuration, it is a suitable adaptation method for the purpose.

The method reference modeling is used for the development of the resulting model of this research and it is also suggested for the reuse of the resulting model. Therefore, this section provides an overview of reference modeling and details of reference modeling techniques.

3.2.1 Overview of Reference Modeling

Reference modeling is the process of construction and application of reference models [Vom Brocke 2003; Fettke/Loos 2004; Fettke/Loos 2007]. A reference model is typically characterized as a semi-formal and cross-aspect[69] model that focuses on semantics and (business) concepts in the requirement definition phase of an information system development[70]. In literature, the term reference model is defined diversely. Usually, the attribute “reference” from the term reference model is understood as a recommendation, which points to the ‘best (business) practice’. Reference models are described as special information models. They are seen also as methods, procedures, or techniques. In general,

[69] An aspect specific characteristic encompasses attribute, behavior, and extended model.

[70] For typology of reference models see (vom Brocke 2003, 98). Following Scheer’s (1999a, 1999b) Architecture of Integrated Information Systems (ARIS), an implementation of information system can be divided in three-tiers i.e. requirement definition (business concept), design specification (technical concept), and implementation description (implementation of information system). For “systematization” see also (Fettke/Loos/Zwicker 2007, 179).

the term reference model in information systems is described by attributes such as ‘universality’ and ‘recommendation’. Universality is understood as the model’s claim to absoluteness for example for a class of domains. Recommendations are considered as normative statements including rules, laws, prescriptions, specification, or standards in order to harmonize or strictly formulate human activities in information systems development [Hars 1994, 15–18; Vom Brocke 2003, 9, 31; Fettke/Loos 2004, 332–333; Fettke/Loos 2007, 4; Thomas 2005, 16]. For instance, Rosemann (2003) defines a reference model as a “*generic conceptual models that formalize recommended practices for a certain domain*” [Rosemann 2003, 595]. Frank (1999) and Fettke and Loos (2003) also underlines universality characteristic of reference models and states that “*a (generic) reference model represents a class of domains*” [Frank 1999, 695; Fettke/Loos 2003b, 35]. Focusing on configuration of standard business software, Schütte (1998) describes a reference model as “*a construction of a modeler stating universal elements and relationships of a system as recommendations for IT and business professionals. The modeling, in this context, is done with a help of a language for a particular moment in time*” [translation by the author] [Schütte 1998, 69]. Following this understanding, reference models are conceptualized as model systems including all possible variants [Schütte 1998; Vom Brocke 2003, 3; Vom Brocke 2007, 48; Vom Brocke/Fettke 2013].

The recent developments in reference modeling, however, emphasize reutilization characteristic. Fettke and Loos (2007), for example, mention that the characteristics best practices (i.e. best business practices), universal applicability (i.e. representation of a class of domains and not a particular enterprise), and reusability (i.e. a blueprint for information systems development) can define the term reference model, but unsatisfactorily and argue that “*the main idea of business patterns or analysis patterns is quite similar to the concept of reference modeling*”. Business patterns describe structures and processes of business and provide solutions for conceptual design of information systems during requirements definition [Fettke/Loos 2007, 4–5; Fettke et al. 2007, 174–205]. According to vom Brocke (2003), the characteristics of universality and recommendation must be rethought. Discussing the term reference model, Thomas (2005) mentions also the need for a uniform understanding. It is seen as problematic to verify the quality of recommendation characteristic of a reference model [Vom Brocke 2003, 32; Thomas 2005, 16–21]. Vom Brocke (2003) postulates reuse-orientation as an important criterion for reference models and describes a reference model as an information model that is developed or used to construct application models. With regard to model theoretic principles[71], Thomas (2005) describes a reference model as a concretion of the term information model and states that a reference (information) model "*is an information model used to support the construction of other models*" [Thomas 2005, 23]. More precisely, a reference model is "*an information model, which contents can be reused to construct other models*" [translation by the author]. The reuse of a reference model persists in the transfer of construction results as well as their adaption and extension in application specific context. By reuse, vom Brocke and Fettke (2013) see increased effectiveness (e.g. model quality) and efficiency (e.g. time and cost) in reference modeling and information systems development. In this regard, reference modeling discusses issues of construction and application of reference models in order to organize the reuse of the contents of a model economically. According to reuse-oriented approach of reference modeling, an information model is classified as a reference model, when it is factually reused or when it is developed for the purpose to be reused. In view of that, a reference modeling process involves designer of reference model and user of reference model [Vom Brocke 2003, 31–34; Vom Brocke 2007, 51; Vom Brocke/Fettke 2013].

In conclusion, universality and recommendation characteristics are no more central criteria for the definition of reference models. A reference model can be defined by its characteristic of reuse. A distinction is made between reference and application models. Furthermore, the declaration of model designer and acceptance of model user of reference model are seen as necessary criteria for reference models in reuse-oriented approach.

The design of information systems is an important success factor for businesses. This enforces the need for contributions regarding design that base on theoretical foundation. Historically, the works done by Scheer[72], and Becker[73] and Schütte[74] in the late nineties are seen as the initial steps in the construction of intensive reference models. Referring to early works on the topic of reference modeling, vom Brocke (2003) mentions monographs[75] by

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[71] developer and user perspectives.

[72] Reference models for industrial enterprises see Scheer (1994).

[73] see Becker (1996) forTrade information systems (German: Handelsinformationssysteme), Reference model for trade – an example (German: Handels-Referenzmodell).

[74] see Schütte (1998) for Principles of orderly reference modeling (German: Grundsätze ordnungsmäßiger Referenzmodellierung).

[75] Hars, A. (1994), Nonnenmacher, M. G. (1994), Kruse, C. (1996), Lang, K. (1997), Schütte, R. (1998), Schwegmann, A. (1999).

Hars (1994), Nonnenmacher (1994), Kruse (1996), Lang (1997), Schütte (1998) and Schwegmann (1999) [Vom Brocke 2003, 3]. The contributions of Frank (1999, 2002, 2007), Fettke and Loos (2003, 2004, 2007) and Zwicker (2007), Becker, Delfmann and Knackstedt (2007), and vom Brocke (2003, 2007), as shortly discussed above, are remarkable in the progress of latest reference modeling.

3.2.2 Design of Reference Models

The term reference model is described from system and model theoretical perspectives [Schütte 1998; Vom Brocke 2003]. Information modeling, in general, is seen as a type of theory formation and theories provide patterns of thoughts. However, modeling as a field and modeling as a process should be distinguished. In a constructivist approach, the development process of reference modeling is divided in construction and application of reference models. The construction oriented terminology stresses inter-subject coordination and subjective perception of reality. In this context, the complexity of a model is regarded as **important**. On the contrary, mapping emphasizes the immaterial and abstract copy of the original (reality) and sees the object of a given original as the **starting point**. Mapping oriented model definition emphasizes the control of model complexity. This understanding of model is generally followed in management sciences [Schütte 1998; Vom Brocke 2003]. The construction process of a model can be described as "*a special process, which (process) object represents a model that experiences an essence forming change of state (in respect of specific purpose of the model) by itself in the flow of function (during construction)*" [translation by the author]. The purpose of a model is typically influenced by object, subject, environment and construction related factors. A construction process oriented model typically involves elements such as starting point model, model designer, model user, model purpose, and resulting model (i.e. model state 1+i) [Vom Brocke 2003, 17–30].

A "*model is the result of a construction by a modeler, who declares a representation (objects and relations) of an original in one point in time with the help of a language as relevant. Hence, a model consists of modeler, model user, the original, time, and a language*" [translation by the author] [Schütte 1998, 59]. The classical model types of information systems or Wirtschaftsinformatik are information models. Information models describe relevant information of business systems. Consequently, "*a reference model is a result of a construction by modeler, who declares information (e.g. contents, semantic, or rules) to application system and organization designer (e.g. business and IT professionals) regarding universal modeling elements of a system in one point in time as recommendation* *with the help of a language in a way that a reference for an information system is generated*" [translation by the author] [Schütte 1998, 69, 74]. In this definition the author states that a reference model preferentially considers semantics of a model in a form of recommendation and that the modeling elements of a system should be universal in nature, which requires a meta-model as a language for the syntax.

Reference models are special information models. The characteristic universality (i.e. applicability for a class of domains), in the context of constructivist understanding, is seen as critical. Firstly, the models with universal applicability are not constructed in consideration of the requirements of a special (empirical) scope of application, but rather the scope of application itself is part of the construction. Secondly, there can not be an objective validity of models. The model validity, in this case, is determined by measures of observed adequacy and not by subject specific intended purposes. Therefore, universality as constitutive characteristic for reference models is seen questionable because of varying inter-subjective perceptions and requirements. The lacking verifiability of the content and quality of recommendation characteristic is also seen as problematic. The recommendation character claims that reference models offer an ideal and guiding representation in comparison to business-specific models and are considered as to-be models. Whereat, the demands on recommendation itself and on recommending individuals remain unclear. Particularly, there is no critical data available that grant or deny the recommendation character. The recommendation characteristic for a reference model can not be specified objectively, but rather during application according to observed adequacy of the model in consideration of subject, object and environment specific purposes. Therefore, universality and recommendation should be determined subjectively. In a simple constellation, it can be a model constructor and a model user. The differences in perceptions increase with intentions and specific perspectives, as well as temporal divergence in judgment of individuals, and anonymity of the user i.e. declaration as reference model and acceptance as reference model [Vom Brocke 2003, 31–33].

According to vom Brocke (2003), reference (information) model can be defined as "*an information model that is developed or used by individuals for supporting the construction of application models. The relationship between reference and application models is characterized by the fact that object or content of the reference model is reused by the construction of the object or content of application model*" [translation by the author]. By this, the term reference model is positioned in the construction process of information models. Reference models are information models that provide content-based support in the construction processes of application models. Thus, reference models serve as

entrance models (i.e. starting point) in the construction processes of application models by reuse. A reference model must not be abstract in comparison to application model (e.g. best practice case). It can be precise in comparison to application model [Vom Brocke 2003, 34–35].

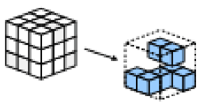
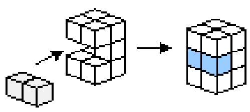
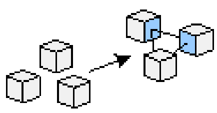
The quality of a reference model is agreed upon during construction process. The process-oriented view makes the value chain of reference modeling transparent. The construction of a reference model is directed towards achievement of a particular state of model that ensures advised benefits for customer. The degree to which a particular state of model is achieved decides over the perceptive recommendation as individual evaluation of benefits. The interest of a possible wide validity addresses the number of customers. The total benefit of a reference model consists of factors such as perceptive recommendation and possible validity. These are planned by the modeler and evaluated by the user. Therefore, the application area of reference models should be planned in consideration of economic aspects [Vom Brocke 2003, 35].

3.2.3 Design Principles of Reference Modeling

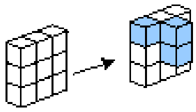
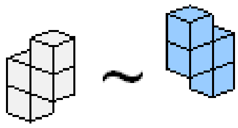
Reference models aim to reduce efforts and cost in the process of reference modeling by reuse of knowledge. The reuse of reference models is only cost effective, if adaptation approaches are efficient [Vom Brocke 2003, 4; Becker et al. 2007, 27; Vom Brocke 2013]. The early approaches of reference modeling focused on configurative 'model systems' that include all possible variant of a system [Schütte 1998]. Firstly, the construction of such model systems is time and cost intensive [Vom Brocke 2003, 4; Vom Brocke 2013]. Secondly, it is hard to exactly predict all user requirements [Vom Brocke 2003; Becker et al. 2007, 28–29; Vom Brocke 2007, 48]. The adaptation of such configurative model systems in the process of reference modeling was primarily done by configuration. In consideration of construction efforts and less predictable user requirements, only the use of configuration principle is insufficient and provides low flexibility (i.e. creative freedom) for adaptation and extension [Schütte 1998; Vom Brocke 2003; Becker et al. 2007].

Modeling, in general, focus on relevant aspects of an information system during design process by **abstraction**. However, the restriction of generality can limit the reuse of reference or information models. The main concept of reference modeling "*is to provide information models as a kind of reference in order to increase both efficiency and effectiveness of modeling processes*". Against this background, Becker, Delfmann and Knackstedt (2007), and vom Brocke (2007) see the requirements of reference model users for economic efficiency and perspective of designer for return on investment of a reference model as crucial and suggests use of additional generic module-oriented, object-oriented, component-based, and pattern-based adaptation principles for reference modeling i.e. aggregation, instantiation, specialization, and analogy. These principles are based on reuse-oriented software engineering. Similar to reuse-oriented software engineering, the reuse-oriented reference modeling design principles distinguish between reference (development 'for') and application (development 'with') models [Becker et al. 2007, 27–35; Vom Brocke 2007, 48–76]. The framework defined by vom Brocke (2007) for relations reusing information models differentiates between innovations (new solution) and modification (changed solution) of models. Similarly, variants (new shaping of problem) and versions (new solution to a problem) are distinguished [Vom Brocke 2007, 52–67][76]. The principles of reference model construction are differentiated in parametric (i.e. configurative) and adaptive (i.e. aggregation, instantiation, specialization, and analogy) approaches [Vom Brocke 2007, 52–67; Becker et al. 2007, 27–58]. The table 9 provides an overview of the construction techniques for reference modeling according to reuse.

Table 9: Overview of Design Principles for Reference Modeling

Principles	**Illustration**	**Description**	**Techniques**
Configuration		The construction of a resulting model "k" by selection decisions (choice) within an original model "K". or "The configuration is characterized by explicit adaptation points enclosed in the reference model" according to define rules. It's basic "concept is based upon the principle of model projection."	By selection
Instantiation		The creation of a resulting model "I" by integrating one or several original models "e" into appropriate generic place holders of the original model "G". or "Instantiation of a reference model aims the insertion of feasible values for placeholders that are provided within the model. These values can reach from simple numeric values to complex model element structures."	By embedding (e.g. generic data structures)
Aggregation		The combination of one or more original models "p" that build a resulting model "T," with the models "p" forming complete parts of "T". or "Aggregation implies that the reference model is provided in the form of model components that have to be combined by the reference model user. The possible combinations of components can thereby be restricted by interface definitions."	By combination
Specialization		The derivation of a resulting model "S" from	By revising (i.e.

[76] For comparison see analysis patterns of Fowler 1997

		a general model "G." That way, all modeling messages in "G" are taken over in "S" and can either be changed or extended without deleting. or "By specification the level of detail of the reference model is consciously restricted. Specialization is performed by adding, changing or removing model elements without any semantic restrictions."	inheritance)
Analogy		An original model "A" serving as a means of orientation for the construction of a resulting model "a." The relation between the models is based on a perceived similarity of both models regarding a certain aspect. or The reuse of reference model structures by the user. It is the least restricted adaptation technique.	By transfer (i.e. free-handedly)

Source: Vom Brocke 2007, 58-67, Vom Brocke 2013, Becker et al. 2007, 33-35.

3.2.3.1 Configuration

Configuration is the adaptation of explicit points enclosed in the reference model according to define rules. The basic concept of configurative reference model adaptation is based on the principle of model projection. Specifically, the starting model is total as model system containing information for each application context, whereat irrelevant model sections are faded out. The fading out is realized by configuration using adaptation parameters as input [Becker et al. 2007, 33]. In other words, configuration is "*the construction of a resulting model 'k' by selection decisions (choice) within an original model 'K'*" [Vom Brocke 2013]. A differentiation is made between model type selection (i.e. only relevant model types and modeling languages for use), element type selection (i.e. modeling language variants for different users), element selection (i.e. particular parts of a model), synonym management (i.e. different naming in different departments of a company), and representation variation (i.e. exchange of symbols of modeling language according to perspective) [Becker et al. 2007, 33–34].

The configuration principle is used, if "*the application domain can be described fully in design time including all relevant adaptations that have to be considered in various applications*". The technique used for configuration is adaptation by selection [Vom Brocke 2007, 69]. The design by configuration for element type selection can be conducted as follows [Becker et al. 2007, 38–39]:

1. Term-based element selection (e.g. invoice auditing for warehousing)
2. Element type selection (e.g. invoice auditing for the perspective overview)
3. Attribute-based element selection (e.g. invoice auditing for the sub-perspective overview, practitioner)

4. Synonym management (e.g. invoice auditing for the sub-perspectives overview, practitioner or different departments of a company)
5. Representation variation (i.e. symbolic representation for different users or departments e.g. overview, practitioner)

3.2.3.2 Instantiation

Instantiation of a reference model aims the insertion of feasible values for placeholders that are consciously provided within the information model. These values can range from simple numeric values to complex model element structures. Instantiation is performed for aspects of an information models that are left, or formulated vaguely or generic by the model developer [Becker et al. 2007, 35, 50]. In the process of instantiation, these generic aspects or statements are replaced by the integrative model representation. More precisely, it is "*the creation of a resulting model 'I' by integrating one or several original models 'e' into appropriate generic place holders of the original model 'G'*". For this purpose, special constructs of modeling language are used, which describes how the generic statements in model G' can be linked with the statements in model 'e' [Vom Brocke 2007, 58].
The instantiation principle is applied, if "*the application domain can be covered by a general framework; this framework, however, has to be adapted in regard to selected aspects that can not be fully described while building the reference model*". The technique used for instantiation is adaptation by embedding. The design by instantiation is conducted as follows [Becker et al. 2007, 60, 69]:

1. "*Select the generic model (e.g., in a tree-view).*
2. *Select generic statement within the model (e.g., by mouse-click).*
3. *Select a model to be integrated in place of the generic statement (e.g., in a tree-view).*
4. *For each relation of the generic statement, specify an equivalent statement in the model to be integrated to take over the relation (e.g., in a table).*
5. *Either select or create a resulting model; the model to be integrated is embedded in the generic model according to the rules (e.g., in a routine)*".

3.2.3.3 Specialization

Becker, Delfmann, and Knackstedt (2007) define specialization of reference model with conscious restriction of the level of detail. "*Specialization is performed by adding, changing or removing model elements without any semantic restrictions*" [Becker et al. 2007, 35]. However, vom Brocke (2007) describes specialization as "*the derivation of a resulting model 'S' from a general model 'G'*". Accordingly, "*all modeling messages in*

'G' are taken over in 'S' and can either be changed or extended" without deleting. Specialization facilitates adaptation general reference models according to specific requirements of project of company. For the differentiation of general and specific models, special modeling language constructs are used for assumed and added construction results [Vom Brocke 2007, 64–65].

The specialization principle is applied, if "*the application domain can be covered by a core solution, which has to be extended and modified (without deleting) in an indefinite manner for various applications*". The technique used for specialization is adaptation by revision. For specialization of models, following steps are required [Vom Brocke 2007, 66, 69]:

1. "*Select a general model (e.g., in a tree view).*
2. *Run a specialization service (e.g., in a context menu).*
3. *Either select or create a special model (e.g., in a tree view); the content of the general model may be transferred to the special model; the takeover may either be carried out by reference or a new instance of the model can be generated.*
4. *Adapt the special model by both changes and extensions (e.g., by standard features); the adaptations may be tracked automatically and displayed on demand*".

3.2.3.4 Aggregation

Aggregation implies that the reference model is provided in the form of model components or statements that is to be combined by the reference model user. The possible combinations of components in new contexts can thereby be restricted by interface definitions [Becker et al. 2007, 34]. In other words, aggregation is "*the combination of one or more original models 'p' that build a resulting model 'T' with the models 'p' forming complete parts of 'T'*". The connection of components or statements of separate models 'p' is performed with the help of a language construct provided by modeling language. By this, components or statements of aggregated models are taken over in the resulting model (i.e. replenishing and positioning of components or statements) [Vom Brocke 2007, 61].

The aggregation principle is used, if "*the application domain can be described partly. Each part can be fully specified, whereas their contribution for replenishing the entire coverage of an application cannot be foreseen when building the reference model*". The technique used for aggregation is adaptation by combination. For aggregation of models, the following steps are required [Vom Brocke 2007, 63-64, 69]:

1. "*Select or create the resulting model.*
2. *Select model to be aggregated.*

3. *Select modeling messages to be integrated in the aggregated model.*
4. *Iterate the process for each model to be aggregated; the messages will be transferred to the resulting model.*
5. *Integrate aggregated messages in the resulting model by additional messages according to the (new) scope of the resulting model.*"

3.2.3.5 Analogy

Analogy is the reuse of reference model structures by the user. It is the least restricted adaptation technique [Becker et al. 2007, 35]. In construction by analogy, "*an original model 'A' serves as a means of orientation for the construction of a resulting model 'a'. The relation between the models is based on a perceived similarity of both models regarding a certain aspect. [...] Although no real means of formalization between the model statements are required, a methodological support of the principle seems to be adequate*". The similarity relation perceived by constructor of the model can be documented with the help of special modeling language constructs. By this, a high degree of freedom in reusing content of an original model is ensured for the solution of new problems [Vom Brocke 2007, 66].[77]

The analogy principle is applied, if "*the application domain can be described by certain patterns recurring in each application. The entire solution, however, has to be replenished in an indefinite manner*". The technique used for analogy is adaptation by transfer. The steps for the construction of a reference model by analogy include [Vom Brocke 2007, 68–69]:

1. "*Selection or generation of the resulting model*
2. *Selection of a model to be reused with the help of analogy (i.e. transfer of the entire model to the resulting model)*
3. *Free-handedly adaptation of the resulting model (i.e. permission of all modification in the resulting mode)*
4. *Documentation of similarity between both models (i.e. for the purpose of comprehensiveness)*".

[77] According to the principle of analogy, constructs may be introduced that serve to document the similarity relation perceived by the constructor. Standardization of documentation can be realized by forms or text-based descriptions. In addition, a classification-based approach can be applied (vom Brocke, 2003).

3.2.4 Representation Techniques for Reference Modeling

Reference models require a language for representation in order to ensure standardization. Generally, modeling languages such as Unified Modeling Language (UML), Event-driven Process Chain (EPC), and Entity Relationship Modeling (ERM) are used for the purpose. Typical characteristics for a modeling language are support of multi-perspectivity, variant management, and reusability and adaptation [Fettke/Loos 2007, 7–8]. Perspectives are generally distinguished on the basis of analytical characteristics or subjective needs [Frank 2002]. They can be built on the basis of perspective specific abstraction levels integrated in the model system (e.g. ARIS views of data, function, or process) standardized with the help of meta-models and perspective specific selection and integration in the model system with the help of meta-models. Meta-models ensure integration of representation techniques as well as perspective specific preparation. A modeling language serves as a meta-model for reference modeling [Vom Brocke 2003, 108–110].

The variant management supports representations of models in consideration of build and run time (i.e. B, R, BR) construction relations. Reference models are described on build time level supporting decision logics such as freedom of choice and type and point in time (e.g. antivalence ‘XOR’, disjunction ‘IOR’, complex decision rules ‘Decision Tables’). Furthermore, rules for declaration of a variant of a reference model at run time level (e.g. feature oriented approach) are used [Vom Brocke 2003, 108–110]. Reusability is the main idea behind reference modeling that should ensure saving of resources (e.g. time, cost). A reference model can be reused simply by copying the model manually. However, adaptation of reference models, in order to avoid redundancies and inconsistencies, is done by using concepts such as configuration, aggregation, specialization, instantiation and analogy [Vom Brocke 2003, 259–319; Fettke et al. 2007, 181–184].

Regarding quality of modeling languages, there is no empirical evidence [Fettke/Loos 2007, 8]. Consequently, the selection of reference modeling language should be made in consideration of system aspect (i.e. aspect specific or cross-aspect), formality (e.g. semi-formal), extendibility (e.g. controlled extendible), and applicability level (e.g. business concept or requirement identification level). Furthermore, feasibility and applicability of a modeling language for reference modeling should be given (e.g. previous usage) [Fettke et al. 2007, 195–197].

3.2.5 Conclusion

The section reference modeling provides overview of reference modeling, reference model construction, and relevant design principles and representation techniques. This research follows the understanding of constructivist approach as suggested by reuse-oriented reference modeling. According to this, a reference model is an information model that can be reused to construct other models. More precisely, an information model is either intended to be reused or factually reused in the construction of other models (i.e. application models). Accordingly, the intended or factual reuse of an information model is the main characteristic of reference models. It does not claim for absolute acceptance and considers universality and recommendation subjectively. The term reference model can be used for descriptive as well as prescriptive purposes. In a descriptive view, a reference model describes the similarities of a class of models. In a prescriptive view, a reference model delivers suggestions or recommendations for the arrangement or appearance of a class of models.[78]. The resulting reference model of this research possesses both descriptive and prescriptive views. However, it intends to develop a reference model for prescriptive purposes.

[78] see vom Brocke 2003, 38; vom Brocke 2007, 49; Fettke/ vom Brocke 2013.

4 Requirements Analysis and Present Approaches

This chapter provides requirements analysis of management of RFID system implementation and evaluation of present approaches. Requirements analysis is based on systematic reviews of project management standards, literature reviews of RFID system implementation approaches, and the practice-oriented research of the author. The state of the art studies of the author reveal two guidelines that address project management in the context of RFID system implementations. These approaches are analyzed and evaluated on the basis of requirements analysis.

4.1 Requirements Analysis of RFID System Implementations Management

In order to provide state of the art of knowledge development, the author conducted several systematic literature reviews at different points in time in the course of research. These include review of project management standards and methodologies, and the state of the art studies. Furthermore, the practice-oriented research of the author helps to refine and structure available knowledge. Accordingly, the review of project management standards and methodologies delivers useful insights and bases for formulation of project management requirements.[79] The state of the art studies facilitate derivation of general requirements for RFID system implementations [Khan 2015]. The practice-oriented research defines requirements in consideration of domain characteristics.[80]

Starting with project management body of knowledge (PMBOK), project management standards and methodologies were reviewed irrespective of classical and agile approaches in order to map similarities between existing project management standards and RFID system implementation projects.[81] These standards provide formal grounds for formulation of the specific requirements of project management and are part of the requirements list of the resulting reference model.

The state of the art analysis covers the time period from 2004 to 2015 and aim analysis of approaches specific for RFID system implementation. The reviews were mainly conducted at three different points in time in the course of this research. These reviews include a broad review in the stating of the research in 2008, a review of selected approaches by topic in 2011, and a review with refinement in terms of categories, extension in terms of time period, and explication in terms of implementation process in 2015. The results are

[79] See Section 3.1.

[80] See Chapter 6.

[81] See Section 3.1.

summarized in the "*RFID system implementation: state of the art of guidelines, frameworks, models, and methods*" [Khan 2015]. The reviews shortlists sixty-seven documents based on defined selection criteria in six categories, namely RFID implementation project management, large enterprises and RFID implementation, SMEs and RFID implementation, RFID economic feasibility analysis, RFID in special business domains, and special implementation aspects of RFID. The study highlights present research gaps on the topic. The analysis of available approaches from the study facilitates derivation of general requirements for RFID system implementations. According to the study[82], RFID system implementations possess a distinctive set of requirements stem from the uniqueness and complexity of the projects. Accordingly, a list of general business and technology requirements is defined for RFID system implementation approaches that aim understanding and application of the technology in supply chain [Khan 2015]. These general requirements provide basis for the specific requirements of different facets of RFID system implementations.

The practice-oriented research, which was started in 2008 in cooperation with food manufacturing industries in Saxony-Anhalt, Lower Saxony, and the network of food businesses of Saxony-Anhalt[83], provides ground for specification of the requirements in consideration of domain characteristics. The companies were confronted with issues of economical and technical feasibility of the RFID technology. Food manufacturing industries are characterized as companies with low-priced and sometimes liquid containing products, less documented logistics processes, and less influence in the supply chain. In view of that, primary business concerns of the companies were preparation and economic feasibility of RFID implementations along with technical feasibility of the technology and exploration of its optimization potentials in intra-logistics. The research focused on aspects of management, analysis, design and feasibility in the context of RFID system implementations. Implementations of RFID technology is primarily a business concern for the participated industries focusing on preparation for and economic feasibility of RFID implementations.[84] These aspects influence the nature of RFID system implementation projects resulting in specific business requirements. These requirements define the overall

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[82] See Chapter 2.

[83] Netzwerks Ernährungswirtschaft Sachen-Anhalt, http://www.netzwerk-ernaehrungswirtschaft.de (last accessed 05.05. 2016).

[84] See Chapter 6.

approach of this research and the list of requirements for project management of RFID system implementation.

In general, the requirements of a project are defined by stakeholder needs and expectations, which are influenced by strategic objectives, business context, and involved technologies [Kerzner 2003, 5-6, 88, 141; Meredith/Mantel Jr 2009, 3, 27, 37; Schwalbe 2011, 8-10, 87, 182; Pietsch 2012]. In view of that, requirements for management of RFID system implementation, according to the author, can be divided in business, project management and RFID technology requirements.

4.1.1 Business Requirements

The business requirements result from enterprise strategy and business context that furthermore encompass aspects of management concerns (i.e. applicability, compatibility, and capability). Accordingly, the specific approach for management of RFID system implementation project should consider aspects of strategy, business domain, technical feasibility, and economic feasibility.

- Strategy (B1): A business strategy is defined by business needs, vision and objectives, which influence stakeholder needs and expectation. For instance, the enterprises may focus on preparation for a potential implementation of RFID technology as project objectives. This results in RFID system design and economic analysis. The project objectives can also be definition and deployment of partial or complete RFID system for an enterprise. In either case, business strategy and project objectives provide bases for the scope of delivery and measurement of project progress or success.
- Business Domain (B2): The business context defines the nature of industry or business domain. Every enterprise possesses specific structure, culture, products and price categories that influence business strategy and needs. There are also other characteristics that are relevant for internal implementation of information systems (i.e. documentation and automation levels) and supply chain wide implementation of information systems (i.e. influence level in supply chain). For instance, potential costs and benefits of an RFID implementation are influenced by product type (e.g. liquid containing), product price (e.g. low price), and available information technology landscape (e.g. degree of automation).
- Technical Feasibility (B3): The characteristic technical feasibility involves applicability, compatibility, and capability aspects. These are the primary concerns of management in dealing with new technologies. For example, applicability of

RFID technology can be questioned because of the environmental effects of the technology or it is crucial to clarify the compatibility of an RFID solution with other Auto-ID and RFID solutions in enterprise.

- Economic Feasibility (B4): Economic feasibility remains a key factor for decision of RFID system implementation for some domains, for example, because of the cost of RFID, enterprise product prices, and potential benefits for the enterprises. Therefore, the approach should be economically feasible and include analysis of cost and benefits and return on investment of RFID technology.

4.1.2 Project Management Requirements

The stakeholder needs and expectations define project requirements and are influenced by business and technology requirements. The needs of stakeholders along with business and technology requirements result in specific requirements for management of RFID system implementation projects. Accordingly, the specific approaches should consider the following requirements for the purpose of simplicity and the ease of management and control.

- Stakeholder (P1): RFID implementation projects involve various stakeholders from management of various departments to internal and external project teams. They possess different backgrounds, levels of knowledge, needs and expectations, and belong to different disciplines. For instance, managers of supply chain have different set of requirements in comparison to (information) technology managers. These differences require proper analysis for definition of an RFID system, for example, for the purpose of requirements specification and use of common language between teams of different professional backgrounds.
- Communication (P2): The intensity of communication is high in large, co-located as well as separated teams as the stakeholders of RFID implementation projects come from different backgrounds and they may be internal or external to enterprise or project. This, as consequence, requires greater synchronization efforts in order to reduce gaps between various stakeholders from different organizational backgrounds with different levels of expertise and different interests.
- Change (P3): The change encompasses redesign as well as organizational change in the context of RFID implementations. On the one hand, an RFID implementation may cause change in supply chain processes. On the other hand, an RFID system deployment requires change management, for example, for user acceptance.

Therefore, redesign and organizational changes both need proper consideration for the success of a project.

- Iteration (P4): The iterative execution of a project ensures rework and lessons learned by frequent feedbacks and continuous improvement by reviews. Intentional repetitions reduce complexity, improve quality and ease risk management. RFID implementations are innovative and complex. Accordingly, intentional repetitions or rework provide opportunities to adjust the quality of deliverables. This can also be done informally in meetings (if required). By reviews, for instance, the team behavior can be improved in order to ensure effectiveness and efficiency (i.e. without direction and control).
- Increment (P5): Incremental development follows scheduling strategies by prioritizing requirements and resources (i.e. evaluation or classification) in order to deliver partial solution without affecting the final results of a project. RFID implementation projects in intra-logistics are complex and impose requirements change upon lessons learned in the course of action. For example, an incremental development of RFID system can consist of deployment of RFID technology in a specific department or area of an enterprise to test and validate the concept, where further increments involve further departments or areas.
- Collaboration (P6): Collaboration with supply chain partners is crucial for supply chain effectiveness and efficiency. Similarly, collaborations between project teams (e.g. project management and technical teams) that facilitate and lead instead of direct and control are important in RFID implementation projects. Collaboration in RFID implementation projects should involve open cooperation with project partners, harmonized approach for specification in project teams, prove of function and maintenance (validation), and interpersonal relations in large, separated and changing teams.
- Interdisciplinarity (P7): RFID implementation projects involve stakeholders from various professional backgrounds and enterprise entities or departments. These entities can be represented in roles such as top managers, supply chain managers, and technology managers. Each of these stakeholder groups possess specific requirements resulting from respective point of views. For instance, the top management focuses on competitiveness of an enterprise at strategic level, whereas supply chain management focuses on logistics activities and their optimization.

These different viewpoints and the resulting requirements require proper consideration for specification of RFID project and system requirements.

- Sophistication (P8): The complexity of RFID system implementations requires systematic and sophisticated project management and system development approaches that aims simplicity and ease of management. Accordingly, the work of an RFID system implementation project should be structured, for example, in phases and work breakdown structure.
- Realism (P9): The applicability of approaches with appropriate information is important in the context of RFID system implementation projects because of the innovative nature and cost of the technology. Accordingly, relevant approaches should provide appropriate knowledge for specific domains. For instance, the approach should be realizable with less efforts (i.e. adaptation), fewer resources (i.e. funds, personnel), or intermediate skills (e.g. scheduling strategies for management, RFID technology).
- Comprehensiveness (P10): Comprehensiveness refers to intensity of documentation and use of tools and techniques. For the purpose of understandability and applicability, RFID system implementation approaches should provide appropriate details along with procedures, tools and techniques. For instance, the diversity in stakeholder perspectives and different backgrounds of stakeholders in RFID implementation projects impose the use of proper tools and techniques for requirements analysis and communication. By this, the approach can ensure ease of management in terms of cost, efforts and skills.

4.1.3 RFID Technology Requirements

The technology along with strategy and business context influences stakeholder needs and expectations that furthermore affect project requirements. RFID technology is innovative and RFID systems in supply chains are complex as discussed in chapter 2. Accordingly, RFID implementation projects possess a unique set of requirements. In this context, these requirements are summarized as supply chain process, RFID system, and test aspects.

- Supply Chain Process (R1): The uniqueness of RFID technology and supply chain processes require consideration of detailed analysis at physical infrastructure, logical, and application levels of an RFID system. The detail analysis should aim to identify requirements and optimization potentials of supply chain processes in consideration of enterprise standards.

- RFID Characteristic (R2): An RFID system consists of hardware (i.e. tags, readers), software (i.e. middleware), and backend systems (e.g. warehouse management system). RFID technology is unique and possesses specific characteristics such as environmental effects, open or closed system, centralized or decentralized data storage, real-time or batch-data processing, physical form of tag, storage capacity of tag, writeability of tag, frequency, energy supply, integrated sensor technology, and security issues. The specification of these characteristics influences system type but also implementation activities. Accordingly, the approach should consider specific characteristics of RFID technology at relevant levels of the system.
- Test (R3): Because of the nature of RFID technology, it requires tests at physical level, for example, for accurate reading of tags and application level, for example, for integration of RFID data with the aim to optimize business value. Repeated and intensive tests are suggested focusing on technical feasibility and system functionality according to process requirements in order to validate an RFID system or part of an RFID system.

4.1.4 List of Requirements

The requirements of RFID system implementation project management as discussed above are summarized in the following table.

Table 10: List of RFID Project Management Requirements

No.	Characteristics	Description
Business Requirements		
B1	Strategy	The approach should involve strategy that is defined by business needs, vision and objectives. The strategy influence stakeholder needs and expectations and provide basis for measurement of project success. Project objectives may be complete system, partial system, system design, and economic analysis.
B2	Business Domain	The approach should consider uniqueness of business domain such as enterprise structure and culture, products and prices, documentation and automation levels, and influence level in supply chain.
B3	Technical Feasibility	The approach should consider technical feasibility involving applicability of RFID system in respect of environmental effects, compatibility of RFID solution with other Auto-ID and RFID solution, and capability of enterprise information systems.
B4	Economic Feasibility	The approach should be economically feasible and include analysis of cost and potential benefits and return on investment as this remains a key factor for RFID implementation decision.
Project Management Requirements		
P1	Stakeholder	The approach should consider needs and expectations of project stakeholders including project team. Stakeholder needs and expectations are influenced by business strategy, business context, and involved technology.
P2	Communication	The approach should consider synchronization efforts in large, co-located, as well as separated project teams and their requirements for intensive communication (e.g. meetings, information availability).
P3	Change	The approach should consider redesign of supply chain processes as well as organizational change in terms of change management.
P4	Iteration	The approach should provide rework and lessons learned by *frequent feedbacks* and continuous improvement by *reviews*.

P5	Increment	The approach should deliver early *partial solutions* and accommodate requirements *change* with high level plan and prioritize requirements and resources (i.e. evolution or classification) in large projects.
P6	Collaboration	The approach should involve collaboration of project partners and between project teams focusing on facilitation and leadership instead of direction and control (e.g. by contracts). This should ensure open cooperation and harmonized approach in large, separated, and changing teams.
P7	Interdisciplinarity	The approach should consider enterprise entities or departments and their requirements for specification of project and system requirements.
P8	Sophistication	The approach should be systematic and sophisticated, for example, for project organization involving division of work according to phase and work breakdown structures in order to ensure simplicity and ease of management and control.
P9	Realism	The approach should provide appropriate information and be realizable with less efforts (i.e. adaptation), fewer resources (i.e. funds, personnel), or intermediate skills (e.g. scheduling strategies for management, RFID technology).
P10	Comprehensiveness	The approach should strive for understandability and applicability providing appropriate documentation details and granularity along with procedures, tools and techniques.
RFID Technology Requirements		
R1	Supply Chain Process	The approach should consider detailed analysis in consideration of unique process requirements and enterprise standards at physical infrastructure as well as application level.
R2	RFID Characteristic	The approach should consider RFID as well as information technology characteristics for specification of the system. These characteristics involve, for example, aspects of system type, data storage, data processing, tag storage capacity, tag writeability and form, frequency, energy supply, environmental effects, and security.
R3	Test	The approach should involve repeated and intensive test in order to validate part of the RFID system or entire RFID system.

Source: By the author.

4.2 State of the Art of Approaches

The reviews of the author reveal that an RFID system implementation process is a multi-facet process including, for example, facets of project management, economic analysis, system design, technical implementation, enterprise size, and business domain. According to the state of the art studies, there are several approaches available that refer RFID system implementation focusing on specific facets of the process. For instance, the approaches by [Pigni et al. 2006; Vogeler 2009; Donath 2010] as discussed in section 2.2 address RFID system development and deployment facets. In the same way, economic analysis facet of RFID system implementation is referred by [Vilkov 2007; Bardaki et al. 2008; Rhensius/Dünnebacke 2009].[85] The project management of RFID system implementations is addressed by two approaches, namely [Gross/Thiesse 2005] and [Gillert 2008] as short listed in [Khan 2015]. This section aims detailed analysis and evaluation of the current project management approaches for RFID system implementation on the basis of the list of RFID project management requirements from section 4.1.

[85] See Section 2.2.

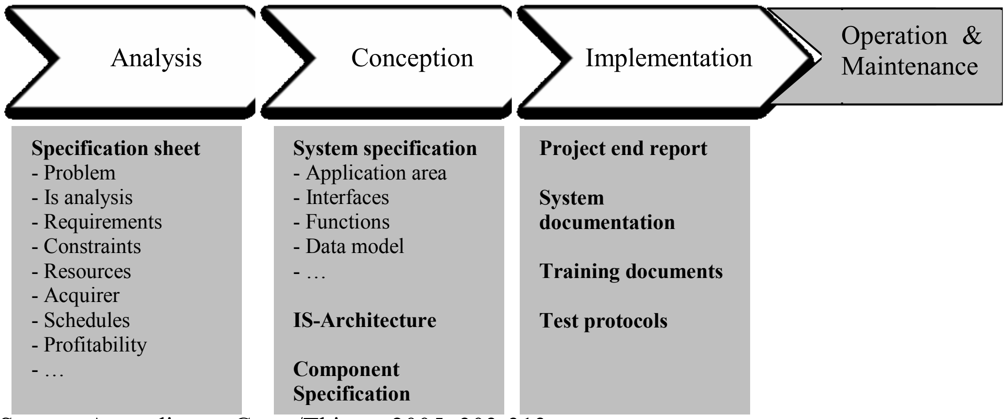
4.2.1 Gross-2005

The guideline by Gross and Thiesse (2005) addresses RFID system implementation and provides suggestions for project managers. It aims to highlight the differences of RFID implementation projects and general IT projects with the help of few key aspects on eleven pages. Accordingly, the guideline covers aspects of project organization in terms of team building, RFID specific activities as process model, and change management [Gross/Thiesse 2005].

According to the guideline, RFID system implementation starts with team building and sees experiences of employees in large projects and profound knowledge of RFID technology as essential. In case of lack of these experiences, it is suggested to hire external experts. The guideline suggests differentiation in core and extended teams. The **core team** is a full time project team involving the roles of project manager with technical, process, and large projects expertise, change manager with process optimization and reorganization expertise, RFID manager with RFID systems expertise, process manager with supply chain management expertise, and application manager with RFID relevant IT expertise. The **extended team** involves individuals responsible for operational areas in an enterprise and individuals such as technicians, RFID vendor, and trade partner. The approach, furthermore, stresses increased **coordination efforts** in supply chain wide projects with global orientation because of differences in requirements and varying standards and regulations (i.e. responsibility and accesses to databases, different levels of technical requirements, migration from other identification technologies, and diverse expectations of enterprises).

The RFID specific activities are exemplified with the help of a process model involving analysis, conception, and implementation phases along with continuous operation and maintenance as shown in figure 11. In the process model, the analysis phase is aimed for structuring of problem area in the form of specification sheet. The conception phase involves solution concept on the basis of specification sheet. The implementation phase should cover development of working solution. The operation and maintenance are seen as continuous activities of RFID system implementation.

Figure 11: Process Model for RFID Implementation by Gross



Source: According to Gross/Thiesse 2005, 303-313.

The guideline outlines the importance of RFID specific activities such as on-site survey involving physical objects, technology selection, and application data specification. It, furthermore, highlights critical success factors that consist of management support, stakeholder management, training, and communication. The guideline concludes with emphasize on RFID specific activities, fewer experiences, less known solutions, no reusable solutions, and involvement of experts.

Evaluation

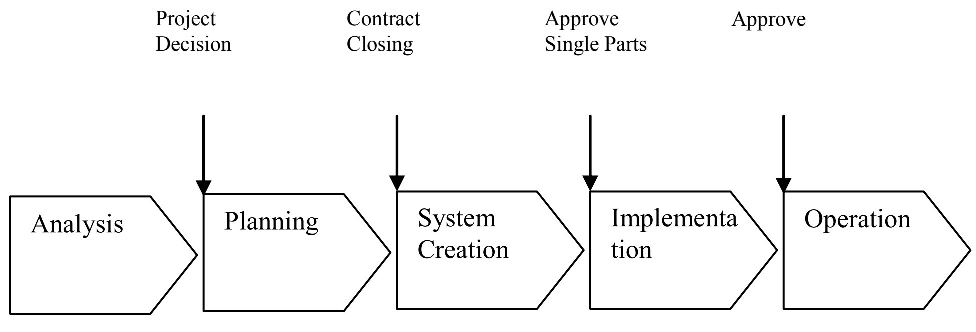
The guideline is intended for project manager guidance (B1) showing differences of RFID implementation and general IT projects. Though, the guideline's view on project management is functional focusing on competencies and not methodical with involvement of planning, organization and execution (B1, P1, P4, P5, P8, P9, P10). Furthermore, acquirer enterprises that aim, for example, economic feasibility are not the focus of the guideline (B1, B2, B3, B4). The guideline covers aspects of project organization in terms of team building and discusses involved roles and responsibilities in the context of large, complex, supply chain wide and globally oriented projects of RFID implementation. It suggests differentiation in core and extended teams and highlights increased coordination efforts in supply chain wide projects (P1, P2, P6, P7). The RFID specific activities are exemplified with the help of a general process model (R1, R2, R3, P8). The guideline stress that management support, stakeholder management, training, communication, and change management are crucial in the context of RFID implementation while highlighting the importance of RFID specific activities (B1, P1, P3). It considers no change in tools and techniques for project management and recommends professional project management team as experts because of fewer experiences, less know solutions, and no reusable solutions (P8, P9, P10). In conclusion, the guideline is not a project management method that supports enterprises (e.g. food industries) in planning and implementation of RFID systems and is only suitable for the use by project management experts as an overview, for example, in enterprises with expert teams (B1, B2, B3, B4, P8, P9, P10). The aspects of planning and realization are referred in [Gross 2005], however the document sees no difference in project and quality management processes of RFID system implementation and general IT projects (P8, P9, P10).

4.2.2 Gillert-2008

The guideline by Gillert (2008) focuses on system integration of AutoID and RFID systems. It aims to structure requirements of a proper system integration of AutoID/RFID solutions and compare different scopes in the context of project management while emphasizing on sophisticated project management and open and goal-oriented cooperation. The guideline provides guidance in project executions for system integrators with desirable range of services (abstractly) and discloses important interfaces between realization partners and suggests how to achieve a reliable cooperation [Gillert 2008].

The guideline follows the work breakdown structure of a system integration project involving analysis, planning, system creation, implementation, and operation phases as figure 12 shows. The analysis phase covers analysis of business process aiming identification of optimization potentials and benefits. The planning phase aims concretization and detailing of analysis phase involving, for example, detailed specification sheet and system specification. The implementation phase involves integration of systems according to defined structures and processes. The operation phase considers service and maintenance aspects. All phases are described shortly sometimes with the help of questions and involve activities and tasks as headings.

Figure 12: Project Phases/Stages by Gillert



Source: According to Gillert 2008, 7.

Evaluation

The guideline specifically addresses RFID system integrator and focuses on project management aspects from system integrator perspective however exclude other perspectives (e.g. acquirer enterprise) (B1, B2, P1). The guideline stresses the importance of sophisticated project management and open and goal-oriented cooperation and provide process model for the purpose (B1, P6, P8). It provides detailed specification sheet and system specifications (P9). However, activities and tasks of involved phases are handled only abstractly with the help of questions and headings (P10). Furthermore, aspects of iterative and incremental execution of projects, interdisciplinarity, and change management are absent (P3, P4, P5, P7). The guideline provides useful insights for system integrator, though it is not suitable for acquirer enterprises such as food manufacturing industries because of different set of requirements (B2, P9).

4.2.3 Conclusion

The state of the art analysis aimed to examine and evaluate present approaches on project management of RFID system implementations. The review bases on the systematic literature reviews of the author made until 2015 [Khan 2015], which reveals two guidelines that address the topic, namely a guideline by Gross and Thiesse (2005) and a guideline by Gillert (2008). The analysis in this section covers only approaches that address project management of RFID system implementation and excludes approaches on special issues such as anti-counterfeiting [Lehtonen et al. 2009].

Table 11: Evaluation of Present Project Management Approaches for RFID Projects

Document	Business Requirements				Project Management Requirements										RFID Technology Requirements		
	Strategy	Business Domain	Technical Feasibility	Economic Feasibility	Stakeholder	Communication	Change	Iteration	Increment	Collaboration	Interdisciplinarity	Sophistication	Realism	Comprehensiveness	Supply Chain Process	RFID Characteristic	Test
	B1	B2	B3	B4	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	R1	R2	R3
Gross-2005	◔	○	◔	◔	●	◕	◕	○	○	◕	◕	◑	◔	◔	◑	●	◔
Gillert-2008	◔	○	◔	◔	◔	◔	○	○	○	◕	○	◕	◔	◔	◔	◔	◔

Legend:

○	0%	Not at all considered
◔	25%	Partially considered
◑	50%	Appreciably considered
◕	75%	Thoroughly considered
●	100%	Fully considered

Source: By the author.

Accordingly, the selection of present approaches addressing project management for the purpose is made on the basis of state of the art reviews [Khan 2015], whereas the analysis and evaluation of the approaches base on requirements analysis from section 4.1 as shown in table 11.

The analysis of available approaches discloses that project management requires an appropriate approach in terms of team competencies and a sophisticated approach in terms of project management activities. The present guidelines for the purpose are structured and provide useful insights in their own contexts (i.e. expert project manager and team competencies, and system integrator perspective). As shown in table 11, these guidelines do not fulfill business and resulting project management and RFID technology requirements of acquirer enterprises such as food manufacturing industries that intend preparation, design, and economic analysis of RFID system implementations. Thus, the following chapter presents a reference model for management of RFID system implementations involving methodical view point for the business domain of food manufacturing industries that aim preparation, system design, or economic analysis.

Part II: Reference Model

5 Reference Model for Management of RFID System Implementations

Management of RFID system implementation (MaRSI) is the resulting **reference model** of this research for planning, organization and realization of RFID system implementation activities. The MaRSI reference model delivers **appropriate knowledge** in order to increase understanding and ease decision making of RFID technology application by providing a frame of reference, a process model, inputs and outputs, and tools and techniques along with relevant knowledge areas. MaRSI, primarily, **focuses** on project management aspects of RFID system implementations for effective and efficient management (e.g. stakeholder management from various backgrounds and their requirements). By this, it intends[86] simplicity of RFID system implementations.

For **appropriateness**, the MaRSI model considers management concerns and perspective of food manufacturing industries and the resulting requirements of projects.[87] The management concerns, in this regard, include preparation for a potential RFID implementation, identification of rationalization potentials for the enterprise, and exposure of economic value of RFID system implementation. The **specific requirements** of RFID system implementation projects of food manufacturing industries are described and listed in requirements analysis[88].

The MaRSI model aims **explication of concerns** in order to increase applicability and profitability of approaches from management and technical point of views. It **emphasizes** on:

- reviews instead of control
- frequent feedbacks instead of change controls
- meetings and transparency instead of risk analysis and control

The contents of MaRSI are intended to be reused and adapted according to the objectives and requirements of a project with the help of specific techniques of reference modeling[89]. As MaRSI is a proven solution[90], it increases effectiveness (e.g. quality) and efficiency (e.g. time and cost) by reuse of knowledge. It refers business as well as technology requirements in the context of RFID system implementations and provides theoretical and

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[86] See Becker 1996, 133-150, Frank 1999, 695-697, Fettke/ Loos 2004, 331, Becker/ Delfmann/ Knackstedt 2007, 27, Fettke/ vom Brocke 2013.

[87] See Chapter 4.

[88] See Section 4.1.

[89] See Section 3.2.

[90] See Sections 6.2 and 6.3.

practical benefits as an artifact of design-oriented science.[91] In particular, the reference model is designed using constructivist approach as suggested by **reuse-oriented** reference modeling. It does not claim for absolute acceptance and considers universality and recommendation subjectively. The resulting reference model of this research possesses both descriptive and prescriptive views.[92] However, it intends to develop a reference model for prescriptive purposes.

For the construction of MaRSI, the **design principle** of analogy (i.e. adaptation by transfer) is applied. Following the principle of analogy, the PMBOK guide served as a means of orientation for the construction of the resulting reference model, where only certain aspects of the guide are taken over (i.e. free handed reuse[93]) in MaRSI.[94] The construction process, however, also involve specialization techniques.[95] The PMBOK standard of PMI (2008) along with other standards[96] serves as an important starting document for the purpose.

MaRSI **addresses** top managers and project managers of small and medium-sized as well as large food manufacturing industries (i.e. acquirer enterprises). It also provides guidance for logistics managers, change managers, and technology managers of the of food manufacturing industries in order to understand the complexity of RFID system implementations. The reference model can also be used by specialists of related technologies and researchers of related disciplines.

5.1 MaRSI Frame of Reference

The MaRSI frame of reference is aimed to communicate **fundamental understanding** of RFID system implementation projects. It, furthermore, provides **guidance** during project planning and realization for perspective specific activities allocation. RFID system implementations are complex because of the unique and innovative nature of RFID

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[91] From practical point of view, the reference model is developed for a class of domain (i.e. food manufacturing industries) and is intended to be adapted according to the requirements of particular enterprises from the domain.

[92] In a descriptive view, a reference model describes the similarities of a class of models. In a prescriptive view, a reference model delivers suggestions or recommendations for the arrangement or appearance of a class of models (vom Brocke 2003, 38; vom Brocke 2007, 49; Fettke/ vom Brocke 2013).

[93] as free handed reuse is a prerequisite for the solution of new business problems.

[94] For free use of model structure see Becker/ Delfmann/ Knackstedt 2007, 35 and vom Brocke 2007, 66.

[95] See Chapter 6.

[96] See Section 3.1.2.

technology[97] and the project characteristics of RFID system implementations[98]. Accordingly, RFID system implementation projects involve different activities and stakeholders. The on-site surveys and RFID data modeling are two of the examples of the unique activities of an RFID system implementation project as discussed in requirements under R1, R2, R3, P3, P4, and P5 in section 4.1. Similarly, the stakeholders of an RFID system implementation project are either internal or external to enterprise, possess different backgrounds, levels of knowledge, and set of requirements and expectations, and belong to different disciplines covered as P1, P6, and P7 in section 4.1. This, as a result, requires proper definition of project and tasks boundaries referred as P8, P9, and P10 requirements in section 4.1 and better synchronization efforts in order to reduce the gaps between project stakeholders addressed as P2, and P3 in section 4.1.[99] For that reasons, the use of a standard frame of reference is crucial.

The MaRSI frame of reference is an **abstract** frame that describes activities of and perspectives on an RFID system implementation process. It covers project management and system development process models (**explication of concerns**), where the **boundaries** to both models are fluid.[100] The MaRSI frame of reference provides **structure, simplicity, and comprehensiveness** for projects in accordance with RFID system implementations requirements[101].

The involvement of different roles from different management and technology disciplines results in multi-perspectivity in RFID system implementations. Multi-perspectivity in RFID system implementations, according to the author, can be managed by subjectivity management, where quality is related to user acceptance.

Subjectivity management is a perspective specific representation technique for design in reuse-oriented reference modeling. It considers subjective perceptions of users in specific domains in order to overcome anonymity. Subjectivity management emphasizes on **system**

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[97] See Chapter 2.

[98] See Section 4.1.

[99] For reference modeling see vom Brocke 2003, 141-142 and for multi-perspectivity see Rosemann/Schütte 1999, 32and Frank 2002.

[100] See characteristics of frame of reference: A terminological frame of reference should possess general validity. It should be at highly abstract level. It can be hardly operationalized than a model. The boundaries to a model or meta-model are fluid. See http://www.qrst.de/wiki/bezugsrahmen.html (last accessed 05.04.2014).

[101] See Section 4.1.

aspects (i.e. characteristics, behavior), **intended purpose** (e.g. process reengineering or system implementation), and **personal preferences** of user. Furthermore, a differentiation is made between perspective coverage (degree of realization of perspectives by user), perspective breadth (number of perspectives), and perspective depth (degree of consideration of user preferences) [Rosemann/Schütte 1999, 22–26; Frank 2002; Vom Brocke 2003, 29–30, 102-103, 141-142][102].[103]

Accordingly, the MaRSI frame of reference possesses five perspectives, namely strategy, project, process, change, and technology. These perspectives are defined on the basis of specific requirements of RFID system implementation projects[104], which are resulted from literature reviews and practice-oriented research of the author. The perspectives are **generic** and **applicable** to any RFID system implementation project in the domain of food manufacturing industries. The MaRSI frame of reference orders suggested perspectives in a **top-down manner** with decreasing **abstraction levels** or varying levels of details. This is regarded as organization along management levels[105]. The activities of an RFID system implementation project are mapped against management levels showing vertical and horizontal flow over time. This is regarded as organization along process[106]. The MaRSI frame of reference shows the involvement of specific roles in specific activities of RFID system implementation in the course of action as shown in figure 13. It connects RFID system implementation process and perspectives in order to ensure integration and cross area communication.

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[102] Rosemann and Schütte (1999) suggest purpose and role orientation in respect of perspectivity in reference modeling. With the purpose orientation, quality deficiencies for various perspectives are avoided in the process of construction and application of reference models. Role orientation considers influences of roles, responsibilities, and capabilities of involved individuals and determines perspectives on the contents of a model. For example, an information model at strategic level in an information system development or deployment is abstract or details are not visible in comparison to operational level, which results in two different perspectives.

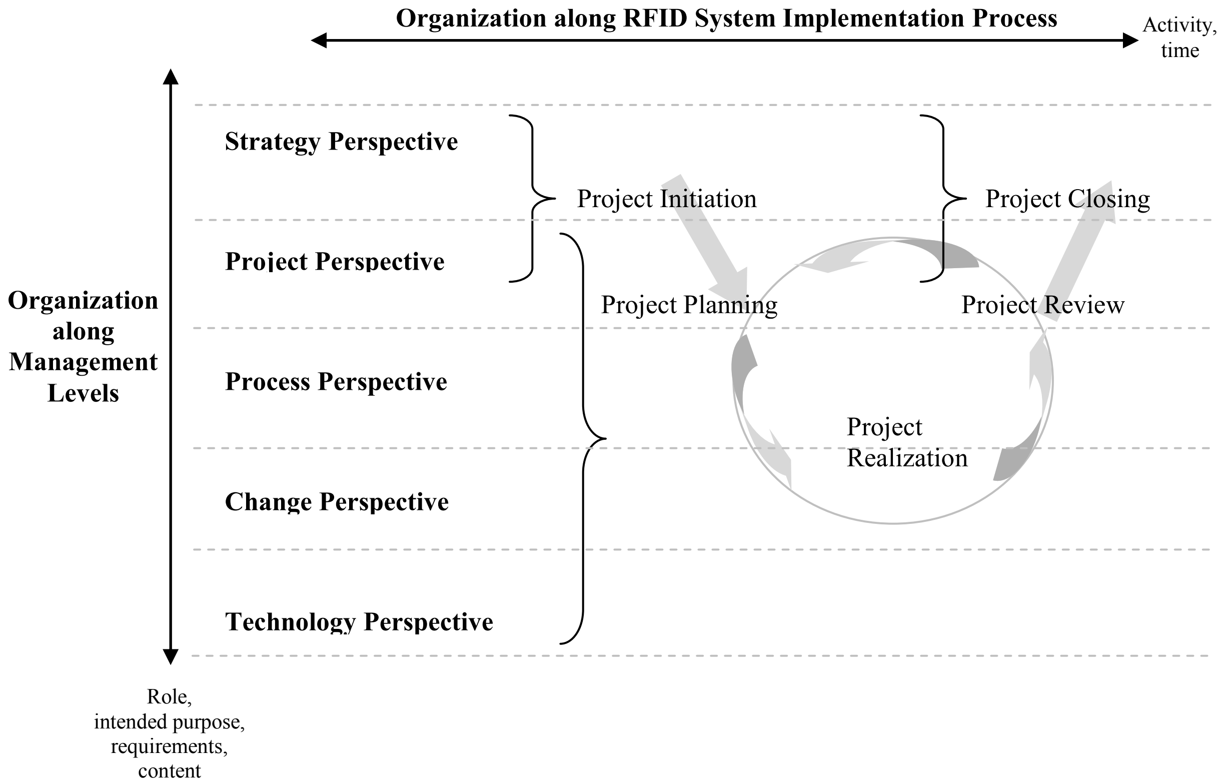
[103] In reference modeling, object oriented approaches for modeling are used for aspects closer to information system implementation (e.g. UML), whereas non-object oriented approaches are nearer to business and modeled e.g. with EPC.

[104] See Section 4.1.

[105] See Section 5.1.1.

[106] See Section 5.1.2.

Figure 13: MaRSI Frame of Reference



Source: By the author.

According to MaRSI frame of reference, the initiation and closing activities during an RFID system implementation project are in the scope of top managers and project manager. The activities of project planning and review mainly belong to the responsibilities of project manager and are carried out collaboratively in project team. The activities of project realization involve project, process, change, and technology perspectives at different stages or in different phases of an RFID system implementation with different focus and intensity of work. The organization along management levels and RFID system implementation process in the MaRSI frame of reference are described in the following in detail.

5.1.1 Organization along Management Levels

In accordance with subjectivity management, organization along management levels is structured on the basis of roles and responsibilities, intended purpose, subjective requirements, and relevant contents (i.e. activities and system aspects). The level of details or interests along management levels varies during RFID system implementation. For instance, strategic planning requires an abstract and holistic view with highly aggregated information in comparison to business process analysis or RFID system design, where detailed information are required and the focus is limited to specific aspects of RFID system implementation. For organization along management levels, the MaRSI frame of reference defines and orders five main perspectives, namely strategy, project, process, change, and technology.

Strategy Perspective

The strategy perspective involves roles and responsibilities of top management. The top management focuses on strategic issues of an organization and ensures competitive position by unique set of business activities.[107] The top management is usually the project initiator or sponsor and authorizes the formal existence of the project. During project initiation activities, the top management authorizes a project manager to manage and apply organizational resources to the project. The project manager is either internal or external to the enterprise.

Project Perspective

The project perspective encompasses roles and responsibilities of project manager. A project manager is hired by the top management during project initiation activities usually after generation of project idea. Accordingly, the project manager is responsible for management of project covering planning, realization (i.e. organizational work), and review from project initiation to project closure and applies organizational resources to complete the project successfully.[108]

Process Perspective

The process perspective covers roles and responsibilities of supply chain or process managers. Supply chain or process managers possess domain and enterprise process knowledge regarding materials and information flows (i.e. physical level of RFID architecture). In intralogistics[109], they may be responsible for strategic supply chain management or daily activities such as receipt, warehouse, production, picking, pre and post assembly, and dispatch.

Change Perspective

The change perspective involves the role and responsibilities of change managers. The change managers are responsible for supply chain stabilization and reengineering as well

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[107] See Porter 1998,55, Stadtler/Kilger 2005, 19, and Springer Gabler Verlag (Herausgeber), Gabler Wirtschaftslexikon, Stichwort: Top Management, online im Internet: http://wirtschaftslexikon.gabler.de/Archiv/58343/top-management-v7.html (last accessed 05.06. 2016).

[108] For project management see Section 3.1.

[109] See Section 2.1.

as change communication and reorganization in the context of RFID technology.[110] Accordingly, the change managers possess knowledge of supply chain and RFID technology forming the interface between the process and technology perspectives, for example, during RFID system design.

Technology Perspective

The technology perspective covers the roles and responsibilities of RFID and IT managers. In the process of RFID system implementation, technology managers are responsible, for example, for RFID system selection, implementation, and tests. RFID managers may focus specifically on RFID hardware components (i.e. physical level of RFID architecture), whereas IT managers may be responsible for RFID related software databases (i.e. integration and application levels of RFID architecture).[111]

5.1.2 Organization along RFID System Implementation Process

In the MaRSI frame of reference, organization along process encompasses RFID system implementation activities of project management and system development at a higher level of abstraction. These activities are grouped according to project management processes in project initiation, project planning, project realization, project review, and project closing processes (IPRRC). The organization along process shows project progress over time. The MaRSI frame of reference orders RFID system implementation activities horizontally and vertically according to relevant perspectives. The activities of RFID system implementation, specifically project management aspects, are discussed in detail in MaRSI process model[112].

Project Initiation

The initiation of an RFID system implementation project is a strategic business activity and is carried out to ensure competitive position of an enterprise in the market place.[113] Along with strategic importance, RFID system implementation projects are complex and

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[110] For change management see Lauer 2010, and Springer Gabler Verlag (Herausgeber), Gabler Wirtschaftslexikon, Stichwort: Change Management, online im Internet: http://wirtschaftslexikon.gabler.de/Archiv/2478/change-management-v9.html (last accessed 05.06. 2016).

[111] See Section 2.1.

[112] See Section 5.2.

[113] See Porter 1998, 55, Stadtler/Kilger 2005, 19, and Springer Gabler Verlag (eds.), Gabler Wirtschaftslexikon, Stichwort: Top Management, online im Internet: http://wirtschaftslexikon.gabler.de/Archiv/58343/top-management-v7.html (last accessed 05.06. 2016).

require intensive use of enterprise resources in the early stages.[114] Accordingly, the aim of project initiation activities is definition and justification of project, assignment of project manager, support in early decision making, definition of initial project scope and resources, and identification of internal and external stakeholders.[115] Project initiation is in the scope of strategy and project perspectives and delivers business case, requirements list, and project charter upon completion.[116]

Project Planning

The project planning provides guidance to project team and project stakeholders and aims effective and efficient realization of project work according to project and stakeholder requirements. Because of strategic and complex nature, RFID system implementation projects are planned formally and realized iteratively focusing on less formal change and adaptation of implementation process and RFID system design and RFID system with risks response upon occurrence in response to the specific requirements from section 4.1. Accordingly, the primary criteria for effective and efficient project planning are realism and involvement of subject area experts.[117] In consideration of different perspectives and concerns, project planning addresses methodical and organizational aspects of planning separately. Project methodical planning involves definition of project and system scope, and estimation of cost, and schedules, whereas organizational planning focuses on organization of project resources. Project planning is in the scope of project perspective and delivers methodical and organizational plans upon completion.[118]

Project Realization

The project realization aims management and realization of project work in order to complete the project successfully according to project plans. Because of complexity, project realization in the context of MaRSI focuses on sophistication and consideration of different perspectives and their requirements.[119] Accordingly, project realization separates organizational and technical work realization. Project organizational work realization aims organization of project resources and is in the scope of project perspective, whereas

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[114] See Section 4.1.

[115] For comparison see PMI 2008, 45.

[116] See Section 5.2.1.

[117] See Schwalbe 2011, 96, and PMI 2013, 72.

[118] See Section 5.2.2.

[119] See Section 4.1.

technical work realization aims development and deployment of RFID system and belongs to process, change, and technology perspectives.[120]

Project Review

The project review in the context of MaRSI provides formal opportunity for continuous improvement and risks response during iterative and incremental realization of the project. Project reviews emphasize on less formal and collaborative discussions, meetings, and presentations and are made at the end of iteration[121] or phase. Accordingly, project review involves revision and adjustment of project process and deliverables on the basis of requirements change and for the future planning. Project review process is in the scope of project perspective and is facilitated by project manager. The result of project review is update of requirements, plans, and reports.[122]

Project Closing

The project closing process aims formal finalization of the project on the basis of project reviews and according to project success criteria or requirements[123]. Accordingly, it involves aspects of evaluation of project, summary of project results, termination of agreements, release of project resources, archive of project records, and lessons learned as historical information. Project closing in the context of MaRSI frame of reference belongs to strategy and project perspectives.[124]

5.2 MaRSI Process Model

RFID system implementation projects possess unique set of business, project, and technology requirements. These requirements are influenced by business strategy, business domain, project stakeholders, and project and technology characteristics. A business strategy is defined by business needs, vision, and objectives such as preparation for a potential implementation of RFID technology or implementation of RFID in specific business processes or areas. A business domain can be characterized, for example, by industry type, enterprise structure, culture, products, products price, automation level supply chain processes, and influence level in a supply chain. Project stakeholders possess specific backgrounds, levels of knowledge, and expectations, and belong to different

[120] See Section 5.2.3.

[121] See Section 4.1.

[122] See Section 5.2.4.

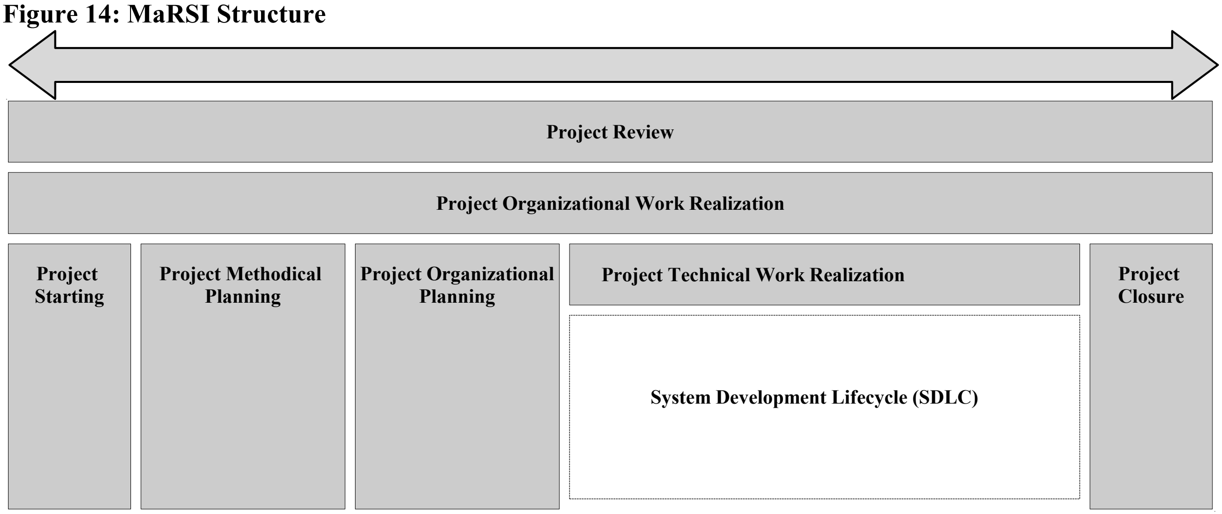
[123] See Section 4.1.

[124] See Section 5.2.5 and PMI 2013, 57-58, and 100-104.

disciplines.[125] Projects, by nature, are temporary undertaking possessing specific constraints such as scope, time, cost, specification level, and user acceptance of involved technology.[126]. RFID technology is innovative and complex. RFID systems, for instance, operate different frequencies such as HF 13.56 MHz and UHF 868 MHz, and with different functionalities involving reading range, coupling mechanisms, data transfer rate, access techniques, and energy supply.[127]

As a result, an RFID system implementation process involves unique activities such as on-site surveys and RFID data modeling, which necessitates a sophisticated approach for realization according to enterprise, stakeholder, and technology requirements.[128] In this regard, the MaRSI frame of reference **serves as a guide** in order to structure RFID system implementation activities. For better understanding, RFID system implementation activities are structured according to project management and RFID system development and deployment activities as shown in MaRSI structure figure 14.

Figure 14: MaRSI Structure



Source: By the author.

According to the MaRSI structure, the work of an RFID system implementation project can be divided in management and system development work. The management work consists of project starting, methodical planning, organizational planning, organizational work realization, review, and closure activities. The system development work involves technical work realization. It is shown as system development lifecycle (SDLC) providing

[125] See Section 4.1.

[126] See Section 3.1.1.

[127] See Chapter 2.

[128] See Section 4.1.

an external view[129] on RFID system development and deployment. The technical work realization or SDLC is integral part of RFID system implementation management. For the ease of management and RFID system development, project planning is differentiated in methodical and organizational planning, whereas project work organization and review are supporting activities conducted throughout the project.

The structural view of RFID system implementation highlights and separates project activities on the basis of different concerns of management and technical teams as well as major deliverables in order to provide overview and understanding. Following MaRSI frame of reference[130], the project management activities represent strategy and project perspectives, whereas RFID system development and deployment activities embody process, change, and technology perspectives. This section describes RFID system implementation activities in detail according to strategy and project perspectives. RFID system development and deployment activities are presented as system development lifecycle (SDLC) that is integral part of MaRSI structure. However, SDLC is not the primary focus of the MaRSI process model in this dissertation.

In view of that, the MaRSI process model, as shown in figure 15, consists of five phases and two ongoing processes. These phases include project starting, methodical planning, organizational planning, technical work realization, and closure phases[131], whereas project organizational work realization and review are ongoing activities supporting iterative and incremental realization of the project. The process model primarily focuses on management of RFID system implementations. The work within each phase of the model has distinct focus involving different organizational entities or organizations and stakeholders. It requires explicit consideration[132] within phase boundaries. The duration or length of each phase varies depending on objective of the phase.[133] The phase structure provides decision making points for management, whereas **the work within each phase** is performed iteratively and incrementally. The MaRSI process model is **linked through outputs** of the phases.[134]

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[129] For differentiation of process model and lifecycle see Hanser 2010, 3.

[130] See Section 5.1.

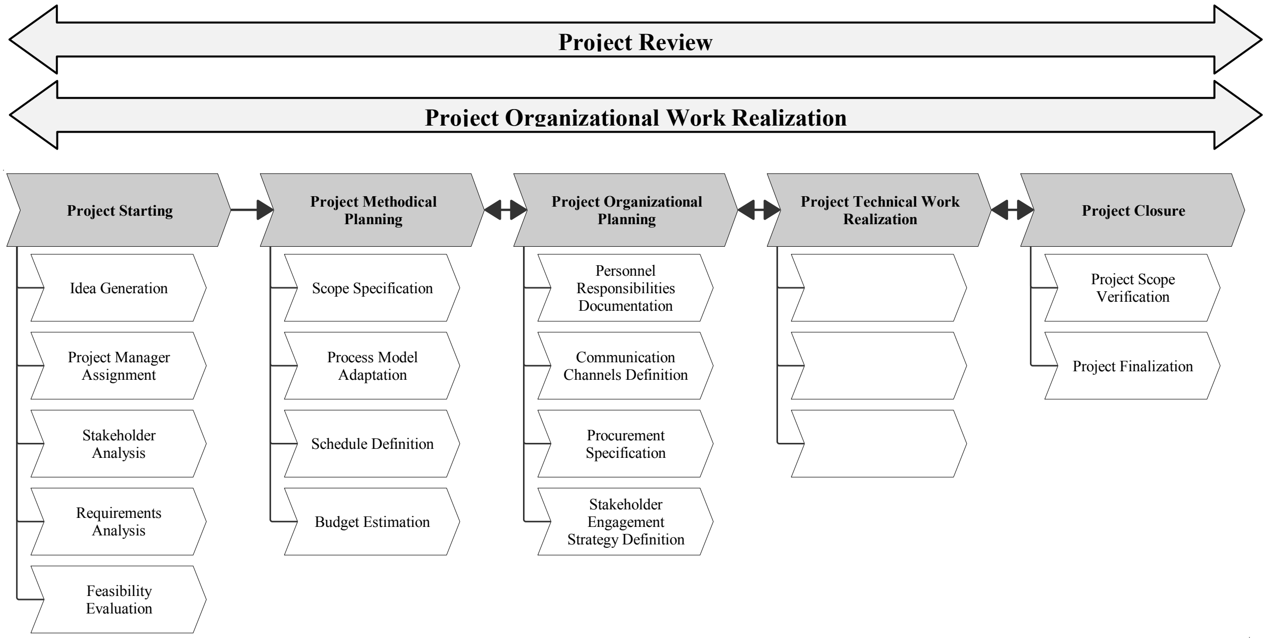
[131] The phase structure provides simplicity and ease of management as aimed by project management (see PMI 2008, 18-20).

[132] No extra degree of control by project governance method.

[133] For sequential phase structure of a project see PMI 2008, 18-20.

[134] For comparison see PMI 2008, 39-40.

Figure 15: MaRSI Process Model



Source: By the author.

For RFID system implementation, the number, size, and sequence of phase activities may vary depending on the nature of industry, culture of enterprise, structure of enterprise[135], objectives of the project, subject area expertise of project team, and the selected process model for the technical work realization. For instance, a project with an objective of definition of an RFID system for an enterprise for the purpose of preparation for a potential implementation can consist of supply chain analysis and RFID system design along with project management activities. Similarly, an economic feasibility study can be treated as a routine pre-project work, first phase of a project, or stand-alone project depending on the organization and management of an enterprise. Nevertheless, the basic structure and concept of MaRSI process model is applicable also for project with varying objectives[136].

RFID system implementation is an **iterative process** applying scheduling strategies[137] for requirements and resources. Because of the complexity of RFID systems that may involve different functionalities of RFID components, special middleware characteristics, and a unique set of business processes and objectives as discussed in section 2.1, requirements and resources according to MaRSI process model are scheduled in iterative manner using

[135] For variation in project handling see PMI 2008, 19 and up to 27.

[136] Objectives for example RFID system design or RFID system economic feasibility analysis.

[137] See Cockburn 2008, Wysocki 2009, 359.

top-down[138] and bottom-up[139] approaches as the requirements change[140] in the course of action. Accordingly, a **high level MaRSI plan** is developed in the beginning of the project, which addresses top management and project stakeholders. The MaRSI plan includes aspects of methodical and organizational planning at high level**.** The methodical planning aspects define project size or scope, whereas organizational planning aspects involve definition of project resources. This high level plan is visionary defining project scope and assumptions. RFID system implementation requires dynamic and less comprehensive planning in the beginning.

On the basis of the high level project plans, **detailed iteration plan** is developed for the first iteration. An iteration plan is detailed (i.e. realistic) version of the MaRSI plan and time-boxed[141] for realization. It is allocated to project team in the scope of a phase. The iteration plan includes aspects of scope, success criteria, schedules, milestones, resources, major reviews, and activities associated to roles. During realization of the work of an iteration by project team, the project manager plans future iteration in detail in accordance with changes from feedbacks and lessons learned. According to MaRSI process model, iterations could be overlapping or in parallel.

The **objectives of iterations**, according to MaRSI process model, are defined on the basis of specified requirements. For instance, they may aim specific functionality of RFID system or RFID implementation in specific business processes or unit (i.e. location). Upon lessons learned in the course of action, subsequent iterations aim either additional functionality of an RFID system, improvement of quality of defined functionality of the RFID system, or implementation of RFID in additional business processes and units.

The project manager, in view of that, requires prediction of the number of iterations for defined project scope or project phases and estimation of required resources. For project work realization iteratively, rolling wave and time-boxing techniques are used. In rolling wave planning[142], the work to be completed in coming iteration is planned in detail, whereas the overall project work is planned at high or summary level. Accordingly, the

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[138] i.e. decomposition in RFID development (see Cockburn 2008, PMI 2008, 20-21, PMI 2013, 44-45, Wysocki 2009, 341-357, Hanser 2010, 5).

[139] i.e. plan based in RFID deployment (see PMI 2008, 181, PMI 2013, 217-218).

[140] See section 3.1.1.2 Changing Project Requirements.

[141] For time-boxing or staging and scheduling strategy see Cockburn 2008, PMI 2008, 20-21, PMI 2013, 44-45, Wysocki 2009, 341-357, Hanser 2010, 5.

[142] See PMI 2013, 560.

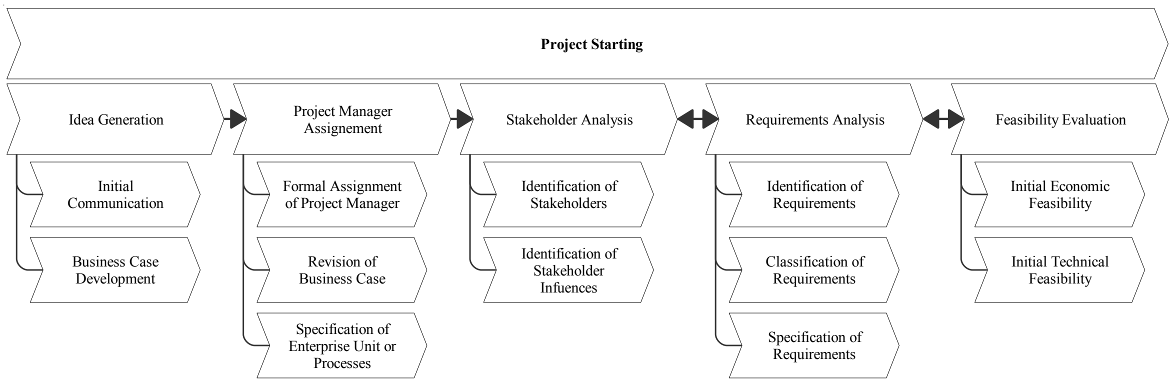
project plans are developed at different point in time. Time-boxing is a top-down technique based on scheduling strategy.[143] In the project beginning, it focuses on achievement of specific objectives or system functionality, for example, RFID system definition for specific business processes or business units.

The MaRSI process model is described in the following subsections in detail. The descriptions of phases and activities of the model involve aspects such as objectives, specific considerations, roles, and inputs and outputs.

5.2.1 Project Starting

The MaRSI project starting phase involves project initiation activities[144]. The initiation of an RFID system implementation project is a strategic business activity to ensure competitive position of an enterprise in the market place.[145] The purpose or objectives of an RFID system implementation project may vary depending on the strategic goals[146] of the enterprise. The reasons for the need of an RFID system implementation are initially documented as **business case[147]**. The project starting phase is led by top management and project manager and requires **collaborative involvement of entire team** from supply chain mangers, change managers to RFID system experts in order to specify requirements (i.e. generate list) and justify initial feasibility.

Figure 16: Project Starting Phase



Source: By the author.

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[143] See Cockburn 2008, PMI 2008, 20-21, PMI 2013, 44-45, Wysocki 2009, 341-357, Hanser 2010, 5.

[144] such as project sponsorship, project authorization, and project manager assignment.

[145] See Porter 1998,55, Stadtler/Kilger 2005, 19, and Springer Gabler Verlag (eds.), Gabler Wirtschaftslexikon, Stichwort: Top Management, online im Internet: http://wirtschaftslexikon.gabler.de/Archiv/58343/top-management-v7.html (last accessed 05.06. 2016).

[146] RFID system definition or RFID system deployment (working system).

[147] See Section 5.3.1 and Appendix 1 MaRSI Business Case.

The MaRSI starting phase consists of idea generation, project manager assignment, stakeholder analysis, requirements analysis, and feasibility evaluation (project and system, economical and technical). The results of the phase are MaRSI business case[148], MaRSI requirements list[149] and MaRSI charter[150].[151]

The project manager is hired after idea generation and is responsible for business case development. The project manager can either be internal or external to the enterprise. The requirements list is initially generated during project starting phase and updated throughout the project. It is influenced by industry standards[152], policies, and culture and by changes in business environment and enterprise strategic objectives. The MaRSI charter contains inputs from the business case and requirements list and makes the foundation for project methodical planning. The closure of the project starting phase provides the opportunity for decision making regarding continuation of the project and review of business case, requirements list, and project charter.

5.2.1.1 Idea Generation

A business problem or potential strategic benefits triggers the activity of idea generation. Idea generation involves aspects of **initial** business objectives and requirements, project constrains, as well as preliminary budget and schedule estimates of the project. Business strategic objectives provide guidance for required functionality of the RFID system. An RFID system implementation project requires **collaborative involvement** of top management, project manager, process manager(s), change manager(s), and IT and RFID experts. Accordingly, the top management let arranges a **meeting** and ensures **initial communication** to discuss the project idea and a potential project start. The result of idea generation activity is a business case[153]. The business case aims justification of the project. Upon approval of the project idea, the project manager is formally assigned. The rejection of the project idea results in termination of the project at this stage.

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[148] See Section 5.3.1 and Appendix 1 MaRSI Business Case.

[149] See Section 5.3.2 and Appendix 2 MaRSI Requirements List.

[150] See Section 5.3.3 and Appendix 3 MaRSI Charter.

[151] For comparison see PMI 2008, 45.

[152] e.g. quality standards, process standards, governmental standards.

[153] See Section 5.3.1 and Appendix 1 MaRSI Business Case.

5.2.1.2 Project Manager Assignment

After approval of the project idea, a project manager is formally assigned by the top management. The project manager is either selected internally or hired externally. The project manager reviews the business case and specifies a unit or a department of an enterprise for the implementation of RFID system with required functionality collaboratively with the top management in order to ensure **iterative and incremental** development. Iterative and incremental development aims prioritization of requirements and resources.

5.2.1.3 Stakeholder Analysis

The initiation of RFID system implementation projects require intensive involvement of project stakeholder and team from the very beginning in order to set objectives, elicit requirements, and make early decisions. Stakeholder analysis helps in decision making processes of project objectives specification, system requirements specification, and project and system feasibility evaluation.

Stakeholder analysis involves identification of project stakeholder and their influences and reactions in order to define stakeholder list and strategy. Project stakeholders are individuals or organizations actively involved in the project.[154] In RFID system implementation projects, the stakeholders' list involves top management (internal), process manager (internal), project manager (internal or external), change manager (internal or external), and technology manager (internal or external). Furthermore, customers and enterprise owner or board members as sponsors can also belong to the project stakeholders. The stakeholder analysis is conducted by the project manager. It results in stakeholder list and strategy[155] as part of the MaRSI charter[156].

5.2.1.4 Requirements Analysis

Requirements analysis consists of identification, classification, and specification of business, process, system, stakeholder, communication, legal, and procurement requirements of RFID system implementation. Business requirements are specified on the basis of the business case. RFID implementation process and RFID system requirements

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[154] For comparison see PMI 2008, 246-247.

[155] Stakeholder list includes information regarding stakeholder roles, responsibilities, requirements, and area of focus. Stakeholder strategy is usually confidential and defined on the basis of area of focus, level of interest, and level of influence of individual stakeholders.

[156] See Section 5.3.3 and Appendix 3 MaRSI Charter.

are defined collaboratively during meetings by means of brainstorming, questionnaires, interviews, observations, classification, and prioritization and allocation involving entire project team. Stakeholder and communication requirements are derived from stakeholder analysis, whereas legal requirements base on enterprise quality standards.

The forecast for requirements analysis is made by the project manager or project management team and technical team collaboratively. However, stakeholder, communication and legal requirements are primarily predicted by the project manager or project management team. The project manager arranges meetings for the purpose. The entire team collaboratively identifies requirements relevant to their area of focus. Subsequently, these requirements are classified, for example, according to business, implementation process, RFID system, and various stakeholder perspectives. For specification, the clusters of classified requirements are prioritized[157], whereas RFID system requirements are additionally allocated to enterprise business or logistics processes at unit or department levels in consideration of direct and indirect optimization potentials.[158] Requirements specification also involves definition of project success criteria and boundaries in consideration of enterprise strategic (e.g. real time localization of pallets in warehouse), implementation process, and system requirements. The result of requirements analysis is an initial requirements list[159].

5.2.1.5 Feasibility Evaluation

RFID system implementation requires initial economical as well as technical feasibility for evaluation of project and system alternatives. The economic feasibility involves cost and benefits and return on investment analysis[160] of the system, whereas technical feasibility of RFID system focus on adoption of the system in enterprise processes.

Economic feasibility evaluation of RFID system implementation in general requires detailed supply chain and RFID system analysis. However, a rough estimation can also be made with the help of existing empirical studies and calculators.[161] The evaluation of economic feasibility is in the scope of project manager responsibilities. Initial technical

[157] Requirements and resources are scheduled in iterative manner using top-down and bottom-up approaches because of RFID systems complexities.

[158] See Section 5.4.1 requirements engineering techniques.

[159] See Section 5.3.2 and Appendix 2 MaRSI Requirements List.

[160] See Schwalbe 2011, 91.

[161] An accurate estimation of cost and benefits and ROI of an RFID system implementation requires detailed analysis of supply chain processes.

feasibility is either performed by tests in respected areas and units of the enterprise or it is evaluated with the help of benchmarking of existing enterprise processes and RFID empirical studies.[162] It is performed by the development team or technical area experts. The result of feasibility evaluation[163] is update of MaRSI requirements list[164].

Subsequently, the MaRSI charter is developed on the basis of MaRSI business case and requirements list. It includes information such as business requirements, stakeholder requirements, assumptions, constraints, and project summary involving project purpose, objectives, boundaries, success criteria, initial steps, budget, schedule, stakeholder, project manager assignment, sponsor authorizations.[165]

5.2.2 Project Methodical Planning

RFID system implementation is carried out iteratively and incrementally applying scheduling strategies[166] to (methodical) requirements and resources in order to reduce complexity. For this purpose, the requirements of implementation process and RFID system with required resources such as time and cost are scheduled in a top-down[167] and bottom-up[168] manners. A high level MaRSI plan is developed on the basis of initial project requirements list[169] and MaRSI charter[170] covering entire project.

The MaRSI plan, at this stage, contains only aspects of methodical planning. It is visionary defining project scope and assumptions. Project methodical planning aims to provide guidance in realization of project work and covers project scope, time, and cost.[171] RFID system implementation requires dynamic and less comprehensive planning in the beginning. Project methodical planning requires consideration of implementation process,

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[162] See Section 5.4.6 for process and system improvement techniques.

[163] Because of iterative development, less intensive tests are performed in early stages of the project. The focus, however, remains on benchmarking.

[164] See Section 5.3.2 and Appendix 2 Requirements List.

[165] See Section 5.3.3 and Appendix 3 MaRSI Charter.

[166] See project review.

[167] i.e. decomposition of work or implementation.

[168] i.e. plan or artifact based implementation.

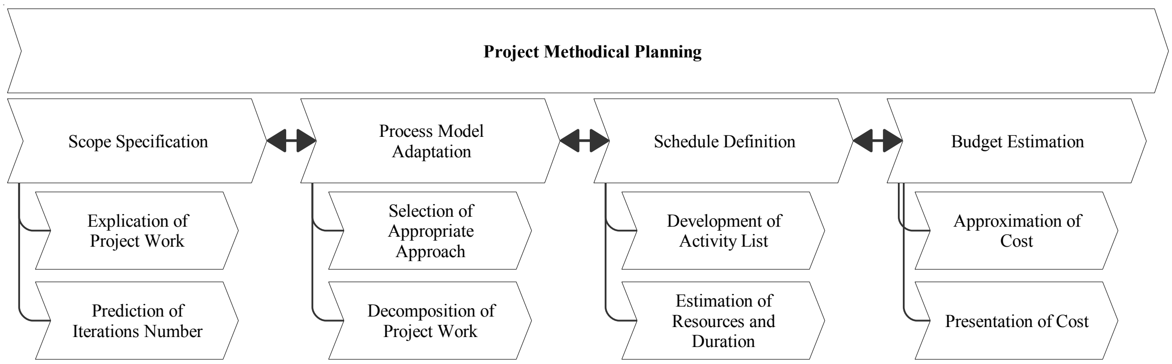
[169] See Section 5.3.2 MaRSI Requirements List.

[170] See Section 5.3.3 MaRSI Charter.

[171] See Section 5.3.4 MaRSI Plan.

RFID system, and stakeholder requirements[172]. Accordingly, it involves activities of scope specification, process model adaptation, schedule definition, and budget estimation.

Figure 17: Project Methodical Planning Phase



Source: By the author.

On the basis of high level MaRSI plan, the project manager develops iteration plan for realization of the first iteration and specifies the number of iterations for each phase and entire project. Iteration plan is detailed enough, allocated to project team in the scope of a phase, and time-boxed[173]. For time-boxing of individual iterations and entire project, traditional scheduling tools and techniques[174] such as critical path method (CPM)[175] and bar charts[176] are used. Subsequent iteration plans are developed in point in time on the basis of high level MaRSI plan (i.e. methodical aspects) and current or previous iteration with corresponding changes upon lessons learned. While the project team realizes the work of current iteration, the project manager plans future iteration. Iterations could be overlapping or realized in parallel. Primary criteria for development of high level and iteration plans are realism, effectiveness, efficiency, and collaboration. The MaRSI and iteration plans with methodical aspects consist, for example, of scope (i.e. intention), success criteria, schedule, milestones, and major reviews.[177] RFID project methodical planning is carried out by project manager or project management team in collaboration

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[172] See Section 5.3.2.

[173] Time-boxing is achievement of specific objectives or system functionality in a top-down manner in a given time.

[174] See Section 5.4.4.

[175] See PMI 2007, 8, Burke 1999, 120, and Schwalbe 2011, 228.

[176] i.e. Gantt charts that list project activities (see WBS) with corresponding planned or planned and actual start and finish dates.

[177] See Section 5.3.4 MaRSI Plan.

with project technical team using requirements analysis, communication, reference modeling, scheduling, and budget estimation techniques.[178]

5.2.2.1 Scope Specification

Scope specification is explication of project work, boundaries, implementation approach, resulting deliverables, and system functionality for entire project at high level and first iteration in detail. It, furthermore, involves prediction of the number of iterations required for the completion of each phase and entire project. For this purpose, top-down[179] and bottom-up[180] approaches are used. Project scope is specified on the basis of initial project requirements[181] and initial project realization approach[182] using rolling wave and time-boxing techniques.

The scope of the first iteration of RFID system implementation is defined in detail according to the high level plan involving iteration boundaries, realization approach, and resulting deliverables or system functionalities. For instance, prioritized system functionality can either address specific functionality of entire logistic processes of an enterprise or specific logistics processes and business units. The scope of the project is updated iteratively, whereas future iterations are planed on the basis of lessons learned in current or previous iterations.

Scope specification is performed by the project manager collaboratively with entire project team involving subject area experts of different phases. The output of scope specification is **scope statement** for entire project and the first iteration[183] as well as requirements list[184] update. Scope statement includes summary of project, summary of project and system deliverables, success criteria, exclusions, constraints, and assumptions of project. The foundations for project and iteration scope statements are descriptions from MaRSI charter such as project summary, constraints, and success criteria. Project and iteration scope statements are part of the project MaRSI plan[185] and accessible to entire project team.

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[178] See Sections 5.4.1, 5.4.2, 5.4.3, 5.4.4, and 5.4.5.

[179] i.e. decomposition in RFID development.

[180] i.e. plan or artifact based in RFID deployment.

[181] See Section 5.3.2 MaRSI Requirements List.

[182] See Section 5.3.3 MaRSI Charter.

[183] See Section 5.3.4 MaRSI Plan.

[184] See Section 5.3.2 MaRSI Requirements List.

[185] See Section 5.3.4 MaRSI Plan.

Subsequent iterations aim improvement of quality by adjustment of project scope upon lessons learned, stakeholder feedbacks, or changes in requirements.

5.2.2.2 Process Model Adaptation

The approach for implementation of RFID system is defined on the basis of **project scope statement**. It involves decomposition of entire project work (i.e. organizational and system development work). For this purpose, the project manager in collaboration with system development team selects and adapts appropriate process model(s) for project technical work realization at high level on the basis of project scope statement using top down (i.e. decomposition of work) and bottom up (i.e. planned results) approaches.[186] For organization and management of project work, the MaRSI process model is intended to be adapted according to the needs of an organization using reference modeling techniques[187]. The first iteration is detailed on the basis of high level process model for organizational and technical work realization. Subsequent iterations of a phase aim improvement of quality upon lessons learned and stakeholder feedback. The process of RFID system implementation is understood by the project management as well as system development teams. It can be represented as process model and work breakdown structure (WBS). Upon lessons learned and changes in requirements, the defined (high level) process for RFID system implementation is adjusted in the course of action. The activity process model adaptation results in definition of a process for RFID system development and deployment (i.e. organizational and technical work realization) and requirements list update.

5.2.2.3 Schedule Definition

Schedule definition involves planning of time dimension of the project work [Burke 1999, 120]. The project work (i.e. WBS of the project) of an RFID system implementation is dissected in further activities in order to develop sequenced activity list. The level of detail of activity list depends, for example, on project team capabilities and enterprise culture. An activity list is "a documented tabulation of *schedule activities* that shows the *activity description*, *activity identifier*, and sufficient detailed *activity scope definition* to the *work* so *project team […]* understand what *work* is to be performed" [PMI 2007, 87]. Activity

[186] See Section 5.2.4 technical work realization, Section 5.4.3 Reference Modeling Techniques, and Section 3.2.3 Design Principles of Reference Modeling.

[187] See Section 5.4.3 Reference Modeling Techniques, and Section 3.2.3 Design Principles of Reference Modeling.

list represents sequenced activities[188] [PMI 2007, 1] of RFID system implementation, for example, as bar charts[189] with planned or planned and actual start and finish dates.[190]

RFID system implementations require iterative and incremental realization aiming scheduling of project requirements (e.g. implementation process, RFID system, stakeholder, procurement) and resources (e.g. personnel, equipments, budget). Consequently, the project manager in collaboration with project team develops a high level activity list and predicts number of iterations for the entire project work in order to estimate project resources (e.g. personnel[191], equipments) and duration (e.g. hours, days). Based on the high level activity list, detailed activity list for the first iteration is developed and estimation of resources and duration are made in detail, for example, by **time-boxing**[192]. The activity list of the first iteration of an RFID system implementation either reflects achievement of specific functionality of an RFID system for an enterprise or implementation of RFID technology in particular logistics processes and business units depending on project initial requirements. Subsequent iterations aim, for example, improvement of project deliverables, additional functionality of RFID system, involvement of additional logistics processes and business units, or improvement of defined functionality of an RFID system. Future iteration planning is made during current iteration on the basis of lessons learned and stakeholder feedbacks.

5.2.2.4 Budget Estimation

Budget estimation is approximation of monetary resources for completion of project work on the basis of estimated resources (e.g. personnel, equipments) and duration [PMI 2013, 207] (e.g. hours) according to high level activity list. As RFID system implementations are conducted iteratively, detailed budget estimations are made for each iteration in order to achieve estimate accuracy and ensure project team commitment. Consequently, the high level budget estimates are adjusted in the course of action. It, furthermore, results in update of requirements list[193] in respect of budget limitations.

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[188] Sequencing of activities, additionally, facilitates parallel realization of project work.

[189] See Burke 1999, 142-155.

[190] See Section 5.4.4 Scheduling Techniques.

[191] Work intensity and expertise of project team influence duration of iterations.

[192] Time-boxing is a top-down technique i.e. achievement of specific objectives or system functionality.

[193] See Section 5.3.2 MaRSI Requirements List.

RFID system implementation projects are innovative undertaken and require involvement of subject area experts for cost approximation. Accordingly, the project manager estimates budget in collaboration with project team. Budget estimation is performed with the help of bottom up estimation, group decision making, and project management software and represented as individual or aggregated activity cost estimates in working hours or currency.[194]

5.2.3 Project Organizational Planning

RFID system implementation is conducted in iterative and incremental manner that applies scheduling strategies to **organizational requirements** (i.e. communication, stakeholder, and procurement) and resources (i.e. personnel, equipments) in order to reduce complexity. For this purpose, the requirements and required resources are scheduled in a top-down[195] and bottom-up[196] manners. The high level MaRSI plan is updated with organizational planning aspects on the basis of methodical planning[197] for entire project. The MaRSI plan at this stage contains aspects of methodical and organizational planning. It is visionary defining project scope, assumptions, and resources. Project organizational planning aims to provide guidance in organization of project resources during realization of project work.[198] It requires consideration of organizational aspects such as communication, stakeholder, personnel, quality, and risk for development.[199] Accordingly, project organizational planning involves activities of personnel responsibilities documentation, communication channels definition, procurement specification, and stakeholder engagement strategy definition.

Quality is planed and managed throughout the project with the help of requirements analysis and stakeholder feedbacks[200] aiming fulfillment of stakeholder needs and expectations. It also involves consideration of organizational standards, for example, legal and financial limitations.[201]

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[194] See Section 5.4.5 Budget Estimation Techniques.

[195] i.e. decomposition of work or implementation.

[196] i.e. plan based implementation.

[197] See Section 5.2.2.

[198] See Section 5.3.4 MaRSI Plan.

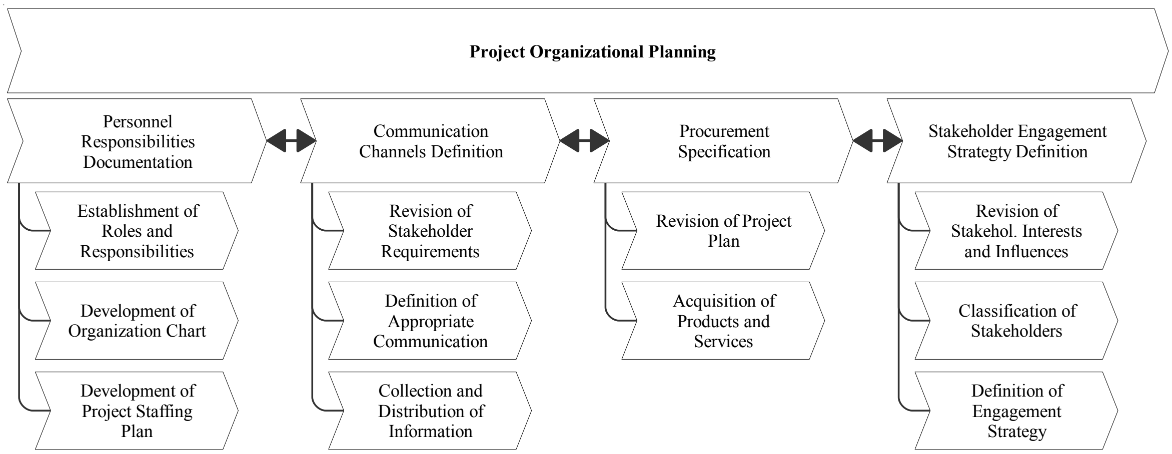
[199] See Section 5.3.2 MaRSI Requirements List.

[200] See 5.3.2 MaRSI Requirements List.

[201] Tools and techniques e.g. meetings, brainstorming, benchmarking, cost and benefits analysis, tests.

Risks are responded only upon occurrence in the iterative implementation process of RFID systems. Transparency and proper documentation of project process and deliverables are planned to minimize risks. Furthermore, reviews provide formal opportunities for risks identification and response, where stakeholder feedbacks are used to adjust requirements in order to reduce risks. For instance, occurrence of risks can be caused by requirements, scope, cost, quality (i.e. process and system), performance (i.e. team and system), communication, and stakeholder engagement.

Figure 18: Project Organizational Planning Phase



Source: By the author.

On the basis of project high level MaRSI plan with organizational aspects, the project manager updates iteration plan for organization of the first iteration. Iteration plan is detailed enough, allocated to project team in the scope of a phase, and time-boxed. Subsequent iteration plans are developed on the basis of high level MaRSI plan and current or previous iteration plan with corresponding changes upon lessons learned. Primary criteria for the purpose are realism, effectiveness, efficiency, and collaboration. The organizational aspects of MaRSI plan consist of project overview and description, team roles and responsibilities, project organization chart and external interfaces, team performance, training and conflict documentation, communication channels description, procurement information, and stakeholder engagement strategy.[202] RFID project organizational planning is carried out by project manager or project management team using requirements analysis[203] and communication techniques[204].

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[202] See 5.3.4 MaRSI Plan.

[203] See Section 5.4.1.

[204] See Section 5.4.2.

5.2.3.1 Personnel Responsibilities Documentation

Personnel responsibilities documentation aims to establish project roles and responsibilities, project organization charts with external interfaces, and project staffing plan with timetable for personnel acquisition and release.[205]

The activity is performed by the project manager in accordance with organizational aspects of MaRSI plan[206] for entire project or phase. It requires techniques such as hierarchical organization charts with position descriptions, networking in order to understand political and interpersonal factors, organizational theory for understanding of team and organizational behavior, expert judgment in order to list personnel skills, and meetings for team commitment to project. Personnel responsibilities documentation is presented as a chart or matrix and updated, for example, at the start of a new phase or upon occurrence of staffing issues.

5.2.3.2 Communication Channels Definition

Communication channels[207] definition aims to define an appropriate approach for communication of project information to project stakeholders in order to reduce the gap between diverse stakeholders from different organizational backgrounds with different levels of expertise and different perspectives and interests.[208] The definition of communication channels requires consideration of stakeholder requirements[209] and organizational resources for communication[210]. Accordingly, communication approach for RFID system implementation takes into account the need for intensity of communication for entire project and within phase boundaries. The approach for collection and distribution of information for RFID system implementation, for example, can involve interactive communication methods such as meetings, presentations, and phone calls, push communication methods such as emails and reports, and communication technologies for online accessibility.[211] These approaches are adapted in the course of action iteratively upon changes in stakeholder requirements. The activity is performed by the project manager on the basis of personnel responsibilities documentation, communication

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[205] See Negotiations in Section 5.4.2 Communication Methods.

[206] See 5.3.4 MaRSI Plan.

[207] See also PMI 2013, 286.

[208] See 5.1 MaRSI Frame of Reference.

[209] See 5.3.2 MaRSI Requirements List.

[210] See Organizational aspects of 5.3.4 MaRSI Plan.

[211] See 5.4.2 Communication Methods.

requirements, and stakeholder requirements. The output of communication channels definition is a communication method[212] for the project consisting of communication requirements, information to be communicated, reasons for communication, timeframe of communication, and organizational resources for communication.

5.2.3.3 Procurement Specification

Procurement specification aims to acquire products (e.g. RFID system components), services (e.g. consultancy), and results (e.g. studies) from outside the project or organization formally through agreements and contracts[213]. It requires consideration of schedules, cost of defined scope, and system functionalities.[214] Procurement specification is performed by the project manager or project management team using techniques such as market research for RFID system components, make-or-buy analysis with total cost and differences, meetings with RFID vendors, expert judgment on vendor proposals, and partner and vendor selection.[215] Procurement specification results in **procurement statement of work** (i.e. contract relevant aspects of scope of RFID system), procurement documents (e.g. proposals from RFID vendor by price and capabilities), and update of procurement requirements[216].

5.2.3.4 Stakeholder Engagement Strategy Definition

Stakeholder engagement strategy definition (i.e. commitment assurance) aims interaction with project stakeholders in order to satisfy their needs and expectations. Stakeholder engagement strategy builds on stakeholder analysis[217]. It is defined by the project manager **in collaboration with project team** that aims effective engagement of project stakeholders.[218] The project manager reviews the strategy for each phase and iteration, and classifies stakeholders in unaware, resistant, neutral, supportive, and leading. The stakeholder engagement strategy definition results in a matrix for stakeholder engagement strategy[219] and stakeholder requirements[220] update. The matrix for stakeholder

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[212] See Section 5.4.2.

[213] See Negotiations in 5.4.2 Communication Methods.

[214] See methodical aspects of 5.3.4 MaRSI Plan.

[215] See Appendix 4 for Procurement Information.

[216] See 5.3.2 MaRSI Requirements List.

[217] See 5.3.3 MaRSI Charter.

[218] See 5.4.2 Communication Methods.

[219] See 5.3.3 MaRSI Charter.

engagement[221] contains desired and current level of engagement, scope and impact of change, interrelationships and potential overlaps, and communication requirements of stakeholders.

5.2.4 Project Technical Work Realization

The project technical work realization aims development and deployment of an RFID system. The technical work of an RFID system implementation varies depending on intended business and project objectives. For instance, the project may aim to design an RFID system, analyze cost and benefits, deploy partial RFID system, or develop and deploy full RFID system. Specifically, if an enterprise intends to be prepared for a potential implementation of RFID in internal supply chain, the result of such a project is an RFID system design involving partial or complete supply chain processes. If it is intended to estimate economic feasibility of an RFID implementation, the resulting product of the project will be evaluation of cost and benefits and return on investment. In case of RFID system deployment as objectives, the resulting output of the project will be a working partial or complete RFID system. The technical work of an RFID system deployment, in view of the differences in project objectives, can consists of supply chain analysis, RFID system design, economic analysis, and RFID system deployment and rollout. These aspects of technical work realization are defined in MaRSI plan as work breakdown structure (WBS) under methodical aspects of the project. In the scope of project technical work realization, RFID system is developed and deployed (i.e. work done, reviewed, and adapted) by subject area experts such as change manager or RFID system experts belonging to project technical or development team. The organization of the project work is performed by the project manager or project management team in parallel to technical work realization. The technical work realization of an RFID system is out of the focus of this dissertation. However, the concerns of food manufacturing industries require **explication of activities** for preparation of potential RFID implementation in respect of technical work realization. Therefore, an overview of supporting concepts is provided in the following.

The differences in project objectives are addressed specifically as the primary objective of involved food manufacturing industries was preparation for a potential RFID system implementation. In view of the objectives of food manufacturing industries and the

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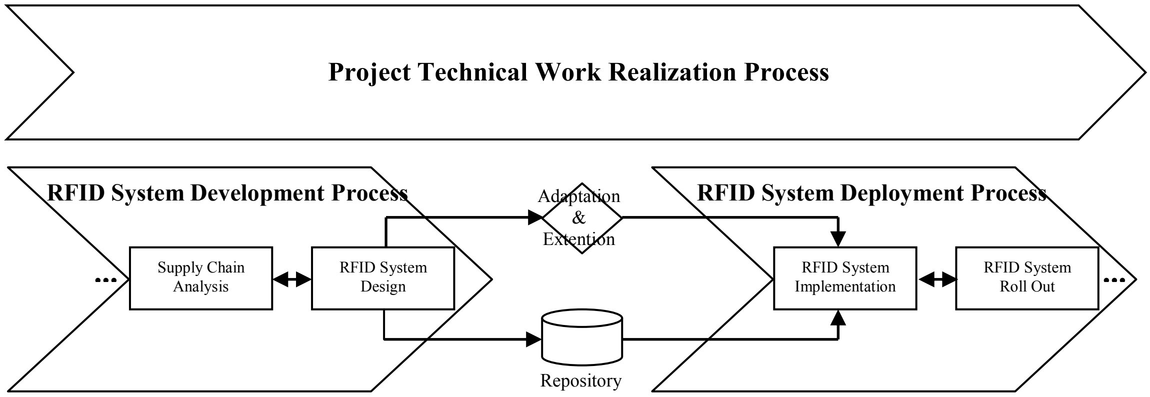
[220] See 5.3.2 MaRSI Requirements List.

[221] See Appendix 3 MaRSI Charter.

differences in objectives of RFID system implementations, this research suggests process orientation in accordance with business and project objectives. It proposes separation of concerns of RFID system development and deployment for project technical work realization as discussed in the context of application in a large enterprise in section 6.3.

Figure 19: Project Technical Work Realization Process



Source: By the author.

According to the author, the technical work realization process can be defined as a process that serves to develop an RFID system for and deploy an RFID system in a particular enterprise as shown in figure 19. In accordance with the objectives of food manufacturing industries[222], the technical work realization process of an RFID system implementation consists of RFID system development and RFID system deployment processes. The RFID system development process involves supply chain analysis, and RFID system design, whereas RFID system deployment process includes RFID system implementation and RFID system roll out with maintenance. The management of the project (i.e. use of MaRSI reference model) is applicable in both separated and combined processes of technical work realization. However, in case of separated activities of development and deployment, few additional aspects need to be considered properly.

The basic concept of technical work realization of an RFID system implementation process is based on the concepts of reuse-oriented software engineering and reuse-oriented reference modeling. According to reuse-orientation, "*information systems are composed of co-operating objects*". These objects are "*entirely specified regarding their properties and behavior*". The co-operation between objects can, for example, take place by inheritance (i.e. specialization), by composition of independent fragments (i.e. aggregation), by generic data structures (i.e. instantiation), or by free-handed use of patterns (i.e. analogy) [vom

[222] See Sections 6.2 and 6.3.

Brocke 2003, vom Brocke 2007].[223] These aspects are discussed in the design principles of reference modeling in detail.[224]

In case of separated development and deployment of technical work realization, an RFID system design is developed and deployed **in different points in time** for a particular enterprise. Furthermore, it may involve **different teams**. This results in a developer design of an RFID system and a deployer design of an RFID system. In this context, the RFID system development process mainly focuses on design of RFID system in order to facilitate preparation for implementation. The RFID system deployment process uses the design of RFID system development process in order to provide a working RFID system for a particular enterprise. The separation of RFID system development and deployment requires definite coordination for effectiveness (i.e. enterprise's satisfaction) and efficiency (i.e. process's rationality).

The process of technical work realization involves RFID system developer(s) and RFID system deployer(s). The RFID system developer constructs the RFID system according to the needs of the enterprise. The RFID system deployer implements the RFID system according to the RFID system design. If the RFID system development and deployment processes are carried out at one point in time, there is no need for extra adaptation of RFID system design. In case of time specific RFID system design, where the deployment of RFID system take place at different point in time, the RFID system deployer adapts and extends the design of RFID system during deployment process, for example, by configuration, instantiation, aggregation, or specialization if and as necessary[225]. Similarly, if the developer and deployer teams remain the same, the implementation of RFID system is considered as ongoing activity and requires no extra adaptation and extension activities of the RFID system design. In case, the developer and deployer teams are different, it is necessary to pay extra attention to coordination activities of adaptation and extension.

In accordance with technical work realization process, the technical work of a project with the intention of preparation for a potential RFID system implementation and economic analysis can consist of RFID development process and additional activities of economic analysis as illustrated in figure 20.

[223] The concept of reuse in reference modeling is used in a similar way as in module-oriented software engineering, object-oriented software engineering, component-based software engineering, pattern-based software engineering, requirement engineering of software engineering (see vom Brocke 2003 and 2007).

[224] See Section 3.2.3.

[225] RFID system specific or aspect specific adaptation.

Figure 20: Example of Project Technical Work Realization Process

Source: By the author.

The process-oriented view of technical work realization of an RFID system implementation guarantees consideration of various organizational objectives[226] (e.g. preparation for potential implementation) and ensures transparency of the RFID system implementation value chain.[227]

5.2.5 Project Organizational Work Realization

Project organizational work realization aims organization and management of project communication, stakeholder as well as procurements and resources such as personnel and equipments from project start to project closure. The MaRSI frame of reference[228] **provides guidance** for the purpose. The project organizational work realization is done in consideration of iterative and incremental project realization[229] on the basis of MaRSI plan[230] ensuring transparency of project process and proper documentation of deliverables. For this purpose, techniques of requirements analysis[231] and communication[232] are used aiming to manage communication, stakeholder, personnel, quality, and risks of the RFID system implementation project. Project organizational work realization is performed by the project manager or project management team that involves activities of communication realization, agreements establishment, stakeholder support assurance and project team management.

Quality is planed and managed throughout the project by stakeholder feedbacks iteratively and incrementally. **Risks** are responded only upon occurrence. RFID project organizational work realization provides transparency of project process and deliverables with proper documentation.

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[226] See subjectivity management as described under the MaRSI frame of reference.

[227] This approach is applied by the author practice-oriented research. (for comparison see vom Brocke 2003, 15-23).

[228] See Section 5.1.

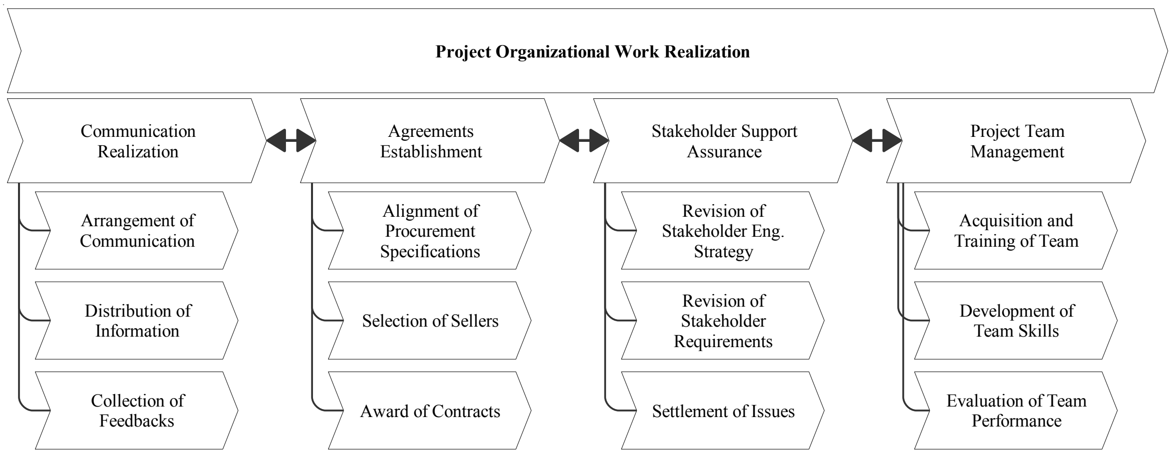
[229] i.e. scheduling strategy, top-down and bottom-up approaches.

[230] See 5.3.4 organizational aspects of MaRSI Plan (i.e. high level and detailed for specific phases or iterations).

[231] See 5.3.2 MaRSI Requirements List and 5.4.1 Requirements Engineering Techniques.

[232] See 5.4.2 Communication Methods.

Figure 21: Project Organizational Work Realization



Source: By the author.

5.2.5.1 Communication Realization

Communication realization aims creation, collection, distribution, storage, retrieve, and disposition of information within project and phase boundaries in consideration of stakeholder requirements and organizational resources. Communication realization requires use of interactive communication methods such as meetings, presentations, and phone calls, push communication methods such as emails and reports, and communication technologies for online accessibility such as collaborative tools for better integration and cross area communication[233]. The realization of communication is guided by the MaRSI frame of reference involving effective and efficient synchronization in order to satisfy the needs and expectations of a diverse project team(s) with different backgrounds, knowledge levels, needs and expectations, and disciplines.[234] It is performed by the project manager or project management team on the basis of organizational aspects of MaRSI and iteration plans.[235]

RFID system implementation projects require less formal communication, for example, for requirements analysis, project reviews, and frequent feedbacks. Meetings are the effective and efficient way of communication for project organizational as well as technical work during iterations. Furthermore, work presentations and status reports ensure efficient and effective flow of project information.[236] Communication realization results in feedback

[233] See 5.4.2 Communication Methods.

[234] See Section 4.1 and 5.1 MaRSI Frame of Reference.

[235] See 5.2.3.2 Communication Channels Definition.

[236] See 5.4.2 Communication Methods.

discussions, presentations, reports, and update of schedules, communication channels and stakeholder engagement strategy.[237]

5.2.5.2 Agreements Establishment

Agreements establishment aims to align procurement specifications according to project and enterprise internal and external stakeholder's needs and expectations for acquiring studies, services, and RFID system components by selection of seller(s) and award of contract(s).[238] The MaRSI frame of reference provides guidance by explication of needs and expectations of stakeholders and their activities of focus.[239] The procurement of RFID system components or services involve short listing of qualified sellers on the basis of preliminary proposals and evaluation of performances on the basis of specific system or stakeholder requirements.[240] Agreements establishment is performed on the basis of procurement specifications from MaRSI plan[241]. Agreements are established by the project manager in consideration of statement of deliverables, schedules, pricing, place of delivery or performance, payment terms, acceptance criteria, product support, termination clause, and other legal aspects.[242] It results in formal documentation of procurements and update of requirements list (i.e. stakeholder and system requirements), as well as MaRSI plan (i.e. schedule, cost, communications, and procurement specifications).

5.2.5.3 Stakeholder Support Assurance

Stakeholder support assurance aims to increase support and decrease resistance of stakeholders by means of communication and transparency[243] in order to increase probability of project success. The stakeholders of an RFID system implementation project are either internal or external to enterprise and possess different backgrounds and levels of knowledge. They, furthermore, own different set of needs and expectations and belong to different disciplines as discussed in P1, P6, and P7 of section 4.1. For stakeholder support assurance, the project manager or project management team manages stakeholder

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[237] See 5.3.4 MaRSI Plan.

[238] See 5.3.2 MaRSI Requirements List.

[239] See 5.1 MaRSI Frame of Reference.

[240] See Negotiations in 5.4.2 Communication Methods.

[241] See organizational aspects of 5.3.4 MaRSI Plan.

[242] See procurement specifications 5.3.2 MaRSI Requirements List and 5.3.4 MaRSI Plan.

[243] See 5.4.2 Communication Methods.

requirements[244], and addresses as well as resolves issues[245] on occurrence during project realization. The MaRSI frame of reference[246] provides guidance for the purpose by explication of specific roles during specific activities in order to synchronize efforts effectively and efficiently. The foundation for stakeholder support assurance is stakeholder engagement strategy[247], intended purpose, personal preferences, and acceptance criteria.[248] Stakeholder support assurance requires skills such as quick decision making, interpersonal skills, and management skills [PMI 2008, 264]. For interpersonal relations, the abilities of trust building, conflicts settlement, change management, and active listening are required. Similarly, the ability to facilitate consensus, negotiate agreements, and influence personnel and organizational behavior for acceptance of project results are crucial for assurance of stakeholder support. The result of stakeholder support assurance activity is update of requirements list[249] (i.e. stakeholder requirements) and organizational aspects of MaRSI plan[250] (i.e. stakeholder engagement strategy, communication channels).

5.2.5.4 Project Team Management

Project team management aims to acquire and train team, influence team behavior, manage conflicts, resolve issues, and evaluate team performance.[251] It requires effective and efficient communication for synchronization of project team with different backgrounds, knowledge levels, needs and expectations, and disciplines.[252] In RFID system implementation projects, the focus and intensity of involvement of project team members vary at different stages in the course of action that necessitate better integration and cross area communication.[253] Accordingly, the foundation for project team management is provided by MaRSI frame of reference[254] and personnel responsibility documentation in MaRSI plan[255].

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[244] See 5.4.1 Requirements Engineering Techniques and 5.3.2 Requirements List.

[245] See Negotiations in 5.4.2 Communication Methods.

[246] See 5.1 MaRSI Frame of Reference.

[247] See 5.3.3 MaRSI Charter and organizational aspects of 5.3.4 MaRSI Plan.

[248] See 5.1 MaRSI Frame of Reference.

[249] See 5.3.2 MaRSI Requirements List.

[250] See 5.3.4 MaRSI Plan.

[251] See 5.4.2 Communication Methods.

[252] See Sections 4.1 and 5.1.

[253] See Sections 4.1 and 5.1.

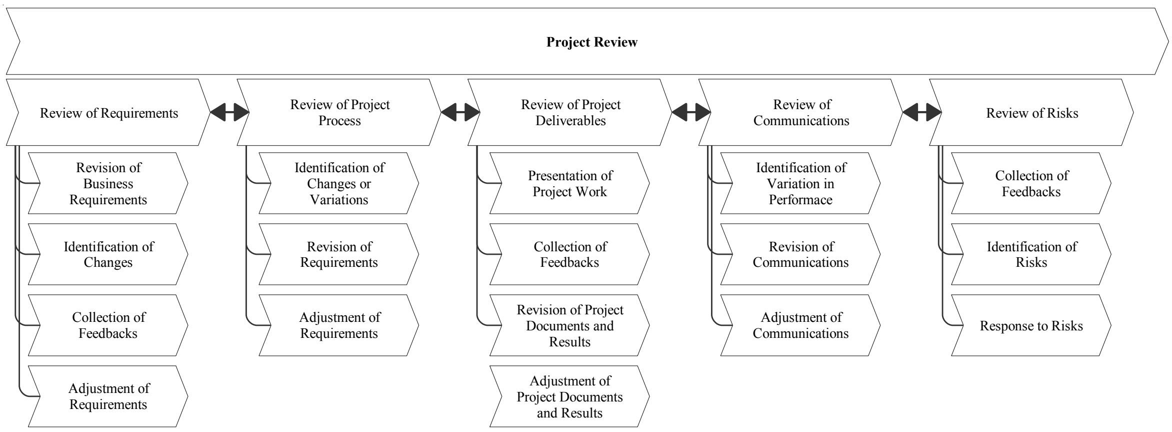
[254] See Section 5.1 MaRSI Frame of Reference.

Project team management is performed by the project manager using acquisition selection criteria, interpersonal skills, and training and team building capabilities.[256] The result of the project team management activity is update of MaRSI plan involving staffing issues and personnel responsibility documentation.[257]

5.2.6 Project Review

Project review provides formal opportunity to reassess changes in project requirements and business environment in order to assure quality of project process and system functionality. It aims continuous improvement of project, phase and iteration work covering adjustment of project requirements, review of team performance and report of project status.[258] Project requirements are adjusted in collaborative meetings in a semi-formal manner involving verbal and written communication (i.e. discussions and proper documentation). Adjustments to business and stakeholder requirements, project process and system functionality, and communication and procurements are documented in RFID project requirements list as reviews and feedbacks on past iterations for improvement in future. Project team performance is also reviewed in collaborative meetings but in an informal manner and verbally for the purpose of skills improvement. Project status is presented formally as reports in status meetings aiming to provide information on project status at a point in time and in future (i.e. current and future iterations) for awareness and decision making of top management and project stakeholders.

Figure 22: Project Review



Source: By the author.

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[255] See organizational aspects in 5.3.4 MaRSI Plan.

[256] See PMI 2013, 273.

[257] See organizational aspects in 5.3.4 MaRSI Plan.

[258] See Section 4.1, 5.3.2 MaRSI Requirements List, and 5.3.4 MaRSI Plan.

The project work of an RFID implementation is performed iteratively and incrementally using scheduling strategies[259] (i.e. prioritizing requirements and resources). Iterative realization provides opportunities for rework and continuous improvement upon lessons learned. Incremental realization ensures early partial solutions of RFID system and opportunities for adjustment of process activities and system functionalities using high level plan and prioritized requirements (i.e. by evolution or classification). Adjustment of RFID implementation process and system functionality primarily builds on lessons learned and feedbacks during previous or current project iterations. RFID project review encompasses all activities from project starting to project closure phases and involves review of project requirements, process, deliverables, communications, and risks. The results of RFID project review are update of project requirements list, assessment of team performance, and documentation of project status report.

5.2.6.1 Review of Requirements

Review of requirements is aimed to identify changes in business environment and consequently in project requirements.[260] Project requirements are formally managed and updated (i.e. add, delete, modify) at the end of an iteration in implementation process of RFID system. The iterative implementation process of RFID system uses scheduling strategies for requirements analysis, where requirements are prioritized and ordered based on specific criteria (e.g. business value). Accordingly, project requirements of RFID system implementation are evolved from high level plan and classified in business, process, system, stakeholder, communication, legal, and procurement requirements[261]. Reviews of requirements are made in collaborative meetings in an informal manner in order to revise requirements, discuss and document changes, gain feedbacks, and adjust requirements. The activity review of requirements results in update of requirements list.

5.2.6.2 Review of Project Process

The review of project process aims continuous improvement of RFID implementation process in terms of scope, time, and cost in order to **ensure process performance** and improve quality.[262] The activity is carried out either upon changes in business needs or

[259] See Cockburn 2008, Wysocki 2009, 359.

[260] See 5.4.1 Requirements Engineering Techniques.

[261] See Appendix 2 MaRSI Requirements List.

[262] See 5.3.4 MaRSI Plan and 5.3.2 Requirements List.

feedbacks from project team and stakeholders upon variations[263] in project plans and upon better understanding of RFID implementation process or lesson learned in the course of action (i.e. work done). Formal management techniques for comparison and analysis of change are variance analysis[264], earned value management[265], forecasting[266]. Accordingly, process requirements and project process are revised and adjusted for the next iteration in collaborative[267] meetings with project team involving project management and system development teams. The review of project process results in adjustment of implementation process and update of MaRSI plan, requirements list[268], and status reports[269].

5.2.6.3 Review of Project Deliverables

The review of project deliverables aims **revision and adjustment** of project documents (e.g. project plans, logistics process evaluation) and RFID system (e.g. system design, partial solutions) at the end of a phase or iteration in order to improve quality of the RFID system.[270] The activity is intended to gain feedbacks on performed work. For this purpose, the work done is **presented and demonstrated**. The review of project deliverables also involves RFID system **performance assurance and validation** upon completion of specific activities and deliverables during RFID implementation process. The approval or disapproval of project deliverables is made formally in **status meetings** involving top managers, project manager, and subject area experts. The activity of review of the project deliverables can be supported by techniques such as inspections (i.e. conformance to defined standards or requirements), group decision making, quality metrics, checklists, and

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[263] Variance analysis is a technique for determining the cause and degree of difference between the planed and actual performance (see PMI 2013, 139).

[264] i.e. performance reviews by comparison.

[265] Earned value management (EVM) is a methodology that combines scope, schedule, and resource measurements to assess project performance and progress. See PMI 2013, 224 for Earned Value Calculations.

[266] Forecasting is comparing the estimate at completion (EAC) and budget at completion (BAC) (see PMI 2013).

[267] by experts judgment.

[268] Including change log (if used) for documentation of changes occurred during project and their impacts in terms of time, cost, and risks.

[269] See 5.3.4 MaRSI Plan, 5.3.2 MaRSI Requirements List, and MaRSI Status Report (i.e. process performance aspects).

[270] See 5.3.4 MaRSI Plan.

tests. It results in formal feedbacks from status meetings regarding **acceptance of deliverables** and update of business, stakeholder and system requirements[271].

5.2.6.4 Review of Communications

The review of communications aims to ensure effective and efficient information flow[272], stakeholder engagement[273], and procurement commitments[274].[275] It involves **revision and adjustment** of communication channels, stakeholder engagement strategies, and procurement relationships[276] based on lessons learned and feedbacks in order to minimize the gap between diverse stakeholders.[277] Communication review is usually triggered by an issue of key performance indicators (e.g. schedule, cost, quality). The reviews of communication are performed by the project manager or project management team using meetings[278], expert judgment[279], information management systems, and records management system[280]. The review of communication activity results in update of communications involving forecasts, performance reports, stakeholder engagement strategy, issue log, costs, schedules, and agreements.

5.2.6.5 Review of Risks

The review of risks aims to reduce risks and improve quality during RFID system implementation. Primarily, transparency and proper documentation of project process and deliverables are used to respond to risks in advance. However, risks are identified and

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[271] See 5.3.2 MaRSI Requirements List.

[272] See 5.2.5.1 Communication Realization: Information flow involving e.g. project status, changes, progress, and future performance plans.

[273] See 5.2.5.3 Stakeholder Support Assurance.

[274] See 5.2.5.2 Agreements Establishment.

[275] See 5.3.4 MaRSI Plan.

[276] Administering procurement contract and protecting own legal rights (e.g. managing relationship among various sellers). It may also involve PM processes such as manage project work (i.e. timing of procurement), control quality (i.e. of vendor product), (perform integrated) change control (i.e. proper approval of changes), and control risks (i.e. reducing risk).

[277] See 5.4.2 Communication Methods.

[278] Meetings aiming reviews.

[279] To ensure comprehensive identification and listing of new stakeholders judged by project manager or subject area experts in meetings.

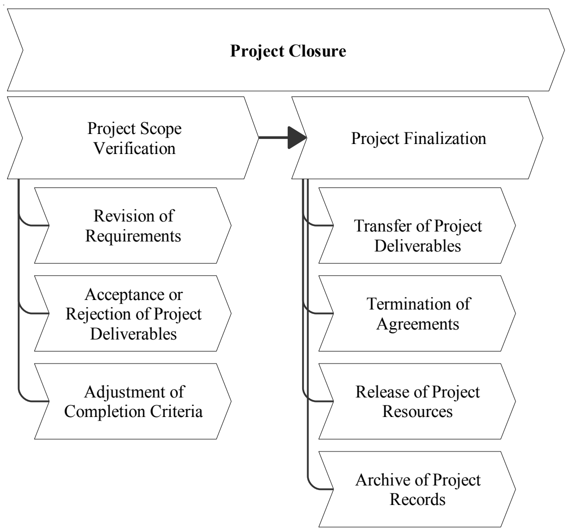
[280] Used by project manager to manage contract and procurement documentation and records (i.e. part of the project management information system).

responded only upon occurrence. Risks during RFID system implementation are assessed using feedbacks on project process and system functionality from project team in collaborative meetings and stakeholders in status meetings. Feedbacks facilitate intentional repetition of project activities or rework of project deliverables upon completion and lesson learned in the course of action in order to minimize, for example, the risk of failure. The review of risks involves project requirements, scope, cost, quality (i.e. process and system), performance (i.e. team and system), communication, and stakeholder engagement. It results in update of requirements list[281] and MaRSI plan[282].

5.2.7 Project Closure

The project closure aims formal acceptance of project deliverables in accordance with defined requirements. It involves finalization of project including contractual obligations, status reports, final report[283], and lessons learned[284]. The MaRSI closure builds on reviews[285] of project process and deliverables and requires expert judgment and stakeholder feedback for finalization. It involves activities of project scope verification and project finalization.

Figure 23: Project Closing Phase



Source: By the author.

The activities of project closure are performed by the project manager, whereas the decision for project closure is made in project status meeting. The results of project closure

[281] See 5.3.2 MaRSI Requirements List.

[282] See 5.3.4 MaRSI Plan.

[283] See 5.3.8 MaRSI Final Report.

[284] See 5.3.7 MaRSI Lessons Learned Document.

[285] See 5.2.6 Project Review.

are verification of performed work, adjustment of completion criteria, delivery of project results, and transfer of project information (e.g. lessons learned).

5.2.7.1 Project Scope Verification

Project scope verification aims formal acceptance of project deliverables. In iterative realization of RFID system implementation, project deliverables covers project, phase and iteration deliverables. Project deliverables of an RFID system implementation vary depending on project objectives such as RFID system design, partial RFID system, or full working RFID system. The deliverables of a phase also depends on the aim and scope of the phase. For instance, the project starting phase, according to MaRSI, delivers a business case, a requirements list, and a project charter. The deliverables of an iteration, for example, during technical work realization may involve adoption of specific supply chain processes or achievement of specific RFID system functionality.

The activity scope verification is conducted on the basis of review of project deliverables[286] and in consideration of defined requirements and quality[287]. The meetings for the purpose are facilitated by the project manager. The verification of performed work is done by project stakeholders. The result of scope verification is adjustment of completion criteria by the project manager on the basis of stakeholder feedbacks.

5.2.7.2 Project Finalization

The project finalization aims formal closure of RFID system implementation project. It involves delivery of project deliverables according to defined requirements[288] and scope[289]. The project finalization, furthermore, covers termination of project agreements, release of project resources, and archive of project records. Project finalization builds on reviews of project process and deliverables.[290] The decision for project closure is taken by project stakeholders collaboratively in a status meeting. Accordingly, the project manager formally closes the project. Project finalization provides the opportunity for post-project review such as team assessment and stakeholder relationships improvement. The activity results in

[286] See 5.2.6.3 Review of Project Deliverables.

[287] See Section 5.2.1 and 5.3.2 MaRSI Requirements List.

[288] See Section 5.2.1 and 5.3.2 MaRSI Requirements List.

[289] See Sections 5.2.2.1 Scope Specification and 5.2.2.2 Process Model Adaptation: e.g. RFID system design or partial RFID system.

[290] See Section 5.2.6 Project Review.

delivery of project results (e.g. RFID system design[291], status reports, and final report[292]) and transfer of project information (e.g. lessons learned[293]).

5.3 MaRSI Inputs and Outputs

Project management follows system approach for management of involved activities. A project exhibits all characteristics of a system. It possesses a clear boundary to the environment (i.e. of operation and deployment) and a number of interlinked sub-components (i.e. work, team, resources). A project receives an assignment from its environment as an input and delivers a result as an output [Jakoby 2010, 13–15; Stair/Reynolds 2012, 8; Brewer/Dittman 2010, 34]. Accordingly, the activities of MaRSI process model are supported by inputs and outputs for the purpose of applicability and comprehensiveness as discussed under requirements P9 and P10 in section 4.1. These inputs and outputs involve MaRSI business case, MaRSI requirements list, MaRSI charter, MaRSI plan, MaRSI technical deliverables, MaRSI status report, MaRSI lessons learned document, and MaRSI final report.

5.3.1 MaRSI Business Case

The MaRSI business case is the initial document that states the need for RFID system implementation. It aims justification of the project and supports in decision making on RFID system implementation initiative by the top management. The reasons for development of business case are changes in enterprise needs, customer demands, or technological advancements. The document is developed during idea generation on the basis of enterprise or project stakeholder inputs.[294] The generation of business case is in the responsibility of project manager and requires business analysis and RFID system implementation expertise. The MaRSI business case consists of problem description, reasons for initiation, preliminary business requirements, project objectives, project constraints, project budget and schedule estimates, and project cost and benefits analysis. The development of the business case requires simple, collaborative, stakeholder oriented, and communication oriented approach that involves RFID system implementation requirements as summarized in list of requirements in section 4.1.4. A template of MaRSI business case is provided as appendix 1.

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[291] See 5.3.5 MaRSI Technical Deliverables.

[292] See 5.3.8 MaRSI Final Report.

[293] See 5.3.7 MaRSI Lessons Learned Document.

[294] See Section 5.2.1.1 Idea Generation.

5.3.2 MaRSI Requirements List

The MaRSI requirements list is a structured, ordered, and live list of best-understood requirements of an RFID system implementation for a given enterprise. It aims maintenance of quality of project process and deliverables by definition of project success criteria and boundaries according to business and stakeholder requirements in iterative and incremental manner. The foundation for development of MaRSI requirements list are the business and stakeholder requirements from the business case. It is initially developed by the project manager during requirements analysis[295].

The MaRSI requirements list consists of business, stakeholder, communication, implementation process, RFID system, legal, and procurement requirements. The business requirements are specified on the basis of the business case[296]. Stakeholder and communication requirements build on stakeholder analysis[297]. RFID system implementation process requirements of food manufacturing industries are focused in this dissertation and could be derived from the list of requirements[298]. RFID system requirements are defined collaboratively during meetings by means of brainstorming, questionnaires, interviews, observations, classification, prioritization, and allocation involving entire project team.[299] The legal requirements base on enterprise and domain standards listed in business case[300]. The MaRSI requirements list, furthermore, includes information regarding project reviews, feedbacks, and tests.[301] The project reviews and feedbacks are documented properly in order to update requirements list. The results of tests primarily provide documentation regarding technical feasibility of RFID hardware and software. It also includes user acceptance tests information (i.e. functional and non-functional requirements fulfillment).

The MaRSI requirements list orders requirements on the basis of business value, optimization potentials, technological risks, and cost. It is a living document that is updated

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[295] See 5.2.1.4 Requirements Analysis.

[296] See 5.3.1 Business Case that is generated during 5.2.1.1 Idea Generation .

[297] See 5.2.1.3 Stakeholder Analysis.

[298] See 4.1.4 List of Requirements.

[299] See 5.4.1 Requirements Engineering Techniques and 5.4.6 Process and System Improvement Techniques.

[300] See 5.3.1 Business Case.

[301] See 5.2.6 Project Review.

throughout the project during reviews until project completion.[302] A template of MaRSI requirements list is provided as appendix 2.

5.3.3 MaRSI Charter

The MaRSI charter is a formal document that authorizes existence of project and assignment of project manager. It aims establishment of organizational internal and external agreements in order to initiate project, assign project manager, and guarantee proper delivery of organizational resources and their application to project activities. The MaRSI charter includes business requirements, stakeholder requirements, assumptions, constraints, and project summary involving project purpose, objectives, boundaries, success criteria, initial steps, budget, schedule, stakeholder, project manager assignment, sponsor authorizations). It is developed by the project manager and project sponsor (i.e. top management) on the basis of MaRSI business case and requirements list.[303] The MaRSI charter requires consideration of organization strategy, stakeholder expectations, domain characteristics, technological requirements, and team collaboration.[304] Consequently, it makes the foundation for project planning. A template of MaRSI charter is provided as appendix 3.

5.3.4 MaRSI Plan

The MaRSI plan is a high level plan that provides guidance and support to project team and stakeholders during project work realization. It aims to achieve project objectives with defined work, realization approach and resources. The MaRSI plan includes methodical and organizational aspects of planning. The detailed versions of MaRSI plan are iteration plans that are valid in the scope of a phase boundaries. The MaRSI plan is developed on the basis of initial project requirements from MaRSI requirements list[305] and MaRSI charter[306]. The project manager is responsible for the development of MaRSI plan in collaboration with project team (i.e. involvement of subject area experts for relevant activities). The definition of methodical and organizational aspects of MaRSI plan may

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[302] See 5.2 MaRSI Process Model.

[303] See 5.2.1 Project Starting.

[304] See 4.1.4 List of Requirements.

[305] See MaRSI Requirements List.

[306] See 5.3.3 MaRSI Charter.

occur sequentially or in parallel. The primary success criteria for the MaRSI plan are realism, effectiveness, efficiency, and collaboration as discussed in section 4.1.[307]

The methodical aspects of MaRSI plan consist of project scope statement, project approach and work breakdown structure (WBS), activity list, and monetary resources. The project scope statement includes summary of project, summary of project and system deliverables, and success criteria, exclusions, constraints and assumptions of project. The project approach (i.e. process model) and WBS represent decomposed work of entire project, which primarily base on the defined project scope statement, and selected project management and system development approaches. The activity list[308], which builds on the defined process model and WBS, describes project activities in a sequenced manner in order to estimate project resources such as peoples, equipments and materials, and duration. Monetary resources are approximation of required budget to complete the project work.

The organizational aspects of MaRSI plan focus on organization and management of project resources during realization of project work. They include details regarding project organization, communication, and procurements. The project organization encompasses details of internal structure and external interfaces, roles and responsibilities (e.g. organization chart), and acquisition and release (e.g. staffing plan). It, furthermore, involves team performance, behavior, conflicts and training aspects. The project communication covers details such as communication methods, required information, and stakeholder engagement strategy. Project procurement information consists, for example, of market research details, make-or-buy analysis for project results or services, RFID vendor proposals and selection, and organizational procurement standards. Organizational planning aspects are defined on the basis of MaRSI requirements list[309] and methodical aspects of MaRSI plan. A template of MaRSI plan is provided as appendix 4.

5.3.5 MaRSI Technical Deliverables

A simple RFID system consists of supply chain process (e.g. arrival, issue), RFID hardware (e.g. tag, reader), RFID software (e.g. middleware), and information system (e.g. warehouse management system). In practice, RFID systems differ depending on business

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[307] See 4.1.4 List of Requirements.

[308] Activity list is "a documented tabulation of schedule activities that shows the activity description, activity identifier, and sufficient detailed activity scope definition to the work so project team members understand what work is to be performed" (PMI 2007, 87 in project standard for scheduling).

[309] See 5.3.2 MaRSI Requirements List.

objectives and requirements, and enterprise structure and culture.[310] For instance, an enterprise may indent to be prepared for a potential implementation of RFID. The result of such an undertaken can either be an RFID system design or RFID cost and benefits and return on investment analysis.

In the process of implementation, an RFID system comprises deliverables such as supply chain evaluation, RFID system design, RFID economic analysis, and working RFID system (i.e. partial or complete).[311]

Supply chain evaluation aims qualitative and quantitative analysis of supply chain processes of an enterprise. It is carried out in the scope of as-is analysis in order to explore strengths and weaknesses of supply chain processes in order to design RFID system and analyze economic feasibility. The supply chain evaluation is performed by subject area experts (i.e. supply chain or change manager) collaboratively in project team (i.e. project manager, RFID manager) in consideration of supply chain requirements of the RFID system[312]. It requires details such as topology of application area, physical appearance of logistic entities, physical and logical structure of supply chain processes, and material (e.g. various products) and information (e.g. environmental, flow) flows with required resources (e.g. machines, hardware, software, transport entities, personal).[313]

The **RFID system design** describes supply chain processes of an enterprise with RFID hardware and application systems with RFID software and data.[314] RFID system is designed in the scope of to-be concept as preliminary and detailed design with the help of scenarios. It requires consideration of business, stakeholder, legal and supply chain requirements, technical feasibility, and RFID technology characteristics.[315] An RFID system is designed by subject area experts (i.e. supply chain or change manager) collaboratively in project team (i.e. project manager, RFID manager) in consideration of RFID system requirements[316].

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[310] See Section 2.1 RFID Systems.

[311] See Section 2.2 RFID System Implementation Process and Chapter 6 Application and Scientific Evaluation of MaRSI .

[312] See 5.3.2 MaRSI Requirements List.

[313] See Chapter 6 Application and Scientific Evaluation of MaRSI.

[314] See Section 2.1 RFID Systems.

[315] See 5.3.2 MaRSI Requirements List.

[316] See Chapter 2 RFID Systems in Supply Chain and 5.3.2 MaRSI Requirements List.

The **economic analysis** of an RFID implementation aims specification of cost and benefits and return on investment of an RFID system for an enterprise. The cost of supply chain processes is evaluated during as-is analysis of supply chain, whereas cost of RFID system components is specified on the basis of RFID system design. The benefits of RFID could be derived by expert judgment using specific approaches[317] for cost and benefits analysis of RFID. The return on investment (ROI) analysis is performed on the basis of cost and benefits analysis using discounted cash flow method. A detailed economic analysis can be carried out after RFID system design. However, rough estimation can be made during project starting phase, for example, with the help of available excel-based calculators. For the purpose of economic analysis a differentiation is made between internal, external, fix, variable and operating costs. According to MaRSI, the project manager is responsible for economic analysis. The economic analysis primarily requires consideration of effectiveness, efficiency, and team collaboration.[318]

The working **RFID system** comprises supply chain and application system of an enterprise supported by RFID hardware and software. RFID technology is applied for optimization (i.e. stabilization or reengineering) of supply chain based on strategic objectives and supply chain requirements. Depending on business objectives and requirements, an RFID system can either be partial or complete. A partial RFID system includes specific supply chain processes or business units of an enterprise, whereas complete RFID system covers whole internal or internal and external supply chain of an enterprise. An RFID system is developed and deployed by subject area experts (e.g. change or RFID manager) in consideration of business and technology requirements.[319]

5.3.6 MaRSI Status Report

The MaRSI status report is a written document that describes project status at a point in time and in future.[320] It involves aspects of project process, team, and system performance. Aspects of process and system performance are presented formally in status meetings of the project and address top management and project stakeholders. However, project process, team, and system performance are the subject of collaborative meetings and handled informally. The MaRSI status report is developed by the project manager in

[317] See 2.2.2 Vilkov-2007 and 2.2.5 Rhensius-2009.

[318] See Chapter 6 Application and Scientific Evaluation of MaRSI.

[319] See Section 2.1 RFID Systems and 4.1.4 List of Requirements.

[320] See 5.2.6.4 Review of Communications.

consideration of MaRSI requirements[321]. It documents details such as availability of schedules, costs, and resources for the purpose of awareness and decision making. A template of MaRSI status report is provided as appendix 5.

5.3.7 MaRSI Lessons Learned Document

The MaRSI lessons learned document provides historical information on project, phase, or increment activities and experiences upon completion.[322] It aims continuous improvement of project process, system functionality, team skills, and stakeholder interactions. The lessons learned document is developed by the project manager on the basis of project team feedbacks in the course of action. It is used throughout the project for continuous improvement and can be used for future projects. The MaRSI lessons learned document includes details of phase or iteration objectives and success criteria, experiences in current phase or iteration, good and bad practices, and recommendations for future phases or iterations. A template of MaRSI lessons learned document is provided as appendix 6.

5.3.8 MaRSI Final Report

The MaRSI final report is a document that is generated after formal completion of the project. It provides overview and aims transfer of project information.[323] The document is developed by the project manager. It is handed over in project final meeting to top management and project stakeholders. The MaRSI final report contains details of project objectives, summary of results, planed and actual schedule and budget information, and project assessment with references to project management and RFID system related documents. A template of MaRSI final report is provided as appendix 7.

5.4 MaRSI Tools and Techniques

The MaRSI reference model provides tools and techniques for the purpose of applicability and comprehensiveness as mentioned under requirements as P9 and P10 in section 4.1. The tools and techniques for RFID system implementation projects include requirements engineering techniques, communication methods, reference modeling techniques, scheduling techniques, budget estimation techniques, process and system improvement techniques, and inspection and review techniques.

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[321] See 5.3.2 MaRSI requirements List.

[322] See 5.2.7.2 Project Finalization.

[323] See 5.2.7.2 Project Finalization.

5.4.1 Requirements Engineering Techniques

The requirements engineering techniques involve identification, understanding, and analysis, as well as documentation, validation and update of requirements[324] [Berenbach et al. 2009, 8; BABOK 2009, 53–140]. In this regard, requirements analysis is structured as elicitation, analysis, specification, validation, and management of requirements [Young 2004, 4–5]. Elicitation of requirements aims to identify stakeholders, gain understanding, and identify and clarify requirements [Young 2004, 4–5] using techniques such as interviews, questionnaires, document analysis, direct observations, brainstorming, and scenario [Young 2004, 61–104; Berenbach et al. 2009, 48–64; Endres/Rombach 2003, 26–27]. Analysis of requirements involves formulation of requirements, for example, according to business, RFID system, and various stakeholder perspectives using classification[325] and projection techniques [Young 2004, 4-5, 61-104; Endres/Rombach 2003, 27–28]. Specification of requirements is made by precision, prioritization[326], partitioning, and allocation of requirements [Young 2004, 4-5, 61-104; Endres/Rombach 2003, 28–29]. Validation of requirements is carried out with the help of reviews, inspections, and tests [SWEBOK 2004, 2–11; Endres/Rombach 2003, 29; Young 2004, 61–104]. Management of requirements aims to add, delete, and modify requirements throughout the project iteratively [Young 2004, 4-5, 61-104; Endres/Rombach 2003, 30]. A list of MaRSI requirements is provided as appendix 2.

- The elicitation of requirements for RFID system implementation is made during initial project meetings (i.e. idea generation). In initial stages of the project, elicitation primarily focuses on business and stakeholder requirements. The project process, communication, procurement, legal, and RFID system requirements are

[324] Elicitation (identify stakeholders, gain understanding, identify requirements, clarify requirements), Analysis (formulate requirements to be understood by stakeholders from various perspectives), Specification (precise detail, prioritize, partition, allocate), Validation (test, review and inspect), Management Update (add, delete, modify requirements throughout the project) (see Young 2004, 4-5).

[325] Requirements can be categorized or grouped based on direct and indirect optimization potentials of RFID technology for given supply chain processes. (see Appendix 2 for RFID system preliminary requirements).

[326] The technique of prioritization is used for specification of preliminary RFID system requirements. This technique supports during complex decision making process and considers aspects such as importance, risk, and cost. In RFID system implementation projects, business value and technological risks of requirements are of importance (i.e. ordering in three different prioritizations).

considered subsequently. Elicitation of requirements is done in a semi-formal manner in collaborative meetings involving discussions with expert judgments and proper documentation.

- The analysis of requirements, which involves formulation of requirements according to business, project process, stakeholder, communication, procurement, legal, and RFID system, is carried out in collaborative meetings involving entire project team.
- The specification of requirements concentrates on precision, prioritization, partitioning, and allocation of requirements. It is also carried out in collaborative meetings in consideration of characteristics such as conformance with business objectives, stakeholder expectations, realism, and testability.
- For validation of requirements, MaRSI requirements are reviewed on the basis of business objectives and stakeholder expectations as well as benchmarking for applicability. RFID system requirements are, however, benchmarked and tested as necessary. During tests [Donath 2010, 123–126], the fulfillment of requirements for particular process or scenario is proved for RFID hardware and software during component tests, RFID hardware and application system interfaces during integration tests, functionality of the whole system for implementation and roll out during system tests, and fulfillment of functional and non-functional requirements during user acceptance tests.
- The management of requirements is made according to changes in business environment and business requirements. Accordingly, the MaRSI requirements list[327] is adjusted for the future iterations of project work. Management of requirements is done in a semi-formal manner in collaborative meetings involving discussions, reviews, feedbacks, tests, and proper documentation.

5.4.2 Communication Methods

The communication methods aim to minimize the gap between diverse stakeholders effectively and efficiently in consideration of information requirements of stakeholders, required communication methods and technologies, and frequency of communication. According to communication requirements of a project, various communication methods are applied. These include interactive (e.g. meetings, presentations, phone calls, video conferencing), push (e.g. emails, reports, fax), and pull (e.g. databases, knowledge

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[327] See 5.3.2 MaRSI Requirements List and Appendix 2.

repositories) communication methods [PMI 2008, 256]. RFID system implementation projects require less formal communication, for example, for requirements analysis, project reviews, and frequent feedbacks. Accordingly, primary and efficient techniques for the purpose are meetings and presentations in an informal manner, and reports and negotiations with formal documentation.

- **Meetings** are generally thought to support and encourage expectations, team building, roles, relationships, and commitments. For RFID system implementation projects, they provide also an opportunity for requirements analysis, feedbacks, and reviews of project work in a semi-formal manner. Accordingly, meetings are differentiated in collaborative and status meetings. Collaborative meetings are aimed during project work realization between project team, whereas status[328] meetings involve presentation of project status to top management and project stakeholders. Collaborative meetings are conducted informally involving discussions, presentations, and feedbacks on requirements changes, project work reviews, and planning of future work. Status meetings are held formally in order to inform top management and project stakeholders.
- The **work presentation** involves illustration and demonstration of performed work of the project. It ensures efficient and effective communication during project organizational as well as technical work realization in order to gain feedbacks. Work presentations are carried out in collaborative meetings (i.e. informally).
- **Reports** are formal documents [PMI 2013, 93]. The communication of RFID system implementations with top management and project stakeholders is conducted by project status[329] and final[330] reports. Project status reports are the result of project reviews that provide information on project status at a point in time and in future for awareness and decision making. Project final report is developed after completion of the project aiming to provide overview of project objectives, results, schedules, and budgets.
- **Networking**[331] and **team organization**[332] techniques are applied for understanding of political and interpersonal interests, and team and organizational behavior

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[328] Project progress i.e. team performance is subject of collaborative meetings.

[329] See 5.3.6 MaRSI Status Report.

[330] See 5.3.8 MaRSI Final Report.

[331] Networking is formal and informal interaction with others (see PMI 2008, 222).

respectively. These techniques are used during project organizational work realization, for example, for personnel responsibilities documentation.

- **Negotiations** are discussions with parties of shared or opposed interests with an aim to reach an agreement [PMI 2013, 517]. In the context of RFID system implementations, procurement contracts, meetings for procurement proposals reviews [PMI 2013, 377, 388], availability of appropriate staff internally, assignment of specialized staff externally [PMI 2013, 270], and management of stakeholder expectations [PMI 2013, 405] are subject to negotiations.
- **Other** tools and techniques for communication realization involve emails and collaborative tools. Emails are an efficient (in terms of time and cost) and informal way of correspondence with and information availability to project team and stakeholder. However, they are not suitable, for example, for conflict mediation and resolving, agreements building, commitment appraisal, are confidentiality. Similarly, collaborative tools (e.g. MS SharePoint, Google Docs) can be used for communication. However, an effective use of such tools requires awareness of their limitations and constrains.

5.4.3 Reference Modeling Techniques

The principles of reference model construction are differentiated in parametric and adaptive approaches. Parametric approach consists of design by selection or configuration. Adaptive approach involves design of a model by aggregation (i.e. combination), instantiation (i.e. embedding), specialization (i.e. revising), and analogy (i.e. transfer) [Vom Brocke 2007, 52–67; Becker et al. 2007, 27–58]:

- "*Configuration is characterized by explicit adaptation points enclosed in the reference model" according to define rules. It's basic "concept is based upon the principle of model projection*".
- "*By specification the level of detail of the reference model is consciously restricted. Specialization is performed by adding, changing or removing model elements without any semantic restrictions*."
- "*Aggregation implies that the reference model is provided in the form of model components that have to be combined by the reference model user. The possible combinations of components can thereby be restricted by interface definitions.*"

[332] Team organization is based on organizational theory aiming information regarding the way of people's, teams', and organizations' behavior (see PMI, 2008, 222).

- "*Instantiation of a reference model aims the insertion of feasible values for placeholders that are provided within the model. These values can reach from simple numeric values to complex model element structures.*"
- By analogy, the user reuses the structure of a reference model free-handedly. It is the least restricted adaptation technique.

These techniques are discussed in section 3.2.3 in detail.

5.4.4 Scheduling Techniques

RFID system implementation is an iterative process applying scheduling strategies for requirements and resources. Iterative realization of RFID system implementation requires dynamic but less comprehensive planning. Scheduling aims realization of project work over time with the help of scheduling techniques.

Scheduling techniques provide structured approaches for realization of project work over time [Burke 1999, 120; PMI 2007, 8; Schwalbe 2011, 228]. For RFID system implementation, requirements and resources are scheduled in iterative manner using top-down[333] and bottom-up[334] approaches because of the complexity of RFID systems (e.g. different functionalities of RFID components, middleware characteristics, unique set of business activities and objectives). In addition, traditional planning tools and techniques such as critical path method (CPM)[335] and bar charts[336] are applied for planning of time dimension of project work realization. Accordingly, techniques such as rolling ware, time-boxing, brainstorming, and critical path method (optional) are of relevant for the purpose.

- Rolling wave technique[337] aims to plan the work to be accomplished next in detail, whereas the overall project work is planned at high level.[338]
- Time-Boxing[339] is a top-down technique that aims to achieve specific objectives or system functionality. For instance, the objectives of an iteration could be

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[333] i.e. decomposition in RFID development.

[334] i.e. plan or artifact based in RFID deployment.

[335] See PMI 2007, 8, Burke 2001, 120, and Schwalbe 2011, 228.

[336] i.e. Gantt charts list project activities (see WBS) with corresponding planned or planned and actual start and finish dates.

[337] See PMI 2013, 560.

[338] See 5.3.4 MaRSI Plan.

[339] See Cockburn 2008, Wysocki 2009, 341-357, Hanser 2010, 5.

achievement of specific functionality of a supply chain process with RFID or application of RFID in specific supply chain processes/ business units.

- Brainstorming[340] is a facilitation technique that is used, for example, in group decision making for estimation of duration on the basis of project activity list in order to generate and collect ideas.
- Critical path method (CPM)[341] is a traditional scheduling technique that can be used for time-boxing of individual iterations and entire project. It is supported by computer based tools and helpful in prediction of project or iteration duration.
- Other techniques such as critical chain method (CCM)[342] and program evaluation and review technique (PERT)[343] can be used for projects with limited resources and projects with hardly predictable activities respectively.

5.4.5 Budget Estimation Techniques

Budget estimation techniques facilitate approximation of monetary resources for project work completion. RFID system implementation projects are innovative undertaken and require creative techniques with involvement of experts for cost estimation. Therefore, techniques such as analogous and parametric[344] estimating, which base on historical data, are inappropriate. Accordingly, suitable techniques for budget estimation are:

- Group decision making techniques such as brainstorming and nominal group technique[345] [PMI 2008, 108] emphasize on collaborative involvement of subject area or technical experts for cost approximation of a project in order to achieve estimate accuracy and ensure team commitment. Using these techniques, the budget of the project is initially estimated on the basis of high level MaRSI plan[346]. The MaRSI plan is updated in the course of action on the basis of iteration plans.

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[340] see PMI, 2008, 108.

[341] See PMI 2007, 8, Burke 1999, 120, and Schwalbe 2011, 228.

[342] see Schwalbe 2007 and 2011, 233-236.

[343] see Schwalbe 2007 and 2011, 236-237.

[344] e.g. constructive systems engineering cost model (COSYSMO), a model that helps to find out economic implications of system engineering on projects (see http://cosysmo.mit.edu/ (last accessed 06.05.2016).

[345] Nominal group technique is “a technique that enhances brainstorming with a voting process used to rank the most useful ideas for further brainstorming or for prioritization“ (PMI 2008, 108 and PMI 2013, 547).

[346] See 5.3.4 MaRSI Plan.

- Bottom up estimation technique [PMI 2008, 172; PMI 2013, 205] calculates cost of individual activities of the project work as specified in WBS[347] or activity list[348] in order to approximate project budget. RFID system implementations require expert judgments for accuracy of cost estimation based on high level plan. The high level plan[349] is updated iteratively. For accuracy of cost estimations, activity cost can be calculated on the basis of realistic, best-case and worst-case scenarios.[350] Bottom up estimation of cost in combination with group decision making techniques facilitate higher cost accuracy and project team commitment.

5.4.6 Process and System Improvement Techniques

During iterative and incremental development of an RFID system, the RFID system as well as the implementation process is improved continuously. Continuous improvement [ISO 24765 2010, 270] involves activities to adapt processes and system on the basis of specified requirements and on consistent basis using proper tools and techniques. Improvements to RFID implementation process and RFID system can be made at any time during project realization, however project reviews provide formal opportunities to reassess or check changes in requirements and business environment. Primary sources for continuous improvement are lessons learned during previous or current project iterations and feedbacks from project team and stakeholders. Continuous improvement techniques in the context of RFID system implementation aim effectiveness and efficiency of the implementation process and RFID system by evaluation of feedbacks in order to achieve business objectives. These techniques include iterative project process, brainstorming, process analysis, cause and effect analysis, benchmarking, and tests.

- **Iterative project process** [PMI 2008, 202; PMI 2013, 229–231] of initiation, planning, realization, review, and closure (IPRRC)[351] is an iterative improvement process that provides the basis for quality improvement. IPRRC applies tools such as MaRSI charter[352] and MaRSI requirements list[353] in order to identify, adjust, or

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[347] See 5.2.2.1 Scope Specification.

[348] See 5.2.2.3 Schedule Definition.

[349] See 5.3.4 MaRSI Plan.

[350] i.e. three-point estimation, see PMI 2008, 172-173 and PMI 2013, 205.

[351] See 5.1.2 Organization along Process in MaRSI Frame of Reference.

[352] See 5.3.3 MaRSI Charter.

[353] See 5.3.2 MaRSI Requirements List.

eliminate implementation process activities and RFID system functionalities with none or less business value.

- **Brainstorming** [PMI 2008, 108; PMI 2013, 115] is a creativity group technique used during collaborative meetings of RFID system implementation. It aims to generate ideas focusing on implementation process requirements, system requirements, and project risks. Brainstorming is performed by identifying problem and potential improvement, and by designing solution.
- **Process analysis** technique [PMI 2008, 204; PMI 2013, 247] uses process mapping to identify potential improvement and examine problems, constrains and none business value-added activities. It also applies root cause analysis to identify a problem, discover underlying cause, and develop solutions. The variations in processes are shown as histograms.
- **Root cause analysis** [PMI 2008, 287; PMI 2013, 236] provides a technique to back trace the actionable root cause of a problem by using the problem as a starting point. It involves identification of a problem, discovery of the underlying cause, and development of solutions. Root cause analysis is shown as cause and effect or fishbone diagram.
- **Benchmarking**, in general, provides opportunity to compare actual and planned practices by analogy [PMI 2008, 197; PMI 2013, 116, 239]. In the context of RFID system implementation, actual and planned implementation processes of an iteration are compared in order to identify best practices, generate ideas for future improvement, and provide basis for performance measurement. For RFID system functionalities improvement, benchmarking of supply chain processes with and without RFID technology with similar industries provides solid ground for decision making regarding technical feasibility of RFID components. Based on existing case studies and tests reports, the project team can build scenarios for applicability of RFID system components and system. By this, feasibility of the technology and optimization potentials of supply chain processes are proved theoretically.
- **Tests** of RFID system and system components are performed for technical feasibility of RFID technology and improvement of RFID system functionality. RFID technology requires tests for both physical and information integration in enterprise processes because of environmental effects on RFID technology and adoptability of users respectively. An RFID system requires system components, system integration, system, and user acceptance tests. RFID system components

tests are performed in order to prove requirements fulfillment of particular process or scenario including RFID hardware and software. RFID system integration tests involve verification of RFID hardware components, and RFID and enterprise system interfaces. RFID system tests are conducted to check functionality of the whole system. RFID user acceptance tests focus on fulfillment of functional and non-functional requirements of users [Donath 2010, 123–126]. For evaluation of tests, checklists are used comprising RFID system requirements and standards.

5.4.7 Inspection and Review Techniques

Inspection is a formal review technique that examines or measures "*to verify whether an activity, component, product, result, or service conforms to specified requirements*" and standards [PMI 2008, 124; PMI 2013, 543; ISO 24765 2010, 178], while review is "*a process or meeting during which a work product, or set of work products, is presented to project*" team or stakeholders "*for comment or approval*" [ISO 24765 2010, 308]. In the context of RFID system implementation, inspections are carried out with the help of checklist comprising RFID standards and project requirements list in management, technical, and informal reviews. Management and technical reviews [ISO 24765 2010, 207, 366] are formal with documented procedures. Contrary to formal reviews, informal reviews are conducted without formal documented procedure in collaborative meetings, however with proper documentation of changes. Management reviews are systematic and carried out in project status meetings focusing on evaluation of system "*acquisition, supply, development, operation, or maintenance process*" in order to monitor progress, confirm requirements, and assess management approach for performance evaluation and improvement opportunities identification [ISO 24765 2010, 207]. Technical reviews are systematic examination of the product (i.e. system) and technical progress against specified requirements and standards [ISO 24765 2010, 366; ISO 26702 2005] involving, for example, RFID system and system component tests, and system design approval. In informal reviews during collaborative meetings, changes in business environment and requirements are identified and examined in order to adapt the RFID implementation process and its deliverables in the future project iteration.

- **Reviewing requirements** aims identification of changes. In iterative implementation of RFID system implementation, requirements are managed and updated (i.e. add, delete, modify) throughout the project. The end of iteration provides an opportunity to gain feedbacks on changes in business and consequently project requirements.[354]

- **Reviewing implementation process** aims continuous improvement the RFID system implementation process on the basis of changing requirements and stakeholders and team feedbacks. RFID system implementation process is adjusted in accordance with reviewed requirements[355] and approved for the future iteration during collaborative meetings with project team using expert judgment.[356] In management reviews, techniques such as variance analysis[357], trend analysis[358], forecasting[359], and earned value management[360] are used for comparison of actual and planed performance in terms of project scope, for comparison of actual and future performance in terms of project schedule, for performance review in respect of project cost (i.e. bottom-up estimate at completion), and for performance and progress assessment in terms of scope, time, and cost respectively.
- **Reviewing technical deliverables** aims revision and examination at the end of iteration or phase with the help of checklists and upon lessons learned in order to validate quality (i.e. formally) and improve results.[361] The adjustments of results of RFID system implementation project[362] are planned in accordance with reviewed requirements[363] for the future iteration during collaborative meetings with project team using expert judgment. The functionality of developed RFID system is reviewed and tested for compliance with requirements as necessary.
- **Reviewing communication** aims revision and adjustment of communication channels, stakeholder engagement strategies, and procurement relationships on the basis of team and stakeholder feedbacks and expert judgments (i.e. for management

[354] See 5.3.2 MaRSI Requirements List and 5.4.1 Requirements Engineering Techniques.

[355] See 5.3.2 MaRSI Requirements List.

[356] See also 5.4.6 Process and System Improvement Techniques.

[357] see PMI 2008, 127, PMI 2013, 139.

[358] see PMI 2008, 186, PMI 2013, 188.

[359] see PMI 2008, 184, PMI 2013, 220.

[360] see PMI 2008, 181, PMI 2013, 217-218.

[361] See 5.3.5 MaRSI Technical Deliverables and 5.4.6 Process and System Improvement Techniques.

[362] i.e. project plans, supply chain evaluation, RFID system design, RFID system.

[363] See 5.3.2 MaRSI Requirements List.

and technical details). It is performed during collaborative and status meetings, for example, to minimize the gap between diverse stakeholders.[364]

- **Reviewing Risks** bases on feedbacks from project team in collaborative meetings and stakeholders in status meetings. Risks can be caused by requirements, scope, cost, quality (i.e. process and system), performance (i.e. team and system), communication, and stakeholder engagement. In RFID system implementation, risks are reduced by iterative realization of project work. Furthermore, transparency and proper documentation of project process and results are used to minimize risks and improve quality.[365]

[364] See 5.4.2 Communication Methods.

[365] See 5.3.2 MaRSI Requirements and 5.2.3 Organizational Planning.

Part III: Validation

6 Application and Scientific Evaluation of MaRSI

The MaRSI model is developed following the coherence concept[366] by conducting state of the art reviews[367]. The development of the model involves three main iterations.[368] The model is constructed and applied in first iteration[369], refined and applied in second iteration[370], and refined and generalized in third iteration[371]. The validation of the model occurred during and at the end of the construction process[372] satisfying specific requirements[373] of the food manufacturing industries[374] and scientific rigor[375].

6.1 Construction Process of MaRSI

The MaRSI model is the result of the **practice-oriented research** of the author with a medium-sized and a large enterprise of food manufacturing industries and the network of food businesses Saxony-Anhalt[376]. The primary objective the food manufacturing industries were preparation for a potential implementation of RFID technology in case of a mandate by customers. The intentions of the enterprises, in this regard, were identification of prospective rationalization potentials of RFID technology for the enterprises, specification of RFID system design for internal supply chain of the enterprises, and exposure of the economic value of RFID system implementation for the enterprises.[377] Therefore, the underlying research objective for the construction of MaRSI reference

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[366] "The coherence concept of truth recommends that a new hypothesis should be in line with an established body of knowledge, for example, with research results and opinions found in acknowledged publications" (see Frank 2007, 133).

[367] See Khan 2015 and Section 4.2.

[368] See Section 6.1.

[369] See Section 6.2.

[370] See Section 6.3.

[371] See Chapter 5.

[372] Validation is the "process of evaluating a system or component during or at the end of the development process to determine whether it satisfies specified requirements" (see IEEE 610.12, 1990).

[373] The evaluation of a model requires a systematic approach involving possible variety of requirements and specific constrains for (re-) usability (see Frank 2007, 119-123).

[374] See Sections 6.2 and 6.3.

[375] See Sections 4.1 and 6.4.

[376] Netzwerks Ernährungswirtschaft Sachen-Anhalt, http://www.netzwerk-ernaehrungswirtschaft.de (last accessed 05.05. 2016).

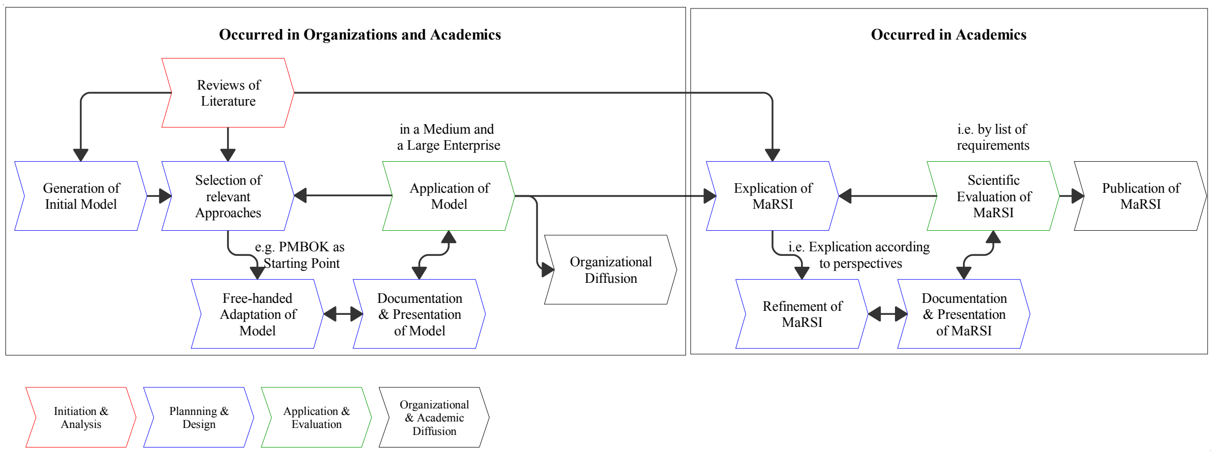
[377] See Chapter 5 and Sections 6.2 and 6.3.

model was development of an approach that is efficient and effective for enterprises aiming preparation of RFID system implementation.

The practice-orientation of a research lays in the objectives of the research of solving problem for practice [van Aken 2004] and developing artifacts for a class of domain [Lacerda et al. 2013; Sein et al. 2011; van Aken 2004; van Aken 2005]. In this regard, this research uses reference modeling approach for construction[378] and is conducted [Holmström et al. 2009] in organizations and academics (i.e. first two iterations), and academics (i.e. third iteration). Accordingly, the construction of the model is in compliance with the design-oriented information systems research [Peffers et al. 2008, 45–77; Österle et al. 2010, 1–4] that involves[379] initiation and analysis, planning and design, application and evaluation, and organizational and academic diffusion phases.[380]

For construction of MaRSI model, the research applies analogy principle of the reference modeling i.e. adaptation by transfer or creativity.[381] The activities of research [Holmström et al. 2009] occurred in organizations and academics and in academics as illustrated in figure 24. For identification, these activities are highlighted as red, blue, green and black according to analysis, design, evaluation, and diffusion phases of design-oriented information systems research respectively.

Figure 24: Construction Process of MaRSI



Source: By the author.

The research in organizations and academics involves reviews of literature, generation of initial model, selection of relevant approaches, free-handed adaptation of model,

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[378] See Section 3.2 Reference Modeling.

[379] For design-oriented information system research approach (i.e. analysis, design, evaluation, and diffusion) see Peffers et al. (2008, 45-77) and Österle et al. (2010, 1-4) .

[380] See Section 1.3.

[381] See Section 3.2.3.5.

documentation and presentation of model, application of model, and organizational diffusion. The research in academics involves explication, refinement, documentation and presentation, scientific evaluation, and publication of MaRSI. For management of RFID implementation activities, the PMBOK guide by PMI (2008) served as a starting point.[382] The SWEBOK[383] standard by IEEE (2004) was an important starting document for system development aspects along with other system development and selection approaches[384]. The activities of system development are, however, out of the scope of this dissertation. A tabular overview of the research is provided in appendix 9.

In terms of **similarities to other standards and methodologies** of project management from section 3.1.2, the MaRSI model provides a methodical view on project management. The activities of MaRSI at a higher level (i.e. initiation, planning, realization, review, and closing) are similar to PMBOK but adjusted and specialized (e.g. organizational and technical work realization) according to the needs of RFID system implementation for respective domain. It involves application of business case in project initiation activities that is similar to the methodology PRINCE. The model uses iterative approach for management of project (i.e. use of high level plan with detailed iterative plans) that has conceptual similarities with UP[385] and RUP. The work of the project is reviewed in an agile manner (see Scrum). With regard to acquirer and supplier of project (see V-Modell-XT), the MaRSI model is developed for top managers and project managers of food manufacturing industries as acquirer of project.

Research in Organizations and Academics

The research in organization and academics consist of two projects in cooperation with food manufacturing enterprises[386]. The research was initiated by the author.[387] The first project involved a medium-sized enterprise, the Anhalt University of Applied Sciences,

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[382] See Section 3.1.2.

[383] SWEBOK (2004) presents software engineering management in six activities (sub-knowledge areas) as initiation and scope definition, software project planning, software project enactment, software review and evaluation, closure, and software engineering measurement. It presents a waterfall life cycle sequence model as software requirements, software design, software construction, software testing, and software maintenance (SWEBOK 2004, 1-9).

[384] See Royce (1998), Becker/Vering/Winkelmann (2007).

[385] See Royce 1998.

[386] See Sections 6.2 and 6.3.

[387] i.e. as usual in design and design-oriented science research.

and the DAAD scholarship body (STIBET). It aimed preparation of the enterprise for a potential RFID implementation focusing on intra-logistics as presented in section 6.2. The project was part of the MBA-Thesis of the author. The second project was conducted in cooperation with a large food manufacturing enterprise, the network for food businesses Saxony-Anhalt, and the Anhalt University of Applied Sciences. It also aimed preparation of the enterprise for a potential RFID implementation focusing on intra-logistics in a broader context. The projects mainly focused on solutions to the problems of two food manufacturing industries.[388] Accordingly, the model developed and applied during the first project was improved and applied in the second project. The projects aimed and achieved preparation for a potential implementation of RFID[389] (i.e. mutual interest, empirical basis, and implementation[390]). The solutions of the projects included a process model with tools and techniques and design propositions, for example, for RFID system design, economic analysis.[391] These solutions were specific to the two enterprises (i.e. a medium and large sized food manufacturing industries).[392]

Each project was started with analysis of state of the art studies of relevant fields (e.g. relevant approaches, technology advancements) [Khan 2015][393]. Accordingly, an initial model was developed during the first project on the basis of the study of relevant fields for RFID system implementation in supply chain. The model was formulized on the basis of available approaches[394] using analogy technique. The guides provided by PMI (2008) and IEEE (2004) served as a starting documents (i.e. PMBOK[395] and SWEBOK[396]) for the free-handed adaptation of management related aspects and development related aspects of the model respectively. The design and application of the model was an iterative process that involved technical and supply chain managers of the enterprise. The practical results

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[388] i.e. as usual in action research and in design and design-oriented science research (i.e. solution incubation and refinement) (see Holmström et al. (2009)).

[389] i.e. as usual in design and design-oriented science research.

[390] Mutual interest, empirical basis, and implementation are compulsory in action research and optional in design and design-oriented science research.

[391] i.e. as usual in design and design-oriented science research.

[392] i.e. specific solutions for two industries as usual in action research.

[393] See also Chapters 2, 3 and 4.

[394] See Section 3.1.2.

[395] See PMI 2008.

[396] See SWEBOK 2004.

of the project were evaluation of supply chain processes, RFID system design, and economic analysis of RFID system implementation. The results of the research were communicated during the project and documented in the MBA-Thesis of the author.

The second project involved further literature reviews in order to improve the model of the first project. The improvement and adaptation was carried out by analogy with available approaches (e.g. PMBOK) and with the model from the first project[397]. However, specialization and instantiation technique were also used for adaptation from the model of first project. The adapted model for the second project was presented and discussed before application (i.e. high level process model and detailed model aspects relevant in the scope of a phase). The application of the model for implementation of an RFID system resulted in evaluation of intra-logistics of the enterprise, RFID system design, and economic analysis of RFID system implementation for the large enterprise. The results of the project were communicated as presentations, documentations, and reports internal to the enterprise and within the network for food businesses of Saxony-Anhalt.

Research in Academics

The research in academics aimed explication and improvement of the model according to stakeholder perspectives and generalization for the food manufacturing industries (i.e. mid-range or substantive theory for a class of domain).[398] It involves the Anhalt University of Applied Sciences, the University of Leipzig, and the Graduate Scholarship Program of Saxony-Anhalt[399]. On the bases of research in organizations and academics, the research in academics (i.e. third iteration) addresses food manufacturing industries that are intending preparation or realization of an RFID system implementation in the intra-logistics of the enterprise. The research in academics also involved a detailed review of literature that specifically focuses on RFID system implementation process. The activities of the resulting model from research in organization and academics were explicated and refined according to involved perspectives. The explication and refinement of activities of RFID system implementation resulted in the MaRSI reference model. The MaRSI reference model, in the context of this dissertation, involves management and organization of RFID system implementations. The artifacts of the model include a frame of reference, a process model, and design propositions such as suggestions, plans, and tools and techniques.[400] The

[397] See Section 6.1 and 6.2.

[398] i.e. as usual in design and design-oriented science research.

[399] Graduiertenförderung des Landes Sachsen-Anhalt (Grad FG and FradFVO).

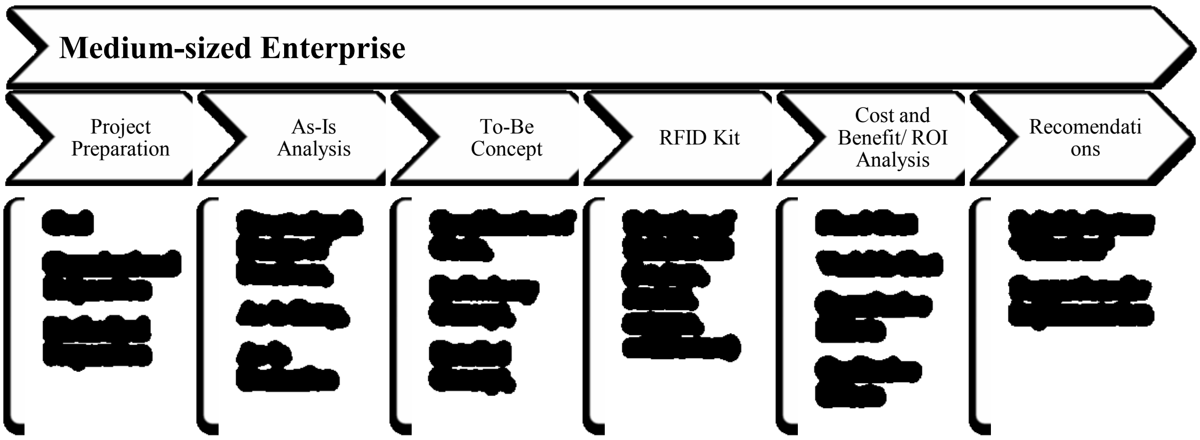
[400] See Chapter 5.

model is evaluated on the basis of specific requirements of food manufacturing industries, RFID system implementation projects, and RFID technology.[401] Various aspects of the MaRSI model are presented and discussed in academics.[402] The result of research in academics is a reference model for management of RFID system implementations with tools and techniques that explicitly considers preparation objectives of food manufacturing industries for a potential RFID system implementation.

6.2 Application in a Medium-sized Enterprise

The medium-sized enterprise is a market leader in the manufacturing of baking mixes in east-north Germany with more than 60 years of history, 90 employees, and total turnover of 17 million Euros per year.[403] The initiative for the project was taken by the author. The project aimed practice-oriented research on RFID system implementation in supply chain in the context of an MBA-thesis. Initial correspondence with logistics and technical managers of the medium-sized enterprise revealed that the enterprise intends definition of a strategy for RFID implementation with exposure of cost and benefits of the technology focusing on internal supply chain activities. In consideration of enterprise objectives, requirements and resources, an approach for execution of the project was designed. The initial approach involved a high level plan with corresponding activities that was detailed and adapted in the course of action upon lessons learned. Accordingly, the project involved project preparation, as-is analysis, to-be concept, RFID kit "selection", cost and benefit/ROI analysis, and recommendations phases. The process model for the project was designed with the help of analogy technique of reference modeling.

Figure 25: Process Model for the Project of the Medium-sized Enterprise



Source: MBA Thesis of Khan (the author) and Madhok 2008.

[401] See Sections 4.1 and 6.4 for Requirements and Requirements Fulfillment.

[402] i.e. during doctoral seminars.

[403] Based on the data from 2008.

Project Preparation

The project preparation phase involved aspects of project management aiming goal (definition), organizational preparation, and methodical preparation. Methodical preparation, for instance, involved definition of project plan. For this purpose, the guides by PMI (2008) and IEEE (2004) were important starting documents (i.e. PMBOK and SWEBOK). The design and adaptation of methods, tools and techniques for the project was considered as ongoing activity because of the unique, complex, and innovative nature of RFID implementation project. The high level process model, as shown in figure 25, was detailed in the scope of a phase with sub-tasks, tools and techniques.

For goal (definition), **requirements** elicitation techniques such as questionnaire, interviews, brainstorming and focus groups were used in order to identify stakeholder requirements and specify enterprise objectives. It was apparent after initial discussions that the decision for definition of RFID implementation strategy was made by the owner of the enterprise. A potential mandate by retailers to tag issuing pallets with RFID transponder triggered the idea for RFID implementation in intra-logistics. The primary reason for rethinking intra-logistics activities was rationalization potentials of RFID technology. Primary objectives of the enterprise were definition of an RFID system at pallet level in order to identify effects of the technology on inventory efforts, process cost, cycle time, control production planning, out-of-stock situations, and transparency.[404]

In the scope of methodical preparation, a process model was defined to structure various activities of the project and to provide systematic continuity. Methodical preparation was aimed to **adapt** methods, tools and techniques of project management (e.g. PMBOK) and system development (e.g. SWEBOK) according to the needs of the project. However, adaptation of the model (i.e. activities, tools and techniques) was an **iterative process** (ongoing activity) throughout the project. For instance, approaches for objectives specification, process analysis and design, system specification, cost and benefits analysis, and return on investment were adapted as necessary before and during realization of each phase according to enterprise requirements. The overall duration of the project was ten months, whereas four months thereof were required for on-site study involving, for example, objectives specification, analysis and (re)design of internal supply chain activities. The **progress** of the project was controlled against project milestones and goals.

Organization preparation of the project started with the idea of the project. Organization of the project was supported by the project plan in terms of project communication, team

[404] A summary of the enterprise objectives is provided as appendix 11.

management and procurements. The information regarding project approach and deliverables were made available to the team in the form of **reports and presentations**. The project stakeholders held **periodic meetings** to review project progress and changes and to adjust project plan, approaches and deliverables accordingly. The meeting, for instance, involved discussions of adjustment of the project approach (e.g. phase activities, tools, techniques) according to stakeholder requirements. The project was managed by the author and executed by the author in a team. The enterprise provided additional personnel for supply chain analysis. For cost specification of the defined RFID system, external RFID vendors were contacted. Selection of appropriate RFID system components and vendors required detailed market analysis.

As-Is Analysis

The first step towards specification of intra-logistics requirements was structured interviews[405] with process and technology mangers of the enterprise. Furthermore, analysis of production and warehouse data[406], and observation and assessment[407] of inter-logistics activities were required to find out patterns of pallet movements and prioritize relevant supply chain processes for RFID implementation. The analysis of intra-logistics activities included aspects of warehouse activities, storage capacities and appearance of warehouses (space, types of racks, number of doors etc.), in use technologies (barcode, ERP etc.), total number of raw materials and finished products, total consumption of raw materials, production of finished products per year, and total number of pallets per year and average per month. The figure 26 provides an overview of the functional areas of the enterprise along with pallet movement.

The main intra-logistics activities of the enterprise include receipt and warehousing of raw materials, production of baking mixes, and transport, warehousing, commissioning and issue of finished products. In practice, raw materials are labeled with barcodes at receipt of production warehouse and stored subsequently in production warehouse. From production warehouse, the raw materials of baking mixes are batched and transported by forklift to production area. The production area possesses different production lines. At the end of each production line, each pallet of finished products is labeled with EAN 128 barcode for internal purposes and transported to production warehouse for short storage. From production warehouse, the finished products are then delivered by truck to logistics center.

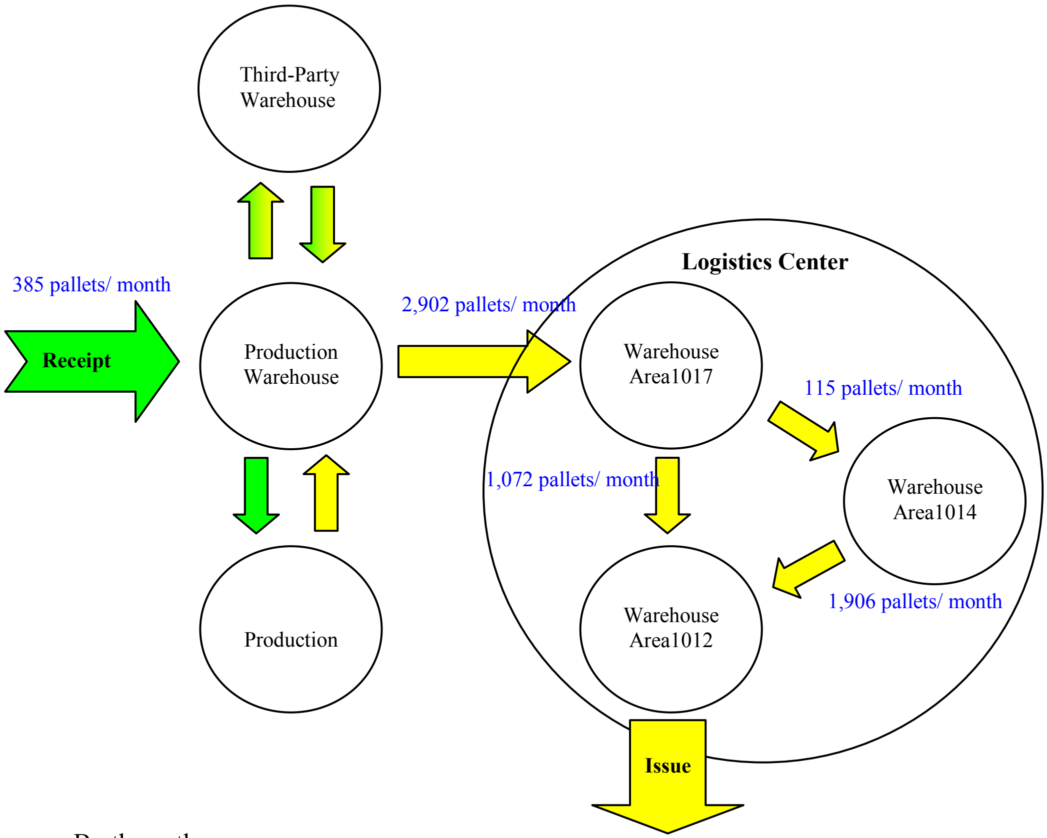
[405] i.e. process analysis tool such as checklists and requirements elicitation technique such as interviews.

[406] i.e. enterprise's annual data.

[407] A Checklist as example is provided as appendix 12.

The logistics center is the main warehousing area that is divided in three sub-units used for storage, commissioning, and issue of finished products. In order to perform activities of warehousing, consignment, order pick scheduling, and issue, each movement of pallets between sub-units is documented in enterprise resource planning system (ERP) with the help of mobile data acquisition device. At issue of logistics center, the pallets are labeled with EAN 128 barcodes for external supply chain. A third-party warehouse is used for storage of raw materials and finished products in peak production times.

Figure 26: Structural View of the Intra-Logistics of the Medium-sized Enterprise



Source: By the author

The concept of event driven process chain (EPC)[408] was applied for documentation of intra-logistics processes involving activities with related information and resources (e.g. machines, software, and hardware).

For the purpose of as-is analysis, internal supply chain activities were divided in before and after production referring to raw materials and finished products. Accordingly, the activities before production include receipt, warehousing, commissioning, inventory control, and continuous inventory of raw materials. The activities after production involve warehousing, commissioning and packing, order pick scheduling, inventory control, continuous inventory, and issue of finished products. Each activity before and after

[408] See Scheer 1999 for ARIS – business process modeling.

production was analyzed and evaluated with the help of checklists[409] in order to identify shortcomings and potentials. The attributes used for analysis, for instance, included process name, process objectives, documentation type, frequency of process execution, average processing time, embedded application systems, frequency of error, process costs, effectiveness of information, and number of personals[410]. For identification of strengths and weaknesses, the checklists involved parameters of process time and potential acceleration, automation degree, considerable rationalization, cost, number of involved personals and equipments.[411]

To-Be Concept

In order to develop to-be concept (i.e. RFID system design), enterprise requirements were reviewed in consideration of strategic objectives, supply chain evaluation and requirements, and potentials and constraints of RFID technology. The design of RFID system consisted of **preliminary and detailed** concepts. The primary focus of RFID design was redesign of internal supply chain at physical level. The aspects of middleware integration were thought thoroughly. However, aspects of RFID data integration were out of the scope of to-be concept. The to-be concept of intra-logistics activities of the enterprise was presented with three different **scenarios**. The scenarios were built in consideration of varying strategic, supply chain, and technology requirements. Benchmarking of available case studies and reports of technical feasibilities studies provided the foundation for technical feasibility of the defined RFID system.

Main physical changes in internal supply chain included replacement of EAN 128 barcodes with RFID tags on pallet level for both raw materials and finished products, introduction of tagging points, tagging of shelves and racks, tagging of warehouse area (considered in a single scenario), placement of antennas gateways (considered in a single scenario), and mounting of forklift with reader. For instance, the tagging of shelves and racks should ensure positioning of tagged pallets in order to comply with the first-in-first-out (FIFO) principle. The use of EAN 128 barcodes with GS1 parameters for external supply chain remained unchanged. The changes to internal supply chain were categorized in automated, optimized, serialized, and new processes in order to identify and calculate benefits of the potential RFID implementation.

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[409] A Checklist as example is provided as appendix 12.

[410] A Checklist as example is provided as appendix 12.

[411] A summary of results of supply chain analysis is provided as appendix 13.

RFID Kit "Selection"

The design and subsequently the selection of RFID system components were made in consideration of domain specific technical aspects such as frequency and communication standards in supply chain, and enterprise strategic and supply chain requirements. Aspects that were relevant for technical feasibility of the RFID system involved reading range, coupling mechanisms, access techniques, standards, and environmental impacts. Accordingly, the suggested frequency was ultra high frequency (UHF) with 868 MHz. The type and form of tags and readers were determined according to the internal supply chain requirements. The middleware was selected in view of integration in existing information system. The selection of RFID kit was primarily aimed to determine the cost of the defined RFID system.[412]

Cost and Benefit/ROI Analysis

RFID implementation was a business rather than technology decision for the involved enterprise. The project aimed to calculate cost and benefits as well as return on investment (ROI) of the RFID implementation. The cost of the RFID implementation was determined on the basis of defined RFID kit or system components and vendors offers.[413] The cost was differentiated in fixed and variable cost. Fixed cost, for example, involves hardware and software, whereas variable cost covers integration, personnel, installation services as well as process redesign. The foundation for calculation of benefits of RFID technology was internal supply chain evaluation. The benefits of RFID technology in supply chain were differentiated in quantitative benefits such as cost reduction, revenue increment and qualitative benefits such as customer service increment and service improvement. As the implementation of RFID was considered only for intra-logistics, the ROI calculation excluded qualitative benefits of the implementation.[414]

Recommendations

The objectives of the project were design of an RFID system for the enterprise and economic analysis of a potential RFID implementation. Therefore, the activities of tests, pilot system implementation, and RFID system deployment were out of the scope of the project. The realization of to-be concept of internal supply chain with RFID as well as calculation of cost and benefits, however, required further activities of tests, pilot implementation and roll out. Accordingly, a list of recommendations including critical

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[412] The list of selected RFID system components is provided as appendix 14.

[413] A list of cost for selected RFID system components is provided as appendix 15.

[414] The calculation of ROI for all three scenarios is provided as appendix 16.

points and activities during tests, pilot, rollout, and maintenance were provided. The list of recommendations was the basis for estimation of required time, cost, and resources. By this, a rough estimation for the future activities was made.

The enterprise intended definition of a strategy for RFID implementation with exposure of cost and benefits of the technology focusing on internal supply chain activities. These objectives were achieved with the defined model (i.e. process model, tools, and techniques).

Conclusion

The project aimed development of a model for RFID system implementation in order to fill the research gaps as disclosed during first state of the art review. From practical point of view, the objectives were solutions to the issues of the medium-sized food manufacturing enterprise. Primary objectives of the enterprise were preparation for a potential RFID implementation in case of a mandate by retail industry and exposure of the economic value of an RFID implementation in internal supply chain. Accordingly, the research focused on practical relevance of the model for enterprise problems.

In the course of the project, the model is constructed, applied and adapted in “real life context” in order to fulfill requirements and achieve objectives of the medium-sized enterprise. It used the method of reference modeling for construction using, for example, PMBOK (PMI 2008) and SWEBOK (IEEE 2004) as important starting guides. From research point of view, the deliverables of the project were a process model with tools and techniques for RFID system implementation involving project management and system development aspects. The aspects of project management were scoped in project preparation, RFID kit “selection” (i.e. procurement), ongoing adaptation before start and after completion of a phase with periodic meetings (i.e. reviews), and recommendations (i.e. suitable partner selection). The system development aspects covered as-is analysis, to-be concept, cost and benefit/ROI analysis, and recommendations (i.e. suggestions for implementation). For the practice, the project delivered results such as evaluation of internal supply chain, RFID system design, and economic analysis. The results were communicated via presentations and reports enterprise internally and as MBA-thesis.

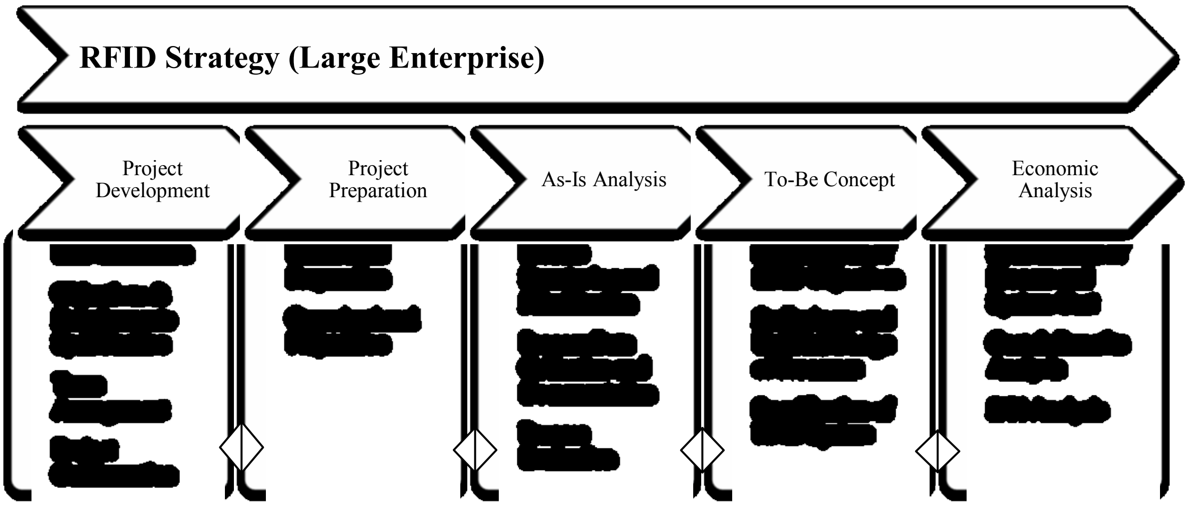
The approach defined for RFID system implementation was appropriate for achievement of the objectives of the medium-sized enterprise. The model, however, required improvements in terms of explication and adjustment of activities, tools and techniques in order to reduce complexity of RFID system implementation projects and to be applicable for other enterprises of the domain of food manufacturing industries.

6.3 Application in a Large Enterprise

The initiative for the second project was taken by Prof. Dr. Ute Höper-Schmidt (Anhalt University of Applied Sciences). The mutual interest of the board of directors of the enterprise (Dr. Dirk Gloy) prompted the first meeting. The enterprise is a leading dairy food manufacturing enterprise in Europe. It was founded in 1947. The dairy food manufacturer employed around 2500 employees and possessed an annual turnover of 1.9 billion Euros with a milk processing capacity of 4.1 billion kilogram per year in 2009. The project was aimed to be prepared for an RFID implementation in case of a mandate by customers, to expose rationalization potentials in internal supply chain of the enterprise, and to calculate competitive benefits by implementation of RFID.

In consideration of enterprise objectives and requirements, the approach (i.e. activities) developed for the first project was adapted at a high level of abstraction. Accordingly, a differentiation was made between **RFID strategy and RFID implementation** activities. The RFID strategy involved phases of project development, preparation, as-is analysis, RFID strategy (i.e. design), and cost and benefits/ ROI analysis, whereas RFID implementation covered phases of **test and pilot implementation, rollout, and maintenance**.[415] In the course of the project (i.e. before start and after completion of a phase), required tools and techniques were also improved according to the needs of the project.

Figure 27: Process Model for the Project of the Large Enterprise



Source: By the author.

[415] The final reports of the project are enterprise and project internal documents and can be provided on demand.

Project Development

The project development phase aimed project initiation and objectives and requirements specification involving activities of idea generation, objectives and requirements specification, team arrangement, and project conformation. In this regard, a three hour agenda was made for the first meeting with participants of logistics management, logistics service and systems, and head of a plant management of the enterprise. The aim of the first meeting was presentation of research idea and objectives, and introduction of the enterprise and enterprise's intentions. The meeting was followed by a decision by the enterprise for the start of the project. Subsequently, an internee was hired by the University team to support on-site analysis activities. The second meeting aimed specification of enterprise's objectives and application area (i.e. enterprise site). Soon after, the details of **contracts and funds** granting by the network of food manufacturing industries were finalized in the scope of project conformation activity. The project team of the enterprise consisted of logistics management, plant management, technology management, warehouse management, palletization management, and a trainee to support on-site analysis activities. The initial meetings revealed that the enterprise aimed to carry out the project at their largest site or plant. The plant produced 83 kilotons of cheese per year with an annual consumption of 840 million kilogram milk and 430 million Euros of turnover. The products include slicing cheese, whey powder, whey products, and butter.[416]

Project Preparation

The project preparation involved planning of methodical and organizational aspects of the project. The research project was formally started after the second meeting. The foundation for specification of project objectives and requirements was the interviews and meetings until the formal project start (i.e. generated list of requirements). During the meeting in the scope of formal project start, strategic objectives of RFID system implementation were elicited with the help of structured interviews, focus group, and questionnaire. For instance, the uniqueness of RFID applications in the context of enterprise's site was discussed in the focus group. For specification and prioritization of enterprise strategic objectives and requirements, techniques of requirement formulation and assessment were used. The specification and prioritization of requirements and objectives required

[416] Figures based on estimations from 2008. Today, the enterprise produces at 22 sites in Germany and employs 5700 employees. It consumes about 6.9 billion kg milk yearly and has an annual turnover of about 4.6 billion Euros. It is one of the leading dairy industries in Europe with exports to more than 100 countries around the world.

consideration of technical feasibility of RFID technology for the enterprise. Accordingly, the objectives and requirements were categorized in direct and indirect optimization objectives and requirements.[417] The direct optimization objectives and requirements could have substantial effects on cost reduction of internal supply chain processes. The indirect optimization objectives and requirements, however, could have positive effects on overall internal supply chain but with less financial impact. In addition to that, enterprise strategic objectives were assigned to functional units of the enterprise's site in view of their feasibility. The discussions revealed that preparation for RFID implementation in case of a potential mandate by customer was the primary reason to participate in the research project. Furthermore, prospective rationalization potentials of RFID and competitive benefits by RFID deployment motivated the enterprise for the undertaken. The dairy food manufacturing enterprise intended to see effects of RFID technology on internal supply chain cost, inventory optimization, and information flows to customer end. Accordingly, it was aimed to achieve optimized management of warehouse and empty pallets, back trace and real time localization of cheese boxes and pallets, real time acquisition of data, and consistent documentation from receipt to issue of the enterprise's site.

The approach applied for the project was based on the concepts of the first project with the medium-sized enterprise. Accordingly, the process model, tools, and techniques for the project were adapted on the basis of **lessons learned** from first project and according to the **needs** of the large enterprise. Because of the complexity, the project was planned with a **high level plan** and process model that were **subject to change** in the course of action. Because of the similar objectives of the project with the first project and in consideration of internal supply chain complexity of the enterprise's site, the adaptation involved **explication of project activities** (i.e. process model) and **improvement of project tools and techniques** (i.e. requirement analysis, supply chain analysis, process evaluation[418] and modeling, RFID system specification, and economic analysis**).** The adjustments were made in the beginning of the project and each phase.

The project required intensive communication with involved stakeholders from the beginning (i.e. project development). The methodical preparation (i.e. planning aspects) provided support for management and organization of project work. For instance, the formal project start also involved aspects of project team building, contracts, and

[417] A summary of Goals of enterprise is provided as appendix 18.

[418] Process evaluation involved quantitative and qualitative analysis. Qualitative analysis furthermore consisted of strengths and weaknesses and traffic light analysis approaches.

communication approach for result and progress of project.[419] Accordingly, the enterprise and university teams held periodic meetings and discussion rounds to review requirements, progress, and changes of the project. The communication of results and progress were made with the help of presentations and reports. The activities of meetings' agenda setting and correspondence with various project stakeholders were on-going activities of the project. The project plan included decision making points, for example, for process requirements and RFID system design specification. **Transparent** communication of the project related information was the key to resolve internal project conflicts. In the scope of organizational activities (i.e. procurements), different vendors of RFID systems were contacted for specification of cost of the defined RFID system for the enterprise's site. The overall duration of the project was fourteen months, whereas on-site activities took eight months. The undertaken was ended with the submission of final report.

As-Is Analysis

The as-is analysis involved analysis of internal supply chain of the enterprise's site. For this purpose, supply chain activities were structured and prioritized on the basis of enterprise observations and requirements as discussed in project preparation. The supply chain analysis required structured interviews, process observations, data collection, and process documentation. It involved observed and historical process data as well as process information such as protocols. The evaluation consisted of qualitative and quantitative analysis of supply chain.

The enterprise's site possesses thirteen different functional units. Each functional unit involved specific production and logistics activities.[420] These activities include bagging of cheese, packing of pallets, warehousing at low, high, and room temperature, repacking of pallets, storage of raw material, storage of finish products in high rack warehouse, and palletization. All functional units of the site are connected via a complex network and sometimes overlapping of material and information flows. For the purpose of simplicity, the internal supply chain processes of the site were structured in a top-down manner that resulted in processes at site, production and warehouse, functional units, and activity levels. By this, on the one hand, the complexity of the networked processes was reduced. On the other hand, the top-down decomposition of processes eased to consider and implement strategic aspects of the RFID implementation during redesign of internal supply

[419] A list of communication activities is provided as appendix 17.

[420] Examples of enterprise units are provided as appendix 20.

chain. The as-is-analysis focused mainly on supply chain specific activities and processes, whereas functional units of production were excluded from the study.

Figure 28: Overview of Functional Units of the Site of Large Enterprise

Source: The Enterprise.

The documentation of internal supply chain included topology of functional units, physical appearance of logistics entities[421], and physical as well as logical supply chain activities. The topology of functional units covered also the number and types of available machines, and storage capacities of functional units. The logistics entities involved transport entities such as conveyor belts, vehicles, forklifts, pallets, and boxes. The appearance of logistic entities was documented explicitly because of RFID hardware installation. The physical supply chain activities included flows of material encompassing documentation of events, number and types of materials or goods, types of information, information systems, number and types of transport entities, and number of personals. The logical activities involved automated and manual flows of information and protocols.[422]

The documentation of supply chain processes focused on material and information flows with required resources. It aimed to ease evaluation and redesign of supply chain

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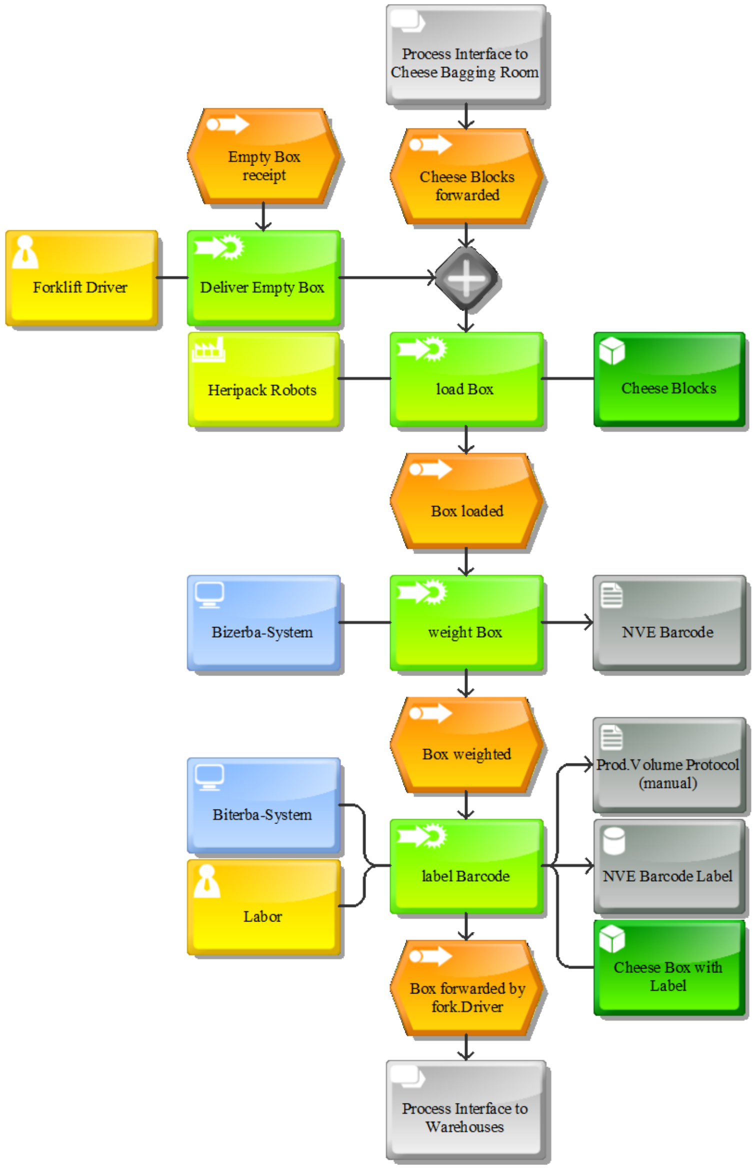
[421] Examples of type of pallets in use are provided as appendix 21.

[422] Summary of Activities at unit levels is provided as appendix 22.

processes. Accordingly, the ARIS[423] modeling and design concepts were applied. The approach used for documentation differentiated between information as environmental and flow data, whereas resources were divided in machines, hardware, software, transport entities, and personnel. An example of one of the six processes of packing at packing unit is illustrated in the following.

Figure 29: Material Flow at Packing Unit of the Large Enterprise



Source: By the author based on supply chain analysis.

The evaluation of supply chain processes included qualitative[424] and quantitative[425] analysis. The qualitative analysis was carried out with strengths and weaknesses analysis that categorized processes in optimized processes, production processes to optimize, and

[423] See Scheer 1999 for ARIS – business process modeling.

[424] An example of qualitative evaluation of a process of the enterprise is provided as appendix 23.

[425] A summary of quantitative evaluation of supply chain processes is provided as appendix 24.

supply chain processes to optimize. For quantitative analysis, the supply chain processes of each functional unit of the enterprise's site were furthermore grouped in accordance with enterprise strategic objectives and supply chain process requirements. The process cost was calculated on the basis of process duration and required resources. For instance, frequency and duration with required personals were relevant for inventory cost calculation. The annual cost of the overall internal supply chain was differentiated in fix and variable costs.

RFID Strategy (i.e. Design)

The RFID strategy phase aimed (re)design of supply chain processes of the site's functional units with RFID. For this purpose, enterprise strategic objectives were reviewed in consideration of internal supply chain and RIFD technology requirements. The design of RFID system (i.e. supply chain processes with RFID) consisted of preliminary and detailed to-be concepts. The system components of RFID were specified on the basis of detailed to-be concept of the internal supply chain.[426]

The preliminary design of RFID system covered plant level processes with abstract definition of supply chain activities at functional unit level. It was defined in consideration of reviewed enterprise's objectives and requirements. Accordingly, main strategic and technology requirements involved real time localization of logistics entities and data capturing with passive RFID system components, write-once-read-many-tags, and centralized data storage. According to the supply chain requirements, cheese carrying pallets and boxes, forklifts, floors, and racks were needed to be tagged. RFID readers were planned to be installed on forklifts, and at the doors and i-points (information points).[427] The legal aspects such as acceptance of automated inventory by the cooperative union were considered during definition of the RFID system. The application of mobile and stationary RFID readers was considered for real time localization and data capture. Installation of RFID readers varied depending on the nature of functional units and supply chain activities. It was aimed to tag pallets and boxes with removable synthetic sticking tags. The floors and racks were also planned to be tagged for localization of logistics entities.

The detailed concept of was designed in accordance with preliminary to-be supply chain. Accordingly, the preliminary design was refined at functional unit level of supply chain processes. It covered all internal supply chain processes of the enterprise's site and considered aspects such as form of tags, types of readers, and installation points of readers

[426] A summary of specified RFID system components is provided as appendix 25.

[427] Issues of mounting readers on existing STILL forklifts were addressed in the preliminary concept.

and printers. The to-be concept was presented and discussed for approval. In view of enterprise strategic and technology requirements, **four different scenarios**[428] were made for the implementation of RFID technology. The primary reasons for different scenarios were varying requirements of supply chain processes and different adoption strategies of RFID technology. The defined scenarios also involved consideration of technical feasibility concerns and RFID system cost. As the project intended RFID system design and economic analysis, two different implementation strategies were suggested i.e. gradual and complete implementation.[429] The RFID system alternatives were defined at ultra high and high frequencies in consideration of their flexibilities and limitations. The detailed to-be concept was supported by to-be typology of site's functional units and description of to-be supply chain processes with a list of RFID system components.[430]

Cost and Benefits/ ROI Analysis

The economic feasibility of the RFID implementation was analyzed in the cost and benefits/ ROI analysis phase. It involved specification of process and system cost, cost and benefits analysis, and return on investment analysis. The total cost of potential RFID system implementation consisted of external and internal as well as fix, variable and operating cost factors ranging from project start to system roll out and maintenance. According to the approach of the project, the activities of tests, pilot, rollout, maintenance belonged to RFID implementation and were out of the scope of the project.

The cost of site's internal supply chain processes was determined by qualitative and quantitative analysis and evaluation of supply chain activities during as-is analysis. It included both direct and indirect process costs. It was reviewed before specification of the cost of RFID system components. Additional market analysis and correspondence with RFID technology vendors were required in order to determine RFID system component cost (i.e. hardware and software cost). The external cost of implementation was differentiated in hardware, software, and service costs of potential project partners, whereas internal cost involved personnel cost (e.g. project team, training) and infrastructure cost (e.g. travel, accommodation). The cost of service for internal supply chain re-design and training of personnel could be internal as well as external and was considered accordingly.[431]

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[428] An overview of suggested scenarios is provided as appendix 26.

[429] An overview of incremental implementation of UHF scenarios is provided as appendix 27.

[430] The list of specified RFID system with total number of components is provided as appendix 28.

[431] An overview of considered cost factors is provided as appendix 29.

The cost and benefits analysis was based on the idea of exposing weaknesses, cost factors, and cost of internal supply chain with applied resources. The cost factors identified during the analysis of supply chain of the enterprise included manual documentation, documentation errors, B-stock, out-of-stock situations, inventory and warehouse management, and cycle time of internal processes. The benefits of RFID technology were calculated by elimination or reduction of internal supply chain cost. The return on investment (ROI) was calculated on the basis of potential cost and benefits of RFID implementation using discounted cash flow method. The calculations for cost and benefits and ROI of RFID implementation were made with the help of an excel-based calculator, which was developed in course of the research.[432]

Conclusion

From research point of view, the project was aimed to improve the model for RFID system implementation, which was developed during the first project. The improvement covered **explication of activities, tools, and techniques** of the model. The research, as in first project, primarily focused on practical relevance of the model for the food manufacturing enterprise and the domain of food manufacturing industries. The deliverables for the research were an improved model with explicite activities, tools, and techniques for RFID system implementations. For instance, it involved refinement and adjustment of project management activities covering addition of project development activities, adjustment of project preparation activities, adjustment of organizational work realization activities (e.g. procurement of RFID system and vendor selection), and refinement of reviews (e.g. requirements analysis and adjustment). The second iteration, furthermore, included separation of RFID system development and deployment regarded as RFID strategy and implementation and refinement and adjustment of as-is analysis (e.g. process data collection and documentation), to-be concept (e.g. specification of RFID system), and economic analysis (e.g. specification of process and system cost) activities.[433] The improvement of tools involved use of a business case during project development and generation of a list of requirements during project development phase and its iterative adjustment throughout the project. The improvement of techniques consisted of refinement of requirements analysis, communication (i.e. emphasis on meetings, work presentation, and networking and team organization), and reviews (i.e. requirements, implementation process, technical deliverables, communication and risks).

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[432] A summary of the cost and benefits and ROI calculations is provided as appendix 30.

[433] For comparison see figure 25 and 27 the process models.

From practical point of view, the objectives of the research were solutions to the issues of the large enterprise. The research, furthermore, involved the network of food businesses of Saxony-Anhalt. In this regard, the enterprise aimed preparation for potential implementation of RFID in case of a mandate by customers, and exposure of rationalization potentials and economic feasibility. The research delivered evaluation of enterprise internal supply chain, RFID system design, and economic analysis for the practice. The results of the research are communicated enterprise internally and within the network using presentations, documentations, and reports.

The project bases on the state of the art studies for research orientation and addresses issues of the domain of food manufacturing industries in Saxony-Anhalt. The model for RFID system implementation was adapted, applied and improved in the course of the project “real life context” in order to achieve the objectives of the enterprise. The model is innovative and addresses specific problems and set of requirements of the respective domain. It applies the method of reference modeling for construction of the model and provides guidance for the use of refernce modeling for the purpose. For practice, the research presents a model for innovative projects of RFID system implementation aiming practical solutions with effective and efficient approach.

6.4 Requirements Fulfillment and Scientific Evaluation of MaRSI

The MaRSI model is developed following the coherence concept[434] by conducting state of the art reviews as discussed in section 4.2 and [Khan 2015]. The development of the model involves three main iterations.[435] Accordingly, the MaRSI model is constructed and applied in the first iteration[436], refined and applied in the second iteration[437], and refined and generalized in the third iteration[438]. The model includes a frame of reference, a process model, and design propositions such as suggestions, plans, and tools and techniques as artifacts. The MaRSI model is evaluated on the basis of fulfillment of specific requirements of RFID system implementation as described in section 4.1 and consequently with rigorous requirements of science for compliance.

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[434] “The coherence concept of truth recommends that a new hypothesis should be in line with an established body of knowledge, for example, with research results and opinions found in acknowledged publications” (see Frank 2007, 133).

[435] See Section 6.1.

[436] See Section 6.2.

[437] See Section 6.3.

[438] See Chapter 5.

Table 12: Overview of Requirements Fulfillment of MaRSI

No.	Gross-2005	Gillert-2008	MaRSI	Assessment
B1	◔	◔	●	The MaRSI model considers strategic requirements (see 5.2.1.4) of preparation for an RFID system implementation of respective domain in full length by providing an approach to conduct respective project with varying objectives (e.g. RFID system design, economic analysis).
B2	○	○	●	The MaRSI model specifically addresses and considers requirements and constraints of the food manufacturing industries (Saxony-Anhalt) (e.g. enterprise culture, product types, influence level in SC).
B3	◔	◔	◑	The MaRSI model suggests consideration of aspects of capability of enterprise information systems, environmental effects on RFID, compatibility of RFID with other Auto-ID and RFID solutions during requirements analysis (see section 4.1). However, the focus of MaRSI in the scope of this dissertation is not on technical work realization (see section 5.2.4).
B4	◔	◔	◕	The MaRSI model strive for efficiency and effectiveness with appropraite comprehensiveness. Economic analysis of RFID system implementation was part of the projects with a midium-sized and large enterprise that is integrative part of the frame of reference and is discussed accordingly in sections 6.2 and 6.3, but the focus of MaRSI in scope of this dissertation is limited to project management aspects.
P1	●	◔	●	The MaRSI model includes a frame of reference to explicity address variuos requirements of involved stakeholders from different backgrounds (see section 5.1). Stakeholder analysis is carried out in project starting (see 5.2.1.3) and stakeholder support is reviewed throughout the project (see sections 5.2.3.4, 5.2.5.3, and 5.2.6.1).
P2	◕	◔	●	The MaRSI model provides transparancy by explication of roles and activities (see section 5.1), which ease communication between project team and stakeholders. Project communication is part of the organizational planning and work realization of MaRSI model and is supported with tools and techniques (see sections 5.2.3.2, 5.2.5.1, 5.2.6.4, and 5.4.2).
P3	◕	○	◕	The MaRSI model includes aspects of change (i.e. redesign of supply chain and change management) as change perspective, where aspects of redesign and optimization belongs to technical work realization and aspects of change management to organizational work realization (see sections 2.3.2 and 5.1).
P4	○	○	●	The MaRSI model provides planning and realization of RFID system implementations in iterative manner by using the concept of high level and detailed plans for planning, and reviews for rework after lessons learned and feedbacks (see sections 5.2.2, 5.2.3, and 5.2.6).
P5	○	○	●	The MaRSI model suggests prioritization of requirements and resources, for example, to comply with enterprise strategic requirements in terms of project objectives as well as ensure system quality in respect of RFID characteristics (see sections 5.2.2.1, 5.2.1.5, 5.2.1.4, and 5.2.6).
P6	◕	◕	●	The MaRSI model considers various backgrounds of project stakeholders as given (see section 5.1) and emphasize on open and harmonized communication, for example, for requirements specification, deliverables validation, and interpersonal relations (see sections 5.2.3, 5.2.5, and 5.2.6).
P7	◕	○	●	The MaRSI model explicitly considers various perspectives of stakeholders in RFID system implementaiton projects by providing the frame of reference (see section 5.1) in order to pay proper attention to different stakeholder requirements and the resulting project and system requirements (see 5.2.1.4).
P8	◑	●	●	The MaRSI model is a systematic and structured approach including a frame of reference for RFID system implementations (see 5.1) and a process model for management of RFID system implementations (see 5.2).
P9	◔	◔	◕	The MaRSI model provides appropriate information for the respective domain aiming efficiency and effectiveness in cosideration of required resources, skills, and efforts in a project (see chapter 5). However, adaptation efforts may vary from enterprise to enterprise depending, for example, on the approach selected for technical work realization.

P10	◔	◔	◕	The MaRSI model provides appropriate details with procedures, input & output templates, tools, and techniques (see chapter 5) for management of respective projects for the purpose of understandability and applicability. The aspects of technical work realization are, however, out of the scope of this dissertation and are only discussed in application context in section 6.2 and 6.3.
R1	◑	◔	◕	A detailed supply chain analysis is considered thoroughly as the MaRSI model is built in projects with detailed supply chain analysis (see sections 2.3.2, 6.2 and 6.3). According to the MaRSI model, detailed supply chain analysis aspects belong to process perspective in the scope of technical work realization (see section 5.1). The model, in the scope of this dissertation, considered aspects of supply chain analysis for requirements analysis and specification (see sections 5.2.1.4 and 5.2.6.1).
R2	●	◔	●	The MaRSI model is constructed in consideration of specific characteristics of RFID technology as it influences stakeholder needs and expectations that consequently affect RFID system implementation process (see chapter 2 and 5).
R3	◔	◔	◑	The specific characteristics of RFID technology require tests for validation at physical as well as application level. According to MaRSI model, tests are required during technical work realization of the project that belong to system improvement techniques (see 5.4.6) and are suggested accordingly for technical feasibility and system functionality.

Legend:

○	0%	Not at all considered
◔	25%	Partially considered
◑	50%	Appreciably considered
◕	75%	Thoroughly considered
●	100%	Fully considered

Source: By the author.

The MaRSI model fulfills specific requirements for the purpose as shown in table 12. Accordingly, it answer the research question (a) and subsequently (b, c, and d) from section 1.2. It fulfills rigorous requirements as discussed in sections 6.1, 6.2, and 6.3 by providing an appropriate approach for RFID system implementation that increase understanding of technology and ease decision making of an RFID implementation with effectiveness and efficiency for the respective domain.

In general, the evaluation of reference models requires a systematic approach [Fettke/Loos 2003]. It is constrained by general problems of conceptual model evaluation i.e. criteria such as simplicity, understandability, flexibility, completeness, integration and applicability, and principles such as correctness, relevance, economics, clarity, comparability and systematic construction. It, furthermore, requires possible variety of requirements and specific constrains for (re-) usability and a variety of objectives of reference model application. The consideration of epistemological aspects is similarly crucial [Frank 2007]. In order to comply with scientific rigor, a reference model construction and application must be done in consideration of certain aspects and perspectives [Frank 2007, 119–123].

In particular, an artifact of design and design-oriented science must deliver business value [Hevner et al. 2004] and stakeholder benefits [Österle et al. 2010, 3]. The MaRSI model, from economic perspective [Frank 2007; Becker et al. 1999], is applied for two enterprises of food manufacturing industries that generated value and benefit for the respective enterprises[439]. In the same way, the model aims effectiveness and efficiency in the future use by providing free of cost acquisition, less training effort for familiarity using natural language for suitability[440], and fulfillment of strategic and organizational requirements[441] of respective domain of food manufacturing industries. The MaRSI model, furthermore, provides tools and techniques for the use and adaptation.[442] However, adaptation of the model, for example, by instantiation or specialization depends on the skills of users of individual enterprises in order to determine adaptation efforts and cost. For efficiency and effectiveness, the MaRSI model aims improvement of productivity and skills of project managers of respective domain and provides support in decision making for management by referring relevant requirements. In this regard, the willingness to use the model for decision making is partially given by involvement of the network of food businesses of Saxony-Anhalt.[443] The MaRSI model provides flexibility in terms of independence from specific vendors, **openness** by complying with available standards (e.g. PMBOK), and relationship to RFID system development artifacts during technical work realization[444]. It also aims to foster communication, for example, by explication of activities and usage of unified terminology in the scope of the project with the help of a frame of reference[445] and support in development of relevant skills of employees. The model specifically addresses RFID technology and is independent of specific technology alternatives.

An artifact must be purposeful allowing thorough evaluation [Hevner et al. 2004] and justification [Österle et al. 2010, 3]. The MaRSI model, from deployment perspective [Frank 2007; Fettke/Loos 2003b], considered aspects of understandability, appropriateness, and attitude during construction and application of the model. For understandability, it provided comprehensive documentation with scenarios and examples by using natural language as well as graphical representations. The appropriateness was addressed by proper requirements analysis. The collaborative approach with the food manufacturing

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[439] See Sections 6.2 and 6.3.

[440] See Chapter 5.

[441] See Section 4.1.

[442] See 5.3 MaRSI Inputs and Outputs and 5.4 MaRSI Tools and Techniques.

[443] See Chapter 1 and Section 6.1.

[444] See Section 5.2.4.

[445] See 5.1 MaRSI Frame of Reference.

industries helped to avoid resistance.[446] The MaRSI model strives for understandability for future use and is appropriate for the purpose of preparation or realization of RFID system implementation (i.e. fulfillment of requirements of respective domain) by addressing specific requirements of the respective domain.[447] The MaRSI model includes a frame of reference to provide views for different groups of stakeholders, a process model with descriptions using natural language, and design propositions as suggestions, plans, and tools and techniques.[448] The model is the result of practice-oriented research in cooperation with the network of food business of Saxony-Anhalt and anticipates further application in the respective domain with less resistance.

An artifact must be applicable to specific problem domain by allowing justification in comprehensible manner [Österle et al. 2010, 3; Hevner et al. 2004]. A reference model requires possible variety of requirements and specific constrains for (re-) usability and a variety of objectives of reference model application [Frank 2007; Fettke/Loos 2003b]. The MaRSI model, from engineering perspective [Frank 2007], is constructed for RFID system implementation projects in the domain of food manufacturing industries addressing specific issues[449] and requirements[450]. The model is based on thorough explanations of available approaches[451] with justification of design decisions. In addition to this, an assignment of model activities to specific requirements of RFID system implementation for respective domain is provided in tabular form in appendix 10.[452] The model uses natural langue that is appropriate for the purpose (i.e. project management and food manufacturing industries). It consists of a frame of reference[453] providing different views and their integration. It includes tools as structured checklists and techniques as descriptions and illustrations for model use and model adaptation.[454] In spite of the use of

[446] See Section 6.2 and 6.3.

[447] See Section 4.1.

[448] See Chapter 5.

[449] See Chapter 1 and Section 2.3.2.

[450] See Chapter 4 .

[451] See Section 2.2 RFID System Implementation Process, 3.1.2 Project Management Standards and Methodologies, and 4.2 State of the Art of Approaches.

[452] For Plotting of MaRSI Activities to Requirements see Appendix 10.

[453] See 5.1 MaRSI Frame of Reference.

[454] See 5.3 MaRSI Inputs and Outputs and 5.4 MaRSI Tools and Techniques.

natural language the model is consistent.[455] It applies concepts of generalization/specialization[456] for MaRSI activities.

In order to comply with rigorous requirements, an artifact must be original in terms of contribution to information systems [Österle et al. 2010, 3]. The novelty of an artifact must be provided by solving unsolved or known problems applying rigorous method for construction and evaluation [Hevner et al. 2004]. Accordingly, reference models requires considerations of epistemological aspects such as precision of description allowing testing against reality; genetic principles of abstraction, originality and judgment; critical distance for evaluation; and scientific progress with elaborated documentation [Frank 2007].

From epistemological perspective, the MaRSI model is precise in terms of concepts and assumptions. It is developed to fill the research gap[457] in the context of RFID system implementation by addressing specific problems[458] of the food manufacturing industries in Saxony-Anhalt (i.e. applied in real life context)[459]. The model is designed as an artifact of design oriented information systems research [Österle et al. 2010] that intends further application. It is developed iteratively as a search process.[460] The MaRSI model is innovative as management of RFID system implementations is not addressed properly at present.[461] It applies reference modeling approach for project management as a novel method for the purpose.[462] Accordingly, the MaRSI model and use of reference modeling approach for project management are the main contributions of this research to information systems or Wirtschaftsinformatiks. The results of the research are communicated in practitioner and researcher communities (i.e. the food manufacturing industries, the network of food businesses, the Universities and the Graduate Scholarship Program of Saxony-Anhalt).

[455] See Chapter 5 MaRSI Model.

[456] See Section 5.1 MaRSI Frame of Reference, 5.2.4 Project Technical Work Realization and 5.2.5 Project Organizational Work Realization.

[457] See Section 4.2 State of the Art of Approaches.

[458] See 1.1 Problem Description and 2.3.2 Implementation Issues.

[459] Aiming to make explicit design decisions and provide reasons for the choice of construction.

[460] See Section 6.1Construction Process of MaRSI.

[461] See Section 4.2 State of the Art of Approaches.

[462] See Chapter 3 Project Management and Reference Modeling.

7 Conclusion and Outlook

The MaRSI model is the result of a practice-oriented research. The model considers specific issues and requirements of the domain of food manufacturing industries and provides appropriate knowledge and approach for management of RFID system implementations. In the following, research contributions of the model are summarized and areas of future research are discussed.

7.1 Research Contributions

The primary contributions of this research to information systems or Wirtschaftsinformatik are the construction of the MaRSI model and the use of reference modeling for the purpose. The MaRSI model provides a novel approach and is appropriate for specific problems and requirements of food manufacturing industries. In order to increase applicability and profitability, the MaRSI model suggests explication of concerns from management and technical point of views. The model describes five perspectives on the basis of involved stakeholder and their requirements that are plotted against RFID system implementation process. The MaRSI model, in the context of this dissertation, focuses on management concerns (i.e. preparation) and perspective (i.e. acquirer organization) of food manufacturing industries, whereas technical concerns (i.e. system development and deployment) are integral part of the model. Accordingly, MaRSI is a reference model for planning, organization and realization of RFID system implementations in food manufacturing industries. It consists of a frame of reference for fundamental understanding and guidance and a process model for project work realization that are supported by project or phase input and output templates and tools and techniques. The project work is realized in iterative and incremental manner and an emphasis is made on reviews, frequent feedbacks, meetings and transparency.

In addition to construction of MaRSI model, the use of reference modeling for project management is innovative. The constructivist approach of reference modeling with prescriptive view was followed for the construction of MaRSI model. Accordingly, the emphasis is made on reuse-orientation, where universality and recommendation are seen subjectively. Research initiatives are innovative undertakings and require creative freedom. In view of that, it was observed that only analogy principle (i.e. adaptation by transfer and creativity) of reference modeling was suitable for the purpose. However, specialization principle was also used for adaptation of certain aspects of available concepts or models.

Furthermore, the context of RFID technology or RFID system implementations is innovative and less studied. It requires studies for practical solutions providing efficiency and effectiveness. Accordingly, a realistic solution with an efficient and effective approach in the context of RFID technology is the contribution of this research to information systems or Wirtschaftsinformatik.

7.2 Future Research

The MaRSI model, in the scope of this dissertation, focuses on project management aspects of RFID system implementations, whereas system development aspects, in the scope of preparation activities, cover RFID system design and economic analysis.[463] Accordingly, the model is of higher practical relevance for the respective domain. In spite of that, separated activities of RFID system development and deployment[464] are constrained with development and deployment of RFID system in different points in time and possibly by different teams. In this regard, the efforts of coordination for effectiveness (i.e. enterprise's satisfaction) and efficiency (i.e. process's rationality) require further studies.

Similarly, the use of MaRSI for RFID system deployment activities (i.e. technology perspective), its use with other RFID system development and deployment approach for project technical work realization (i.e. process, change, and technology perspectives) and its application for projects in other domains can provide extension opportunity for the model.

The MaRSI model focuses on intra-logistics of food manufacturing industries. The study of applicability of the model in collaborative RFID implementation projects (i.e. cross organizational) of the respective domain is another area for the future research.

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[463] See 5.2.4 Project Technical Work Realization, 6.2 Application in a Medium-sized Enterprise, and 6.3 Application in a Large Enterprise.

[464] See 5.2.4 Project Technical Work Realization.

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Appendix

Appendix 1 MaRSI Business Case

Prepared by:	Date:
Project Title:	
Project Start Date:	
Problem Description: e.g. strategic aspects (i.e. strengths and opportunities analysis with present state of the supply chain or implemented identification technology and alternatives e.g. make or buy decision) or change in business environment (e.g. customer demand)	
Reasons for initiation: i.e. background (e.g. enterprise needs i.e. optimization of internal supply chain, demand by customers, or technological advancements)	
Business Objectives: Involving strategic objectives e.g. increase traceability, visibility, and profitability	
Preliminary Business and Stakeholder Requirements: high level statement of goals and objectives of the enterprise e.g. traceability of pallets, or designing an RFID system in order to react on time in case of a demand by customers aiming preparation	
Project Objectives: e.g. economic analysis of an RFID system implementation or deployment of RFID in specific business units	
Project Constraints: e.g. employee support, ROI, involvement of customer (i.e. retail), and privacy	
Budget Estimates e.g. cost and benefits analysis i.e. costs of entire project including personals with working hours and costs, procurements of studies and RFID system components, and potential benefits	
Schedule Estimates e.g. time required for completion of the project	
Related Documents: MaRSI Requirements List, MaRSI Charter for Stakeholder List	

Appendix 2 MaRSI Requirements List

Version: 0.0 Date:

Project Title:

Project Start Date: **Project End Date:**

Project Overview:
Stating the reasons (i.e. purpose, objectives, scope, and constraints) for initiating the project (e.g. optimization of internal supply chain , demand by customers, design of system only)

Requirements (ordered and prioritized)

Business Requirements:
high level statement of goals and objectives of the enterprise
(initially adopted from business case)

Stakeholder Requirements:
(initially adopted from business case and builds on stakeholder analysis)

Communication Requirements:
builds on stakeholder analysis
i.e. information to be communicated according to stakeholders strategy, required frequency, required communication methods (interactive, push, or pull), technologies, and resources

Implementation Process Requirements:
(initially adopted from preliminary approach defined in MaRSI Charter on the basis of MaRSI Process Model)

RFID System Requirements: (initially adopted from feasibility evaluation in project starting phase)

Supply Chain Process	**Requirements**	**Business Value** (importance and cost)	**Technological Risks**	**Potential Optimization** (direct or indirect)

Legal requirements:
e.g. enterprise quality standards also in respect of budget, supply chain standards, domain standards

Procurements Requirements:
e.g. acquisition of RFID system components, consultancy services, studies

Reviews and Feedbacks

Reviews:
Reassess or check changes in requirements and market-place in order to adapted process activities and system functionality

Test Results:
i.e. component, integration, system, and user acceptance tests

Feedbacks:
for continuous improvement of implementation process and system functionalities

Related Documents:
e.g. MaRSI Lessons Learned Document, MaRSI Business Case, MaRSI Charter

Appendix 3 MaRSI Charter

Prepared by: Date:

Project Title:

Project Start Date: **Project Close Date:**

Project Summary:
i.e. purpose, objectives, boundaries (e.g. RFID system design or deployment, application area or business units)

Project Sponsor:
Name and authority of sponsor

Project Manager:
Name and contact details

Business Requirements:
i.e. business strategic objectives adopted from MaRSI Business Case and Requirements List

Project Assumptions and Constraints:
e.g. employee support (e.g. lack of interest of employee, and disagreement of SC professionals with process improvement), return on investment, technical feasibility

Project Success Criteria:
economic or technical criteria the RFID system or RFID system implementation project must meet

Preliminary Approach:
initial steps required to plan and structure the project (e.g. scope summary, schedule, procurements, progress objectives) adapted on the basis of MaRSI Process Model

Budget Information:
Allocation of funds, major cost factors

Stakeholder List:

Name	**Role in Project**	**Responsibilities** (organizational internal or external position and area of focus)	**Level of Interest* and Influence****	**Communication Requirements**	**Management Strategy** (confidential)	**Contact Information**
	Project Sponsor					
	Project Manager					
		Supply Chain Manager (internal), Warehousing				
		Change Manager (e.g. internal)				
		Technology Manager (e.g. external)				
	…					

* unaware, resistant, neutral, supportive, and leading
** scope and impact of change, interrelationships and potential overlaps

Related Documents:
MaRSI Business Case, MaRSI Requirements List

Appendix 4 MaRSI Plan

Version: 0.0	Date:
Project Title:	
Project Start Date:	**Project End Date:**
Project Overview: Stating the reasons (i.e. purpose, strategic objectives, scope, and constraints) for initiating the project (e.g. optimization of internal supply chain , demand by customers, design of system only)	
Methodical Planning Aspects (high level or abstract)	
RFID Project Scope Statement: i.e. summary of project, summary of project deliverables, success criteria, exclusions, constraints, and assumptions of project	
MaRSI Process Model and WBS: i.e. decomposed work of entire project (or iteration) For Example: **1. Project Starting** 1.1. Idea Generation 1.1.1. Initial Communication (Correspondence, Meetings, Objectives, Requirements, Constrains) 1.1.2. Business Case Development 1.2. Project Manager Assignment 1.3. Stakeholder Analysis 1.4. Requirements Analysis 1.5. Feasibility Evaluation **2. Project Methodical Planning** … **Project Technical Work Realization** …	
Schedule Information: i.e. a sequenced activity list to estimate project resources such as people and time	
Budget Information: i.e. approximation of monetary resources (e.g. costs of entire project including personals with working hours and their costs, procurements of studies, RFID system components)	
Organizational Planning Aspects (high level or abstract)	
Project Organization: e.g. internal structure and external interfaces; organization chart with personal roles and responsibilities; staffing plan with acquisition and release; team performance, behavior, conflicts, and training	
Communication Details: build on stakeholder and communication requirements from MaRSI Requirements List and involve e.g. information to be communicated, frequency, communication methods (e.g. meetings or emails and reports), reviews of stakeholder engagement strategy (i.e. classifies stakeholders in unaware, resistant, neutral, supportive, and leading)	
Procurement Information: build on procurement requirements from MaRSI Requirements List and cover e.g. market research details, RFID vendor proposals and selection, and organizational procurement standards, make-or-buy analysis for project results or services	
Related Documents: MaRSI Requirements List and MaRSI Charter	

Appendix 5 MaRSI Status Report

Date:
Project Title:
Reporting Phase or Iteration:
Project Overview: Stating the reasons (i.e. purpose, objectives, scope, and constraints) for initiating the project (e.g. optimization of internal supply chain , demand by customers, design of system only)
Project Work Completed in Present Phase or Iteration: Schedules Costs Available resources
Project Work to Complete in Future Phases or Iterations: Schedules Costs Available resources
Team Performance: (i.e. Good and Bad Practices with Reasons)
Process Performance: (i.e. Good and Bad Practices with Reasons)
System Performance: (i.e. Good and Bad Performances with Reasons)
Issues:
Suggestions:

Appendix 6 MaRSI Lessons Learned Document

Date:
Project Title:
Reporting Phase or Iteration:
Project Manager:
Project Overview: Stating the reasons (i.e. purpose, objectives, scope, and constraints) for initiating the project (e.g. optimization of internal supply chain , demand by customers, design of system only)
Phase or Iteration Objectives Achievement Summary: (whether or not) Scope Schedule Cost
Phase or Iteration Success Criteria Achievement: (whether or not) based on MaRSI Requirements List
Lessons Learned in Present Phase or Iteration: i.e. experiences covering implementation process, system functionality, team skills and stakeholder interactions
Good Practices:
Bad Practices:
Recommendations for Future Phases or Iterations:

Appendix 7 MaRSI Final Report

Date:
Project Title:
Project Sponsor:
Project Manager:
Contents: 1. List of Project Objectives 2. Summary of Project Results 3. Schedule and Budget Information (Planned and Actual) 4. Project Assessment 5. References to Project Management and System Development Related Documents

Appendix 8 Preliminary Requirements Elicitation Questionnaire

Project Title:
Project Start Date:
Strategic Reasons for Project Initiation: Technical Know-How Inspiration from Supplier Owner's Idea Push from the Branch Rationalization Potentials Customer's Demand Competitive Advantage Company's Strategy Others
Means of Documentation and Currant Technologies: Manual or Digital Documentation Barcodes (e.g. EAN 128) RFID Others
Backend Software: Warehouse Management System (WMS) Transport Management System (TMS) Logistic Management System (LMS) Supply Chain Inventory Management System (SCIMS) Others
Supply Chain Processes for Potential Implementation of RFID: Stock Management Arrival of Goods Issue of Goods Picking Of Goods Production Planning & Control Control Of State (e.g. Temperature or Humidity) Management of Cases or Boxes Route Planning Back Trace of Products or Pallets Access Point Real Time Processing of Goods Theft/ Security/ Loss Piracy Avoidance Spare Part Management EDI Automation Production Data Acquisition Others
Technical Reasons for Project Initiation: Technological Improvement

Make-up of RFID Know-How Disclosure of Concepts for Integration in Logistics or Business Processes Disclosure or Identification of Data Management Concepts Assurance of RFID Implementation throughout the Supply Chain Standardization of Technology for overall Internal Business Processes Exposure of Benefits over Barcode Technology Hardware and Tag Prices Clarification of Cost & Benefits and ROI Security Issues Low Communication Cost Others
Expectations from an RFID Implementation: Reading without Visual Contact High Reading Range High Data Capacity on Tag Low Error Bulk Scanning Capability Reusability of Tags Dynamic Information Flow Robustness (e.g. Against Staining) Capturing Goods in Transit Others
Prioritization of Goals for RFID Implementation: Reduction in Inventory Efforts Reduction in Stock Reduction in Process Cost Reduction in Lost Reduction in Out-Of-Stock Situation Reduction in Lead Time Increased Transparency of Processes Better Security against Piracy Theft Avoidance Improved Flexibility Improved Customer Relation Improved Data Quality Better Image Others
Preferred User Model for Procurement of RFID System: Buying RFID System Leasing Without Service Mix of Leasing & Buying Fully Service Leasing Did not decide yet Others
Details of the Company: Business Area (e.g. products, services, customer goods, semi-furnished products, end products) Branch Business Strategy No. of Employees Turnover No. of Customers
etc.

Appendix 9 Overview of Research Projects and Academic Research

Criteria/Characteristics	Medium-sized Enterprise Project	Large Enterprise Project	Research in Academics
Research Objectives	Development of a model for RFID system implementations Solutions to the issues of the medium-sized food manufacturing enterprises	Improvement of the model for RFID system implementations Solutions to the issues of the large enterprises and the domain of food manufacturing industries	Explication and refinement of the model according to perspectives (i.e. activities, tools, and techniques) for the purpose of simplicity, understanding, and applicability the mid-range theory according to specific requirements of food manufacturing industries and scientific rigor for the purpose of generalization
Research Rigor	The research applied reference modeling method that is design science/design oriented information systems research approach.	The research applied reference modeling method that is design science/design oriented information systems research approach.	The research applied reference modeling method that is design science/design oriented information systems research approach.
Research Focus	Intra-Logistics of a medium-sized Enterprise with 90 employees, and yearly turnover of 17 million Euros in 2008. The focus was mainly on practical relevance of the model for the enterprise.	Intra-Logistics of a large Enterprise with around 2500 employees, annual turnover of 1.9 billion Euros with a milk processing capacity of 4.1 billion kilogram per year (2009) Domain of food manufacturing industries supply chain (Saxony-Anhalt) The focus was mainly on practical relevance of the model for the domain.	Internal supply chain of the domain of food manufacturing industries (specifically Saxony-Anhalt) The focus was mainly on theoretical foundation (i.e. scientific rigor) of the model for the respective domain.
Enterprise Objectives	Preparation in case of a mandate by retail industry Exposure of the economic value of RFID for the company	preparation in case of a mandate by customers prospective rationalization potentials exposure of the economic value of RFID	It addresses food manufacturing industries that are intending an implementation or preparation for an implementation of RFID system in the intra-logistics of the enterprise.
Research Deliverables	For research, the project delivered a model with tools and	For research, the project delivered an improved model with	The artifacts include a frame of reference, a process model, and design propositions such

	techniques for RFID system implementations involving project management and system development aspects. For practice, the research delivered evaluation of enterprise internal supply chain processes, RFID system design, and economic analysis.	tools and techniques for RFID system implementations involving project management and system development aspects. For practice, the research delivered evaluation of enterprise internal supply chain processes, RFID system design, and economic analysis.	as suggestions, plans, and tools and techniques for project management.
Research Duration	Overall duration: 10 months, On-site duration: 4 months	Overall duration: 14 months, On-site duration: 8 months	Overall duration: more than 4 years
Research Stakeholders	Enterprise's Owner, logistics manger, technical manager, the researcher, professor of university, DAAD-scholarship body (STIBET)	A member of the board of directors, managers of logistics, plant, technology, warehouse, and palletizing, a trainee, the researcher, professor of university, and the network of food businesses Saxony Anhalt	University of Leipzig, Anhlat University of Applied Sciences, and the scholarship body (Grad FG and GradFVO) of Saxony-Anhalt
Research Communication	The results of the research were communicated via presentations and reports enterprise internally and as MBA-thesis.	The results of the research were communicated enterprise internally and within the network of food businesses of Saxony-Anhalt using presentations, documentations, and reports.	Presentations, a paper and the dissertation addressing scientific, and practitioners community
Model as Artifact	The construction of the model followed reference modeling method and provided a process model, tools and techniques for the purpose.	The construction of the model followed reference modeling method and provided improved process model, tools and techniques for the purpose.	The reference model is designed as an artifact that addresses problems of the respective domain.
Problem Relevance of the Model	The research addresses problems of the medium-sized food manufacturing enterprise. It based on the state of the art studies in	The research addresses problems of the domain of the food manufacturing industries of Saxony-Anhalt. It based on the state of	It based on the state of the art studies and the practice-oriented research in order to fill research gaps (see Khan 2015 and Chapters 2, 3, 4).

	order to fill research gaps (see Khan 2015 and Chapters 2, 3, 4).	the art studies in order to fill research gaps (see Khan 2015 and Chapters 2, 3, 4).	
Evaluation of the Model	The model is developed, applied and adapted in the course of the project "real life context" in order to achieve the objectives of the medium-sized enterprise.	The model is adapted, applied and improved in the course of the project "real life context" in order to achieve the objectives of the large enterprise.	Compliance of the reference model (see Chapter 5) with scientific rigor (see Sections 4.1 and 6.3) involving specific requirements of RFID system implementations of the focused industries.
Research Contributions of the Model	The model is innovative as it addresses specific problems and unique set of requirements of respective enterprise. The method of reference modeling is not used before for the purpose. Accordingly, the research provides guidance for execution of research with similar objectives. The research provides an approach for an innovative undertaken of RFID implementation aiming practical solution.	The model is innovative as it addresses specific problems and unique set of requirements of respective domain. The method of reference modeling is not used before for the purpose. Accordingly, the research provides guidance for execution of research with similar objectives. The research provides an approach for an innovative undertaken of RFID implementations aiming practical solution with effectiveness and efficiency.	The model (i.e. MaRSI), applied method (i.e. reference modeling for project management), and the context (i.e. RFID implementation) are innovative and are the contribution of this research to information systems or Wirtschaftsinformatik.
Construction Process of the Model	The construction of the model is carried out iteratively (i.e. use of high level plan and adaptation of the approach, tools and techniques before and after phase completion).	The improvement and adaptation of the model of the first project according to the needs of the large enterprise in iterative manner.	The MaRSI model is developed iteratively as a search process (see Section 6.1).

Appendix 10: Plotting of MaRSI Activities to Requirements

Features/ Activities	**Business Requirements**				**Project Management Requirements**										**RFID Technology Requirements**		
	Strategy	Business Domain	Technical Feasibility	Economic Feasibility	Stakeholder	Communication	Change	Iteration	Increment	Collaboration	Interdisciplinarity	Sophistication	Realism	Comprehensiveness	Supply Chain Process	RFID Characteristic	Test
	B1	B2	B3	B4	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	R1	R2	R3
MaRSI Frame of Reference	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
RFID Project Starting	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Idea Generation	+	+	+	+	+	+	+	-	-	+	+	+	+	+	+	+	-
Project Manager Assignment	+	+	-	-	+	+	-	-	-	-	~	-	-	-	-	-	-
Stakeholder Analysis	+	-	-	-	+	+	-	-	-	-	-	+	-	-	-	-	-
Requirements Analysis	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Feasibility Evaluation	+	+	+	+	+	~	+	+	+	+	+	+	+	-	+	+	+
RFID Project Methodical Planning	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Scope Specification	+	-	+	+	-	-	+	+	+	+	-	-	+	-	+	+	-
Process Model Adaptation	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Schedule Definition	-	-	-	+	-	-	-	+	-	-	-	-	+	-	-	-	-
Budget Estimation	+	-	-	+	-	-	-	-	-	+	-	-	+	-	-	-	-
RFID project Organizational Planning	+	-	+	+	+	+	-	-	-	+	-	+	+	-	-	+	-
Personal Responsibilities Documentation	-	-	-	-	+	+	-	-	-	+	-	+	+	-	-	-	-
Communication Channels Definition	-	-	-	+	+	+	-	-	-	+	-	-	+	-	-	-	-
Procurement Specification	-	-	+	+	-	+	-	-	-	+	-	-	+	-	-	+	-
Stakeholder Engagement Strategy Definition	+	-	-	+	+	+	-	-	-	+	-	-	-	-	-	-	-
RFID Project Technical Work Realization	+	+	+	+	~	~	~	~	~	~	~	~	~	~	~	~	~
RFID Project Organizational Work Realization	+	-	+	+	+	+	+	-	-	+	-	-	+	-	-	+	-
Communication Realization	-	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-
Agreements Establishment	-	-	+	-	+	+	-	-	-	-	-	-	+	-	-	+	-
Stakeholder Support Assurance	+	-	-	-	+	+	+	-	-	+	-	-	-	-	-	-	-
Project Team Management	+	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-
RFID Project Review	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+
Review of Requirements	+	+	+	-	+	-	+	-	+	-	-	+	-	-	+	+	-
Review of Project Process	+	+	+	+	+	+	+	+	+	+	-	+	+	-	+	-	+
Review of Project Deliverables	-	+	+	+	-	-	-	-	-	-	-	-	+	-	+	+	-
Review of Communications	+	+	-	+	+	-	-	-	-	-	-	-	+	-	-	-	-
Review of Risks	-	-	+	-	+	+	-	+	+	+	-	-	-	-	-	+	-
RFID Project Closure	+	-	+	+	+	+	-	+	+	+	-	-	+	-	-	-	-
Scope Verification	+	-	+	-	+	+	-	+	+	+	-	-	+	-	-	-	-

Project Finalization	+	-	-	+	+	+	-	-	-	+	-	-	-	-	-	-	-
MaRSI Inputs and Outputs	+	+	+	+	+	+	+	+	+	+	+	+	+	+	~	+	~
MaRSI Tools and Techniques	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Medium-sized Enterprise

Appendix 11: Summary of Objectives of Medium-sized Enterprise

Queries	Responses
Reason for considering RFID	Owner's Idea Rationalization Potentials
Technologies use for identification of objects	**Manual Documentation:** Order processing at supplier and customer end approx. 20% **Digital Documentation:** Order processing with EDI at supplier and customer end approx. 80% **Barcode (1D):** EAN 128 production, warehouses & Logistics processes
Backend Software	CSB-System (ERP)
Possible implementation areas of RFID	Inventory control Continuous inventory Positioning & back trace of pallets Increase transparency of processes Production planning & control Minimizing scan time of dispatch (arrival & issue)
Parameters, when to consider RFID	Clarification of Cost & Benefits and ROI Cheap hardware Cheap tags Security Issues Make-up of RFID know-how in the firm Disclosure of concepts for integration in business processes (SC)
Changes expected from RFID implementation	Reusability of Tags Improvement of Logistics Processes (High Reading Range)
Objectives for implementing RFID	Reduction in Inventory Efforts Reduction in Out-Of-Stock Situation Increase transparency of Processes (Intern) Reduction in Process Cost Reduction in Lead Time
Model preferred	Mix of Leasing & Buying

Appendix 12: Checklists for Supply Chain Analysis an Example

Process name	Receiving of Raw Materials & Label Printing
Process objectives	Documentation of pallets (raw materials) in ERP system with EAN 128 barcode at arrival
Internal / internal & external process	Internal and external
A. Process:	
Documentation type	Manual entry in ERP system at arrival of pallets, generation of EAN 128 for each pallet
Frequency of process execution	once per pallet
Average processing time	3 to 5 min.
Embedded application systems (databases and graphical user interfaces)	CSB (ERP system)
Frequency of error	
Process costs	2 labels (0,01 € per label)
Possible alternatives	
Specific requirements of activities	
Quantity of equipment	Computer, scanner, label printer
Space requirements	
B. Moves:	
Frequency	Once per pallet
Speed	
Rate	

Volume	
Distance	
Sources	
Destinations	
Cross-traffic	
Required flow between work areas	
Location of receiving and shipping	
General linear flow	
C. Information:	
Type	EAN 128 barcode/ CSB
Way of Communication	
Effectiveness	
D. Personnel:	
Number	1
Movement	
Desired location of personnel services areas (entrances, locker room)	
Comments:	

Appendix 13: Results of Medium-sized Enterprise Supply Chain Analysis

	Activity/ Process Name	Process Objective	Average Process Time	Documentation Type	No. of Personal Involved
Production Warehouse	Receiving of raw materials & label printing	documentation of raw materials in ERP with EAN 128	3 to 5 min.	manual, generation of EAN 128	1
	Warehousing	storage of raw materials	1 min.	EAN 128	1
	Commissioning	-	-	-	-
	Inventory	Inventory control	5 hours monthly, 10 hours yearly	electronic with EAN 128	2 monthly, 4 yearly
	Continuous inventory	no	no	no	no
Production	EAN coding at production lines	documentation of finished products in ERP with EAN 128	1 min.	manual, generation of EAN 128	1
Transport	Transport of finished products	Shipment of finished products from production warehouse to logistics center	5 to 10 min.	EAN 128	1
Logistics Center	Warehousing	Storage of finished product	5 sec. per pallet, 100 to 150 pallets a day	ERP (daily protocol)	1
	Commissioning and packing	picking	0.5 to 8h per order, 30 to 200 pallets a day	CSB, EAN 128	1
	Assortment of pallets in warehouse area 1014	Mix-card 2000-4000/month, Chep-pallet 100-400/month, Display	2 min. per mix-card, 8 min. per chep-pallet,	Batch record in CSB, EAN 128	1 to 5

		0-50/month	10 min per display		
	Commissioning	planning	30 sec. per order, 10 to 30 orders per day	terminal printer, CSB	1
	Inventory control	Inventory on monthly bases	8 h, once per month	CSB lists, excel sheets	8
	Continuous inventory	Inventory on daily bases	1 to 2h, once per day	CSB	1 to 2
	Issue	Issue of pallets	45 min. per Issue	EAN 128, D-Shuttle Dachser (CSB)	1

Appendix 14: Selection of RFID Hardware Components for Medium-sized Enterprise

UHF 868 MHz RFID tags				
Type	**Range**	**Objects**	**Memory**	**Form**
Passive	< 3 m	Metal racks	Read / Write once	Large Rigid
Passive	< 3 m	Wood pallets	Read / Write	Large Rigid
Passive	< 3 m	Floor	Read / Write once	Capsule

Specified readers		
868 MHz Frequency Range		
Reader	**Related Products**	**Connectivity**
Forklift Mounted	Fixed Mount Display, Antenna Cell	802.11, RS232[465]
Stationary-Dock Door	Antenna	802.11, RS232
Handheld	-	802.11

Passive UHF 868 MHz RFID kit for scenario A	
Equipments	**Quantity**
Tags	
Passive Large Rigid UHF 868 MHz RFID tags (Read/ Write)	5000
Passive Large Rigid UHF 868 MHz RFID tags (Read/ Write once)	1000
Readers	
Forklift Mounted Reader	05
Handheld Reader	02
Antennas and Display	
Forklift Mounted Display	05
Forklift Mounted Antenna	10
Passive UHF 868 MHz RFID kit for scenario B	
Equipments	**Quantity**
Tags	
Passive Large Rigid UHF 868 MHz RFID tags (Read/ Write)	5000
Passive Large Rigid UHF 868 MHz RFID tags (Read/ Write once)	1000
Passive Capsule UHF 868 MHz RFID tags (Read/ Write once)	250

[465] RS-232 (Recommended Standard 232) is a standard for serial binary data signals connecting between a DTE (Data Terminal Equipment) and a DCE (Data Circuit-terminating Equipment)

Readers	
Forklift Mounted Reader	05
Handheld Reader	02
Antennas and Display	
Forklift Mounted Display	05
Forklift Mounted Antenna	10
Passive UHF 868 MHz RFID kit for scenario C	
Equipments	**Quantity**
Tags	
Passive Large Rigid UHF 868 MHz RFID tags (Read/ Write)	5000
Passive Large Rigid UHF 868 MHz RFID tags (Read/ Write once)	1000
Passive Capsule UHF 868 MHz RFID tags (Read/ Write once)	250
Readers	
Forklift Mounted Reader	05
Stationary-Dock Door Reader	03
Handheld Reader	02
Antennas and Display	
Forklift Mounted Display	05
Forklift Mounted Antenna	10
Dock Door Antenna	10

Appendix 15: Cost Estimation of RFID Hardware (fixed) for Medium-sized Enterprise (Scenario C)

Hardware	Equipments	Quantity	Cost (Euro)	Total Cost (Euro)
Tags	Wooden pallets	5000	4.2	21000
	Metal racks	1000	4.2	4200
	Floor	250	4.2	1050
Reader	Forklift Mounted Reader	5	3195	15975
	Handheld Reader	2	800	1600
Antenna and display	Forklift Mounted Display	5	2,792.41	13962.05
	Antennas Cable	5	27.68	138.4
	Dock Door Antenna	5	131.60	658
	Forklift Mounted Antenna	10	131.6	1316
Total				59899.45

Appendix 16: ROI of RFID System for Medium-sized Enterprise

Cost & Benefits	Scenario A	Scenario B	Scenario C
Variable cost	19112.11	19112.11	19112.11
Hardware cost	58053.05	59103.05	59899.45
V_i Investment	77165.16	78215.16	79011.56
V_t Monetary yield	22387.04	22387.04	22387.04
OOS benefit	68000	68000	68000
n No. Of period	5 / 2 Years	5 / 2 Years	5 / 2 Years
D Discount rate	0.045	0.045	0.045
ROI with in 5 years	0.273613441	0.256515808	0.24385071
ROI Incl OOS benefit in 2 years	1.193614283	1.164166092	1.142352298

Large Enterprise

Appendix 17: List of Communication Activities of Large Enterprise Project

1.	The initiative for the second reseach project and initial contacts with the food industries of the region was taken by Professor Ute Höper-Schmidt.
2.	Final calculation of the cost of research project. Finalization of the correspondence and with different dairy food industries (e.g. frischli-milchwerke, Bab Bebra e.G., Börde Käse) and Acknowledgement of “no fit”. Decision to contact the large enterprise section 6.3.
3.	Contact to the large enterprise section 6.3.
4.	(Mutual) interest and acceptance (zusage) of Mr. Dr. Dirk Gloy, member of the board of directors, from the large enterprise section 6.3.
5.	First meeting offers by Mr. Hermann Köster, member of logistics management (Zeven). And confirmation of 27th May Meeting at 9:00 in Magdeburg. Participants: Mr. Köster, logistics manger (member of logistics management) Mr. Brauer, Logistics Service and Systems Mr. Prott, the large enterprise section 6.3
6.	Confirmation of the agenda for the meeting on 27th May: 1. Kurzdarstellung the large enterprise section 6.3 2. Kurzdarstellung Hochschule Anhalt 3. Ziele und Inhalte des Forschungsvorhabens 4. Einsatzmöglichkeiten RFID bei NM 5. Festlegung weitere Vorgehensweise Duration 3 hours
7.	Internee Mr. Müller was taken in team for support in on-site study.
8.	Content with Mr. Köster to confirm the need for research. Information regarding Netzwerk Ernährungsindustrie and Mr. Wild to the large enterprise section 6.3.
9.	Talk to Mr. Brauer regarding further process. And information regarding preparation/readiness.
10.	Invitation from the large enterprise section 6.3 to discuss project execution.
11.	Willingness of the large enterprise section 6.3 to carry out project in Edewecht (Lower Saxony). Meeting offer from Mr. Köster: 29th June from 11:00 to 15:00.
12.	Confirmation of the meeting on 29th June to Mr. Köster. Purpose: discussion of specification of application area in the company To discuss execution of the project Discussion of project duration (roughly)
13.	Participant of the meeting on 29th June were made known by Mr. Köster. Mr. Lucht, Head of the Plant Management Mr. Siebels, Technology Mr. Hilljegerdes, Head of the Warehouse Mr. Baumeyer, Palletization Center
14.	A study made by SALT Solutions GmbH was provided. Confirmation of the meeting on 03.09.2009 at 10:00.
15.	Contract discussion of the author with Anhalt University of Applied Sciences (related persons were Ms. Schöps from presidential administration and Schellenberg, contact person from HS Anhalt to Netzwerk). Funds granting from Netzwerk was initiated.
16.	Start of the adoption of the “questionnaire”. Deadline first week of August 2009.
17.	Second last version of the questionnaire. Comments from Prof. on 31st July.
18.	**Last versions of the questionnaire**. Planning of the routine of the meeting on 3rd September (internal): - Short presentation (benefits of the research project, purpose of the questionnaire) - Objectives of the project - Team building (organizational) - Goals and types of documentation (methodical)
19.	Email correspondence with Mr. Brauer regarding meeting. And sending of questionnaire.
20.	Further planning of travel and accommodation. Booking at Hotel am Thielnplatz for 2nd and 3rd September.
21.	Communication of the agenda of the **meeting on 3rd September** with Mr. Brauer: - Short presentation (benefits of the research project, purpose of the questionnaire) - Objectives of the project and team building (organizational) - Communication of the approach for documentation “adoption of types and goals of

	documentation (methodical approach) before each phase”
22.	The meeting Appointment of a trainee (Mr. Deyk Tiedemann, production/ logistics) by the large enterprise section 6.3 to support on-site during the study until 5th October 2009.
23.	Feed back on the meeting by Prof.
24.	Protocol of the meeting on 3rd September with questionnaire by Prof.
25.	Evaluation of the questionnaire.
26.	Receipt of **construction drawing** of the plant. Open questions and further required data (QA) were promised by Mr. Tiedemann.
27.	**Adaptation of the checklists**. Steps: - Structuring of processes with separate short checklists - Analysis with detailed checklists - Request for historical data from SAP LES until 5th October (to design pallet movement) Confirmation of the meeting on 5th October 2009.
28.	Internal communication of the approach for As-Is Analysis and (see email from 1/10/09) Finalization of checklists.
29.	Arrangement and confirmation of accommodation by the large enterprise section 6.3. Availability (sending) of data regarding pallets movement and warehouses.
30.	Correspondence regarding questionnaire data.
31.	Availability of initial **process data (protocols)** by Mr. Tiedemann. **Initial design** of As-Is Processes.
32.	Communication and explanation of the **4 step approach of As-Is Analysis** with examples and lists (to Mr. Müller). - 1st level (questionnaire) - 2nd level Design checklists - 3rd level As-Is execution detailed checklists - 4th level process view (activities)
33.	Execution of detailed As-Is analysis (first steps).
34.	Completion of As-Is execution (Checklists). Rough design of level 4 processes. And explanation of 4 steps of documentation to Mr. Müller.
35.	Preparation and presentation of **As-Is data in tables**.
36.	Receipt of data regarding personal **cost** and pallet quantity, barcode cost.
37.	Explanation of Modeling with company process example. Until 14.11.2009.
38.	Report of the progress of process modeling (As-Is Evaluation). **Modeling with BPM** – reasons/benefits: - Visualization of process to stabilize or optimize (with or without RFID) - Ease design of To-Be and integration as well as customization of software First Models were created (It was a gradual development).
39.	Finalization of the As-Is table Completion of **preliminary models of As-Is**. On going communication within team members (University, Company) and (iterative) optimization and development of models. Adoption of documentation and models until 18.11.2009
40.	Middleware solutions and cost (SAP) – Market analysis
41.	Finalization of modeling and documentation. Communication of meeting on 15th December 2009.
42.	Completion of the 19th version of the **overall process model**.
43.	Discussion of Master thesis by Prof. With Mr. Müller.
44.	**Evaluation of As-Is analysis** and strengths and weaknesses of processes.
45.	Use and adoption of **traffic light analysis** for strengths and weaknesses
46.	Completion of the version 1.1 of the As-Is-Documentation (Phase 1 and 2).
47.	First steps of **qualitative traffic light analysis**.
48.	Improvement of traffic light analysis.
49.	Planning of the meeting on 15th December. - Presentation of results and further steps (approach) - Discussion over strengths and weaknesses of processes and approval
50.	Completion of the presentation of the results of phase 1 and 2 (version 5). Design of **quantitative evaluation of activities** from traffic light analysis (version 1 and 2). Correction of warehouse data (space) by Mr. Müller.
51.	Completion of the presentation of the results of phase 1 and 2 (last version)

	Completion of BPM (last version) Design of quantitative evaluation of activities (last version) for inquiry of cost
52.	Completion of first quantitative evaluation.
53.	**Summary of quantitative evaluation**
54.	**Conflict**, Misunderstandings of quantitative evaluation by company. The company was not agree to accept the results (were proud to the right job).
55.	**RFID Design** – First Step: - Approach – process model - Market analysis (selection of RFID System) - Preliminary Concept
56.	Response to misunderstandings and unclear issues. Clear interpretation of evaluation that it is in no way a critic on organization of employees. On 6th January 2010 the problems were solved. Further Planning: - Definition of preliminary strategy (design) - Meeting in Edewecht to discuss the design - Definition of the final concept Confirmation of the meeting.
57.	**Preliminary concept** (version 1) First draft of As-Is and To-be processes (physical)
58.	First draft detailed process design. Physical changes (As-Is and To-Be plus comments). Two scenario consideration
59.	First draft of scenario representation.
60.	Completion of detailed As-Is and To-Be processes (version 2) with 4 scenarios.
61.	Finalization of RFID hardware list.
62.	First documentation of RFID design (doc version 1 and 2)
63.	Adoption of the documentation of RFID design (doc version 2)
64.	Adoption of RFID Hardware list according to scenarios.
65.	Completion of phase 3 documentation (RFID Design) and communication with Mr. Brauer. Planning for next meeting.
66.	Level 4 design
67.	First contact with Ms. Thalmann regarding dissertation by Prof.
68.	First step toward market analysis
69.	Finalization of RFID system list
70.	First contact with Vendors: - B&M (Tricon) Auto-ID Systeme GmbH - Waldemar Winckel GmbH & Co. KG - Rodata Mobile Computing AG - COT GmbH - IdentPro GmbH
71.	Completion of documentation from phase 1 to 3 (second last version).
72.	Status report: Completion and communication of phase 3 documentation. Decision of deadline for phase 4. Planning of Meeting.
73.	Market analysis – Online shop (http://www.autoid-shop.com/rfid/rfid-etikettendrucker/index.html)
74.	**First calculations** on the basis of offers. Telephone with UCS and IdentPro. Preliminary design of the calculator for RFID Implementation by the author.
75.	Email correspondence with bm-tricon. Calculation and ongoing market analysis.
76.	Design of ROI calculator and cost and ROI calculation (example) Adoption of the documentation from phase 1 to 3 by Prof.
77.	Final document of phase 1 to3.
78.	Offer of Rodata (email). First documentation of phase 5 (economic analysis).
79.	Confirmation of the final meeting by Mr. Tiedemann. Invitation/communication with Netzwerk (Mr. Dr. Lange) regarding final presentation of the project by Prof.
80.	Documentation of report including ROI. Ongoing adoption and correction.
81.	Completion of the last version of the report of the project. Finalization of the last presentation.

82.	Finalization of report with calculations and process model.
83.	**Final Meeting**
84.	Positive feedback from Prof. Small corrections in final report.
85.	**Final Report**
86.	Final and complete report of the project for the company.
87.	Status report – Report of the project for Netzwerk in process.
88.	Decision of deadline for final content of the report for the netzwerk.
89.	Completion of the report for the Netzwerk.

Appendix 18: Summary of Goals of Large Enterprise

Effekte	**Einsatzziele**	**Unternehmensbereiche/ -einheiten**
Direkte Optimierung möglich	Lagerverwaltung	Vorwärm, Warm- und Kühllager
	Warenein- und ausgang	Verladehalle, Tor 6, Kommissionierhalle
	Erfassung der externen Ware	Konfekt
	Produktionsdatenerfassung	HBV-Lager
	Lückenlose Dokumentation	Unternehmensweit a. Produktion
	Echtzeitdatenerfassung	Unternehmensweit a. Produktion
	Echtzeitlokalisierung der Kisten/ Paletten	Unternehmensweit a. Produktion
	Kisten/ Palettenrückverfolgung	Unternehmensweit a. Produktion
	Behältermanagement	Leergut
Indirekte Optimierung möglich	Warenkommissionierung	Verpackung
	Konfektionierung	Konfekt

Appendix 19: Packaging and Warehousing Areas of the Large Enterprise as Example

Appendix 20: Example of Manual Documentation

Appendix 21: Examples of Types of Pallets in Use by the Large Enterprise

Schnittkäsekiste und Burlanderkiste


Europalette und H1 Palette


Appendix 22: Summary of Activities at Unit Level of Large Enterprise

Bereich	Name des Prozesses/ der Aktivität	Ziel des Prozesses	Durchschnittliche Prozessdauer	Dokumentationsart	Umfang an Ausrüstung
Mayerraum	Mayerraum	Einbeuteln von Käseblöcken	k. A.	Einzelauszeichnung (Tintenstrahl-druck); Verpackungs-protokoll	2 MA; 4 Einbeutler; Förderbänder; Bizerba-System; Metalldetektor/Röntgengerät
Verpackung	Verpackung	Kisten- oder Palettenbefüllung	Ca. 4-5 min. /Kiste; Ca. 4 min. /Palette (ETT)	Großes-Etikett (EAN 128);	2 MA; 2 Stapler; 2 Heripack; ETT; Bizerba-System
Lagerhaltung	Lagerhaltung	Lagerung	k. A.	Manuell auf Tafeln, Produktions-mengenprotokoll, Käseauslagerungsprotokoll und Chargenbestandsliste; EAN 128 (in der Kiste)	ca. 6-8 MA; ca. 6-8 Stapler
Umpackung	Umpackstation automatisch	Umpacken auf Paletten	Zweischichtbetrieb 6-23 Uhr; 1200 Block/h Schnittkäse oder 700 Block/h Großlochkäse	Umpackprotokoll; Einzelauszeichnung und großes Etikett (EAN 128); laufende Nummer	2 MA; 2 Transnova Roboter; Stapler; Bizerba-System
	Umpackstation Boden	Packen von besonderen Kundenwünschen	Je nach Anzahl MA	Umpackprotokoll; großes-Etikett (EAN 128); laufende Nummer	2-5 MA; Stapler; Bizerba-System
Verladehalle	Verladehalle (Versand)	Versand	Zweischichtbetrieb 6-23 Uhr; Standard Verladung: ca. 45 min. je Lkw oder Seecontainer: ca. 2 h je Lkw	Scanne der zusammengestellten Ware (EAN 128); Verladeplan; Kommissionierschein; Lieferschein	1-3 MA (wenn 2 Packer nötig); Stapler; PC; Scanner
	Verladehalle (Annahme)	Annahme	je nach Lager	Scannen der externen Ware (wenn möglich Übernahme Chargennr.); Leergutschein	1-2 MA; 1-2 Stapler; Scanner
Hilfs-, Betriebs-mittel und Verpackungs-material	HBV-Lager	Versorgung der Abteilung Konfekt, Verpackung und Butterei	Täglich 6-15 Uhr	Manuelle Eingabe ins SAP; Lieferschein; Artikelnr.; EAN 128 (nicht verwendet)	2 MA; 2 Stapler; Schieberegal; PC

Konfektionierung	Konfektionierung; Auspackstation	Versorgung des Konfekts mit Blockware	Dreischichtsystem 24 h	Kistenbereitstellungs-protokoll; Externe Ware manuell (Protokolle) und interne Ware scannen	2 MA; 2 Stapler; Auspackroboter; PC; Scanner
Palettierung	Palettierzentrum	Palettieren und Einlagern ins Hochregal-lager	Dreischichtsystem 24 h	Fertigungsauftrag; Linienbarcode; Scannen manuell/auto; Inhouse-Etikett (EAN 128)	ca. 5 MA; 4 Packroboter; 1 Satelliten-strecher; Fördertechnik; 2 Stapler; 2 Etikettierer (einer manuell); PC; Scanner
Hochregal	Hochregallager	Ein- und Auslagerung/ Versand	Zweischichtbetrieb 6-23 Uhr	Automatisches scannen Inhouse-Etikett (EAN 128); elektronisch über SAP (LES); Versandetikett	min. 1 im Büro; ca. 2 MA ; ca. 2 Stapler; RBG (Regalbedien-gerät); Bizerba-System; PC; Scanner
Butterei	Butterei	Portionierung der Butter	Dreischichtsystem 24 h	Packprotokoll;Daten manuell oder elektronisch ins PZ	ca. 2 MA zur Handsortierung; Kartonierer; Förderbänder; Maschinen
Leergutmanagement	Leergutmanagement	Versorgung mit Leergut	k. A.	Manuelle Auflistung auf Leergutscheinen	Ca. 2 MA; 2 Stapler

Appendix 23: Qualitative Evaluation of Supply Chain Processes of Large Enterprise an Example

Appendix 24: Summary of Quantitative Evaluation of Supply Chain Processes of Large Enterprise

Art der Kosten	Kosten/ Jahr in Euro
Fixe Kosten	
Inventur	6800
Inhouse Etiketten	43698
Zwischensumme der fixen Kosten	**50498**
Variable Kosten	
Lagerplatzverwaltung, Leerguterfassung, Manuelle Datenerfassung, Scannfehler und –Ineffizienz	30000
B-Warenverkauf	14952
Zwischensumme der variablen Kosten	**44952**
Gesamtkosten	**95450**

Appendix 25: Summary of Specified RFID Hardware Components for Large Enterprsie

Komponente für UHF/ HF System	Einsatzbereiche/ -einheiten
Passive Write-Once-Read-Many Transponder	Kisten, Paletten, Boden, Regale (Papier/ Kunststoff)
Montierte RFID-Lesegeräte	Gabelstapler
RFID-Handhelds	Verladehalle, PZ, Kommissionierhalle, Konfekt
Stationierte RFID-Lesegeräte	Tor 1-4, 7-9, Durchgang Lager 10, Roboter
RFID-Drucker	Tor 6 und 5 (Kommissionierhalle), Konfekt, PZ

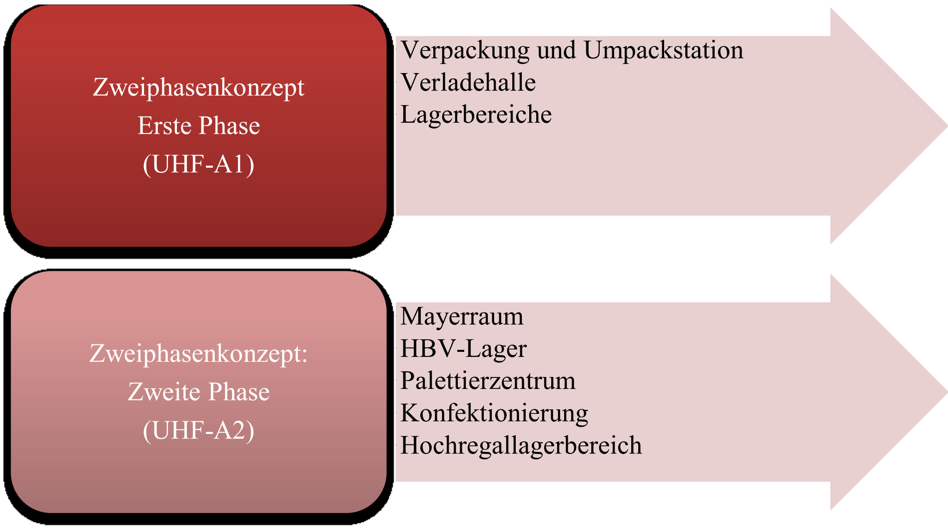
Appendix 26: Overview of Suggested Scenarios for Implementation in the Large Enterprise

	UHF	HF
Zweiphasenkonzept	- Flexible Gestaltung der Logistikabläufe - Schrittweise Implementierung in zeitlich getrennte Phasen - Geteilter Implementierungsaufwand und –kosten - Vermutlich **höhere** Systemkosten <u>Erste Phase:</u> - Als individuelles Szenario Einsetzbar - Optimiert für Reduzierung oder Eliminierung der B-Waren <u>Zweite Phase:</u> - Optional - Gesamt Kisten/ Paletten- und Informationsmanagement	- Zum Teil **eingeschränkte** Gestaltung der Logistikabläufe - Schrittweise Implementierung in zeitlich getrennten Phasen - Geteilter Implementierungsaufwand und –kosten - Benötig **höhere Zahl** an Transponder und Lesegeräte - Vermutlich **geringere** Systemkosten <u>Erste Phase:</u> - Als individuelles Szenario Einsetzbar - Optimiert für Reduzierung oder Eliminierung der B-Waren <u>Zweite Phase:</u> - Optional - Gesamt Kisten/ Paletten- und Informationsmanagement
Einphasenkonzept	- **Flexible Gestaltung der Logistikabläufe** - **Zeitgleiche Implementierung in allen untersuchten Bereichen** - **Sichert standardisiertes RFID-System** - **Gesamt Kisten/ Paletten- und**	- Zum Teil **eingeschränkte** Gestaltung der Logistikabläufe - Zeitgleiche Implementierung in allen untersuchten Bereichen - Sichert standardisiertes RFID-System - Gesamt Kisten/ Paletten- und Informationsmanagement - Benötigt **höhere Zahl** an Transpondern und Lesegeräten

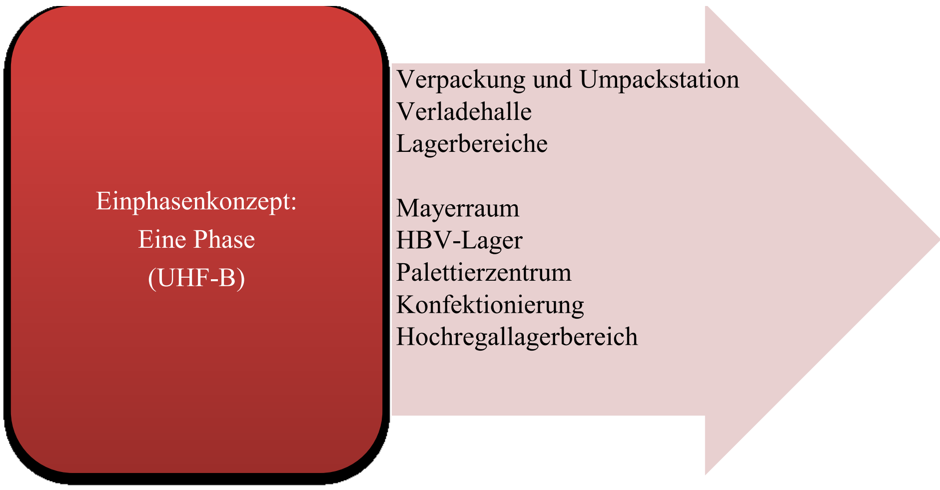
	Informationsmanagement - **Vermutlich höhere Systemkosten**	- Vermutlich **geringere** Systemkosten

Appendix 27: Overview of Incremental Implementation of UHF Scenarios

Scenario UHF (A)



Scenario UHF (B)



Appendix 28: Specified RFID System with Total Number of Components for Large Enterprise

Einheiten	**Anmerkungen**	**Anzahl**	
Passive Transponder (Read-Many-Write-Once)		**UHF**	**HF**
Transponder (Kunststoff/klebe - Optional)	Für Holzkisten bzw. Paletten	30000	60000
	Für Metal (Klebe - optional)	2100	2100
	Für Boden (Klebe - optional)	1800	5500
Transponder für Holzpaletten		1000	2000
Kunststofftransponder für Metalregale		2100	2100
Transponder für Boden		1800	5500
Lese- und Schreibgeräte			

Lese- und Schreibgeräte für Gabelstapler	Szenario UHF: A1+A2 =12+8 oder B =20 Szenario HF: A1+A2 = 24+16 oder B =40	20	40
Lese- und Schreibgeräte für Förderband	Max. Antennen/ Reader = 2 Szenario UHF: A1+A2 =7+2 oder B =9 Szenario HF: A1+A2 = 14+4 oder B =18	9	18
	Max. Antennen/ Reader = 4	3	6
Lese- und Schreibgeräte für Warenein- und ausgang	Max. Antennen/ Reader = 2	0	8
	Max. Antennen/ Reader = 4 (Verladehalle = 2 + Kommissionierhalle =2)	4	0
Handhelds	+2 Verladehalle (optional)	6	6
Drucker			
RFID Drucker		6	6
Papiertransponder (Rollen)	Laufende Beschaffung	190,000	380,000
Accessories			
Accessories zu dem Kit		Passend	Passend
Middleware			
Middleware integrierbar in SAP Landschaft			

Appendix 29: Overview of Considered Cost Factors for RFID Implementation of Large Enterprise

	Fixe Kosten	Variable Kosten	Betriebskosten
Externe Kosten (Partnerunternehmen) Hardware Kosten Software Kosten Dienstleistungskosten	**Hardware** - RFID Lese- und Schreibgeräte - Transponder - Antennen - Kabel und Connectors - Klient und Server Computern - Netzwerkschalter, Wireless Access Points und Repeater **Software** - Database - Middleware - Interface Systems (Display)	**Dienstleistungen** - Projektdurchführung - Anpassung von Stromversorgungsnetzwerk - Anpassung von Informationsnetzwerkumgebung - Abschätzung der Distanz für die Lokalisierung - Struktur/ Topologie der RFID Readers und Ausschilderung - Anpassung der Antennen und -orientierung - Sicherstellung der RFID Reads - Anpassung von Software - Schulung - Business Process Re-Engineering	- Software Updates - Ersatzinvestitionen von RFID-Hardware und IT - Maintenance und Support

Interne Kosten (Unternehmensintern) Personalkosten Infrastrukturkosten	- Projektmitarbeiter - Hard- und Software - Reise und Raum	- Schulung - Business Process Re-Engineering	- Betreuung

Appendix 30: Summary of Cost and Benefits and ROI Calculations for Large Enterprise

Kostenfaktoren	**Kosten in €**	**Nutzen in €**			**ROI/Amortisation**
Szenario B (Preise von Anbieter 1)		Jahr 0	Jahr 1	Jahr n	
Hard- und Softwarekosten	295.798	-398.298	-549	43149	in 10,2 Jahren
Integrationskosten	102.500				
Gesamtkosten	398.298				
Szenario A1 (Anbieter 1)					in 7,0 Jahren
Szenario B (Preise von Anbieter 2)					
Hard- und Softwarekosten	287.088	- 389.588	- 549	43149	in 10,0 Jahren
Integrationskosten	102.500				
Gesamtkosten	389.588				
Szenario A1 (Anbieter 2)					in 6,4 Jahren

Declaration of Originality

(Selbständigkeitserklärung)

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