THALES ELECTRONIC SYSTEMS GMBH

Cost-Benefit Analysis of Data Matrix Codes in a Project-based Business

A Business Case

Bachelor Thesis in the field of study Industrial Engineering and Management BSc.
University of Twente

Document prepared by Chris Sproates, a Bachelor student in the field of study Industrial Engineering and Management. The objective of this study is to explore the possibilities for improvement in the data quality in the SAP system of Thales Electronic Systems GmbH by the use of Data Matrix Codes. The purpose of this document is to support the decision for the investment of a new identification technology.

“Data! Data! Data!” he cried impatiently. “I can’t make bricks without clay!” – ***Sherlock Holmes***
The Adventure of the Copper Beeches written by Arthur Conan Doyle

Bachelor thesis for University of Twente Faculty MB	
Assignment given by and carried out at Thales Electronic Systems in Kiel, Germany	
A Cost-Benefit Analysis of Data Matrix Codes in a Project-based Business A Business Case	
Author:	Chris Sproates
Supervisor University of Twente:	Ms. Iacob
Second Supervisor University of Twente:	Mr. Heerkens
Supervisor Thales Electronic Systems:	Mr. Paul
Second Supervisor Thales Electronic Systems:	Mr. Demir
Assignment carried out in:	November 2013 – March 2014 Preceded by an internship in September and October 2013
Submission date:	28-04-2014

Management Summary

At TES there was doubt about the data quality in the ERP system SAP. There was a feeling that errors were made in SAP and that more time than strictly necessary was spent in SAP. For this reason a business case was developed in order to find out whether a new technology would be able to improve the current situation. For the computing platform the AIDC technology Data Matrix Codes was chosen, since various other locations of Thales already work with these types of barcodes and it is already possible to produce these Data Matrix Codes at TES. To find out whether the Data Matrix Codes would improve the efficiency of data input in SAP at TES, a modified version of the BC4IOP methodology has been used together with BPE and SMART. The scope of the analysis has been narrowed to the supply chain at TES in which the presumed problems occurred. The research question, which is answered in this bachelor thesis, is as follows:

'How can the AIDC technology Data Matrix Codes contribute to the performance of business processes conducted by Thales Electronic Systems GmbH in a cost-efficient way?'

By analysing the current processes via observations, tests and interviews, it turned out that the amount of errors made in SAP were very small. The main reason for this conclusion is the number of material movements conducted at TES, which is relatively small in comparison with other locations of Thales, like Arnstadt. Although the number of material movements is small, areas are still indicated for improvement largely in the field of data input efficiency. However these areas of improvement are not always related to the AIDC technology of Data Matrix Codes. The added value of materials with labels containing a DMC was too little to make such a solution cost-efficient. The proposed solutions were either too costly or risky and the benefits received by the solutions were too small due to the number of material movements at TES.

For the moment there are two solutions that will save considerable time in the administrative process at TES. Therefore it is recommended that TES makes a catalogue of all the spare parts for its products (starting with the LUCIE device) in which a DMC can be scanned for the data input in SAP. The investment costs are € 2.730,-, which is paid back (soft savings) in the first year. The implementation time is short and the difficulty is not complex. The necessary hardware needs to be ordered and the reading of a DMC in SAP needs to be programmed in which Thales Arnstadt already has experience. It also recommended that TES allows the creation of a master file in IQ02 (Solution D) for complete systems (with a certain 12NC). The programming costs are estimated on € 1.000,- and the implementation time can also be relatively short. The soft savings will be approximately €2.100,-. Once the changes have been programmed it can be put into use when a new system needs to be registered. It is possible to have both solutions implemented within a month, when there are no difficulties concerning the programming of the changes in SAP.

It is also recommended that every newly produced product will get a label with an added DMC. This does not cost additional time or money, but will reduce the implementation time when solutions with wireless or corded barcode scanners become feasible. This can happen when multiple locations of Thales were to introduce these DMC for which the investment costs can be shared.

Table of Contents

List of Abbreviations

ABP	Algemene Bedrijfskundige Probleemsaanpak
AIDC	Automatic Identification and Data Capture
AHP	Analytical Hierarchy Process
BAAINBw	Bundesamt für Ausrüstung, Informationstecknik und Nutzung der Bundeswehr
BC4IOP	Business Case for Inter-Organizational Projects
BDN	Benefits Dependency Network
BEL	Bundeseigenes Lager
BM	Benefits Management
BMP	Benefits Management Process
BM4IOP	Benefits Management for Inter-Organizational Projects
BPD	Business Process Diagram
BPE	Business Process Engineering
Bsc.	Bachelor of Science
DMC	Data Matrix Codes
ECC	Enterprise Core Component
ERP	Enterprise Resource Planning
GmbH	Gesellschaft mit Beschränkter Haftung
IEM	Industrial Engineering and Management
IT	Information Technology
MM	Materials Management
PDA	Personal Digital Assistant
RFID	Radio-frequency Identification
SID4IOP	Structured Information Disclosure for Inter-Organizational Projects
SMART	Simple Multi-Attribute Rating Technique
TDS	Thales Defense & Security
TDS NORD	Thales Defence & Security (Location Kiel and Wilhelmshafen
TES	Thales Electronic Systems GmbH
VM	Value Model
VM4IOP	Value Model for Inter-Organizational Projects

List of Figures

List of Tables

Preface

At the end of every Industrial Engineering and Management BSc. a student has to write a bachelor thesis in which he or she integrates the knowledge learned from the different courses. For this bachelor thesis a student has to solve a problem or a research question by him- or herself to show his or her capabilities. I have chosen to do this Bachelor thesis abroad to learn a different working culture and to improve my knowledge of a foreign language. I found a place to do my Bachelor thesis in Kiel, Germany. Thales Electronic Systems GmbH (TES) allowed me to learn their company and processes, and to write a bachelor thesis. I would like to thank Mr. Paul for giving me that opportunity.

In September and the beginning of October at TES I was given the opportunity to take 'a look behind the scenes'. During those weeks, I learned a lot about the business activities, and gained a global insight in the business processes and IT-systems currently in use at TES. The goal of my term here was to find a suitable subject for my Bachelor thesis in the area of Industrial Engineering and Management (IEM). There were a number of subjects available, but many of these subjects were too small, or not solvable as a bachelor thesis. Finally, a subject concerning the data quality in SAP was found. In the weeks prior to working at TES there were a number of wrong inputs in SAP which lead to additional work that could had been avoided. I would like to thank Mrs. Iacob and Mr. Heerkens for their feedback and for being my supervisors.

Special thanks go out to Mr. Demir and the other employees at the logistics, who have given me a lot of information about the processes and above all a memorable time at TES.

Chris Sproates
s1109804

Chapter 1: Research Design

The first chapter describes the assignment and the context of this research. Background information will be provided, together with the reasoning to justify this assignment. As well as the scientific relevance of the assignment, the research approach chosen in order to solve this assignment will also be discussed.

1.1 Background Information

TES, located in Kiel (Germany), is part of the worldwide concern Thales which originated in France. The parent company is divided into different groups (geographical areas) such as Thales Deutschland Group (Main office located in Stuttgart). This group also consists of different sectors with various expertises relating to Transportation Systems or Defence and Security. This sector also consists of various locations in Germany, for example, the location of Arnstadt, which is part of the sector Transportation Systems. Figure 1 gives the global overview of the organizational structure of Thales Deutschland Group.

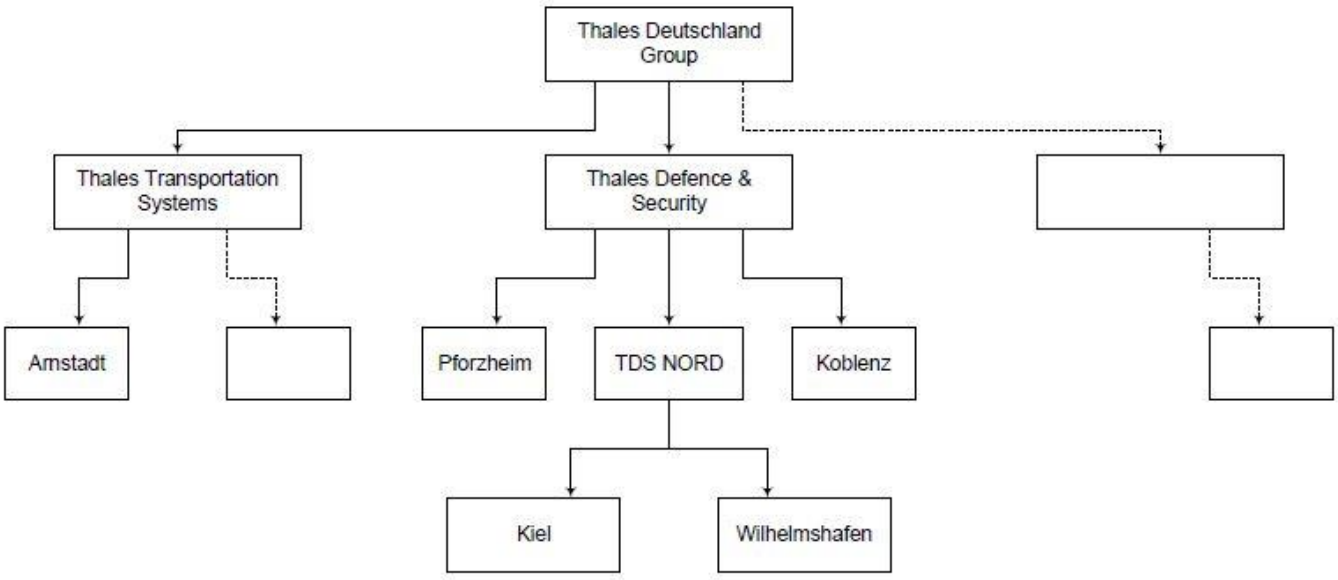

Figure 1. Global Structure of Thales Deutschland Group

This bachelor thesis is primarily related to the location in Kiel (which will be referred to as Thales Electronic Systems GmbH (TES) throughout this thesis).

The organization produces subparts for larger projects in the areas of communication, radar systems and weapon systems (such as cables for missile systems). Not only are these subparts produced in Kiel, but also devices for the Bundeswehr, Polizei and other organizations are repaired (for example heat vision and night vision devices). Most of those products are not produced in Kiel but at Thales France (location Agnénieux). It is also the case that some items repaired in Kiel, were not produced by any Thales location.

Due to the uniqueness of every order and the long service life of the products produced here, the production could be described as some kind of 'job shop'. This makes it very difficult to plan certain parts of the logistics (stocking etc.) and therefore most items are ordered on an 'as needed' basis. Some general items (the cheaper parts), however, are stocked, but much of this is specially ordered for specific projects. Due to the small number of parts actually needed (and therefore a low order quantity), problems could occur when a supplier demands that a minimum order quantity is required. The situation could also occur that some parts are in stock for a long time, and eventually might never be used, for example, due to technology changes, which happens from time to time.

A different problem related to the advancement of technology is that certain parts have to be in stock for the event that an older project needs repairs. There is a significant risk that a supplier does not deliver the outdated technology anymore. This problem also causes warranty issues, as the warranty starts when the supplier has delivered the goods. In addition, the problem is compounded when, for example, a project contains an order for three new ships or submarines but which are not delivered all at once. The time between the deliveries of two units could, in fact, be some years. In this case, certain parts for such project need to be ordered all at once due to the technology changes.

Two years ago, Thales Defense and Security (TDS) implemented a new Enterprise Resource Planning (ERP) system intended to improve internal and external communication (with the locations at Wilhelmshafen, Pforzheim and Koblenz). They have chosen to use SAP, a German ERP provider. This bachelor thesis concerns this subject. The quality of the information stored in this system could be improved to prevent errors and to save time being spent in correcting the errors introduced due to poor information quality. This thesis will look at the possibilities of improving the data quality.

1.2 Problem Description

TES was not able to provide a specific problem even though there are some concerns about the data quality of input in SAP, and there were some issues which potentially could have been solved with better information facilities from SAP. In this section the central problem statement will be defined that will be central to the research for solutions that will solve/improve the problem of data quality that TES is facing at this moment. First, the assumed causes leading to this research will be stated and investigated, as well as the impact of poor data quality. Secondly, an outline for the current situation will be given, and the current computing platform selection. Finally, the problem statement will be described that will form the topic of this research.

1.2.1 Underlying Causes

As described in the background, there is a consensus that the information in SAP could be improved and errors could be prevented from entering SAP. The specifics of this problem were not easily defined. This consensus of poor data quality in SAP results from some issues which occurred in the previous months (September and October 2013).

The main problem concerns the input in the SAP system at TES. One of the core business processes of TES is the repair service for the customer. It is possible that items repaired at TES are not produced at the location in Kiel or at any other Thales location. Nevertheless, it is possible to repair those items in Kiel. When items are delivered at goods sent/received, an employee opens a service notification in SAP and the sales department will open a project for which the costs are negotiated with the costumer (after someone from the repair department evaluated the defects of the item and the need for spare parts). When the customer agrees with the terms, then the repair will be executed. A problem can occur when incorrect data is entered in SAP in making the service notification. The serial number is needed to verify whether the product is still under warranty. Significant issues will arise when an incorrect serial number is entered in SAP. In the previous months, employees have regularly made errors (typos) in setting up a service notification. For example, a service notification which contained multiple items had an item with a wrong serial number and the mistake was only discovered late in the process. The only way to correct the error is to cancel the current order (as a whole) and repeat all the steps for the input in SAP. SAP does not allow the serial number to be changed manually once it is in the system. The amount of man-hours that are expended in order to correct this type of issue could be extensive especially when it concerns orders with lots of items.

The example above illustrates the potential of generating poor data quality in SAP. This is not only applicable to the business process of registering repairs. At various stages in the logistics chain at TES there are chances that poor data quality is generated. The feeling is that there is room for improvement in SAP since more time is spent in SAP than strictly necessary (1), which is caused by rework in SAP (2) in order to correct errors caused by poor data quality or the lack of information (3). Those errors are mainly caused by the manual input in SAP (4), which can lead to typos and duplicate information. Duplicate information can be caused when a search is made for specific information in SAP (for

example an address of a customer or product specifications) and when the information cannot be found a new file will be made although the information is already is available in SAP.

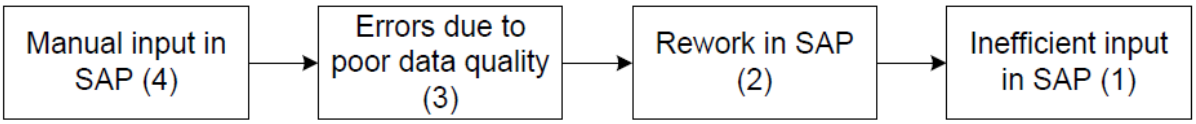

Figure 2. Problem Tree

There is also an additional problem, but this is not related to the problem described in Figure 2. However, it is expected to solve this additional problem together with the previous problem.

XXXXX

The identified additional problem will be referred to as 'the label issue'.

1.2.2 Impact of Poor Data Quality

With the rise of IT systems, data is now considered as a key organizational resource and therefore should be managed accordingly (Tayi & Ballou, 1998). Data should be accurate, but it is often difficult to determine the appropriate level of data quality. According to Tayi & Ballou (1998) it isn't necessary for data to be perfect, which is almost impossible to achieve and would bring high costs. However data should be, in their reasoning, fit to use. This implies that the appropriate level of data quality depends on its context. When the data quality is poor, it can have a far reaching effect since it can impact employee morale, breed organizational mistrust and difficulties to align the enterprise (Redman, 1998). It can have an impact on operation costs, according to Redman (1998), because time and other resources are spent detecting and correcting errors.

The technology to improve this data quality is available on the market. The past 20 years have illustrated technological changes in the area of physical distribution or supply chain management systems (Smith & Offodile, 2002). Nowadays, barcode scanners or RFID readers collect information and pass this data up to a main system, usually some ERP system, which manages the information of the organization or even for multiple organizations. Important is that when decision makers require data on which they base their decisions, they need confidence in the quality of the data collected (Smith & Offodile, 2002). Problems can, however, occur when data is entered manually where the risk on errors increases with the complexity of the data entry task. In order to reduce this risk, some form of automated identification technology is needed, as the error rate of the human element is commonly held at 1 to 300 and for example the error rate of a barcode UPC-A is to be held at 1 to 5,400,000 (Smith & Offodile, 2002).

So it can be concluded that data quality *does* matter and therefore an improvement of the data quality can lead to better usage of time and resources. This will have significant benefits to the company. If an Automated Identification and Data Capture (AIDC)[1] technology was available then data will be standardized (data is always collected in the same way) in which eventual errors will be prevented and hence time will be saved. With an AIDC technology it is also easier to build in the control points in SAP that need to be followed, although such a technology is not mandatory for building such control points. AIDC technology barcodes is already in use at TES, but not in the current processes for which these problems have been encountered.

[1] A term used to group various technologies which are employed to automatically identify items and collect the data of those items with the ability to enter the data into computer systems. Examples of these technologies are RFID tags, barcodes, magnetic strips etc (aimuk.org).

1.2.3 Outline for the Current Situation

The assumptions made in subparagraph 1.2.1 and 1.2.2 lead to the conclusion that an AIDC technology will improve the data quality and consequently a more efficient usage of SAP. However, it is not known whether the savings and benefits with such a system will eventually outweigh the costs for implementing and using it. Additionally, it is not clear to what degree these errors actually cost the company on a yearly basis.

Before research into these questions can be started, a more fundamental research needs to be conducted. The current business processes need to be determined and specified, and which are suitable to use an AIDC technology. If it is possible to find more business processes than purely the ones in which the problems occurred, then economies of scale comes into play. It will then possible to spread out the development costs over more processes.

It is also currently unknown how other locations in the TDS group (same SAP system), or inside the Thales Deutschland Group, have dealt with these issues. In order to work economically, and keeping the eventual project costs as low as possible, it is desirable not to have to re-invent the wheel, but re-use processes already in place. Answering this question could help choosing the type of computing platform needed to improving the efficiency. This question was already addressed and answered by an initial orientation period conducted in the first two weeks of October by the same author of this research. For the coverage of this question see subparagraph 1.2.4 in which the kind of AIDC technology researched will be supported.

To summarize, answers are needed to become more aware of the current situation, and a solution is required to find the contributed value of such a system in order to improve the data quality and thereby contributing to the efficiency of input in SAP.

1.2.4 Computing Platform

As previously described, an initial orientation already led to a choice of a computing platform from which the contribution is researched in this thesis. In consultation with the management of TES, it had been decided that the computing platform for an AIDC system should be taken into consideration, where use will be made of the 2D barcode type Data Matrix Codes (DMC) for the following reasons:

- The new barcode readers can also read the 1D barcodes which are already used in some processes.
- Other locations also consider the same technology or already have implemented the AIDC technology[2,3] and therefore development costs can be potentially lower and the 'lessons learned' are taken into consideration from other locations that have already implemented this, or similar, solution.
- It is already possible to manufacture such codes at TES, because at TES some products are already delivered to the ‘Bund’ due to the ‘Technische Lieferbedienungen’ (BAAINBw, 2013). It is however not possible to read the codes at TES for information purposes (only possible to read for testing).
- Other technologies have turned out to be too expensive, such as RFID-tags, which would cost an estimated total of 200,000 euro[4].

Therefore the added value of DMC to the business processes of TES will be analysed in more detail.

[2] At the location in Pforzheim the 2D barcodes are also planned due to the new technical delivery demands for the ‘Bund’ (BAAINBw, 2013), according to XXXXX.

[3] At the location in Arnstadt (see Figure 1) they already work with 2D barcodes and within SAP, but they produce in mass volume in contrast to TES which is more job shop based. Also they have different designations for their products then at TES. Information provided by XXXXX.

[4] According to XXXXX.

1.2.5 Problem Statement

The previous subparagraphs have made it clear that the current situation could be improved when some kind of AIDC technology was implemented. In the case of TES, the most appropriate AIDC appears to be DMC, which has been chosen as the computing platform. However, it is still unclear if the costs of the new technology will outweigh its benefits. An initial literature review made it clear that data quality does matter, but the scale of the problem of poor data quality at TES remains unclear. Therefore, it is necessary to put the data quality issue in context with the business processes at TES and to find out if DMC contributes to an improvement of the current situation. So the main problem to be solved in this research can be described as follows:

"Lack of insight in the consequences of poor data quality at TES and the possible contribution of Data Matrix Codes to the current business processes."

In order to find an answer to this question the research described in paragraphs 1.3 and 1.4 defines the main goal of the research in terms of its scope and the questions to be answered in order to formulate a solution.

1.3 Research Goal and Scope

In this paragraph the intended research will be defined and the scope of this research will also be described. Boundaries will be set on this research and its possible outcomes, since a possible solution still needs to be practical in order to contribute to the current business processes.

1.3.1 Main Research Goal

As already described in the previous paragraph, there is little to no insight in the consequences of poor data quality at TES and the possible contribution of DMC to the current business processes. With this research an answer needs to be found on how an investment in DMC would contribute to an improvement of the data quality and therefore possibly making the data input in SAP more efficient. The goal of this study can be described as follows:

"Developing a business case for the DMC technology in order to find out if investing in the new technology is worthwhile for improving the efficiency of data input in SAP."

In a business case, the costs and benefits of a project are rationalized and on the basis of such a business case a solid decision can be taken whether it will be cost effective to carry out the project. The technology will be worthwhile if the benefits outweigh the costs. With efficiency, it is meant that the time needed to conduct a task within SAP. A consequence of errors being made in SAP is an increase the time needed to successfully finish a task within SAP.

Since multiple locations are considering an implementation of the new technology a general framework will be built in order to measure the benefits received from the new technology and compare these to the current situation in order to find out whether the investment is beneficial. This framework will be used to assess the different possible investments at the location at Thales Kiel.

1.3.2 Project Framework

First this study will gather insight in the current business processes, and then the possible risk of poor data quality in these business processes will be described. Secondly, how an implementation of DMC will improve these business processes will be assessed.

The scope of this study contains various areas in the supply chain of TES (see Figure 3., an adjusted version of the original figure found in (Murray, 2009)). In principal, the elements concerning the in-house movements will be analysed for possible usage of the new technology. A major issue for the described problems is the repairs. It is likely that the data quality needed in the repair process can be improved with the DMC. This is the reason the customer service and the receiving element are linked. The DMC will also have interactions with elements outside the red box, because for example a customer has specific requirements for the label.

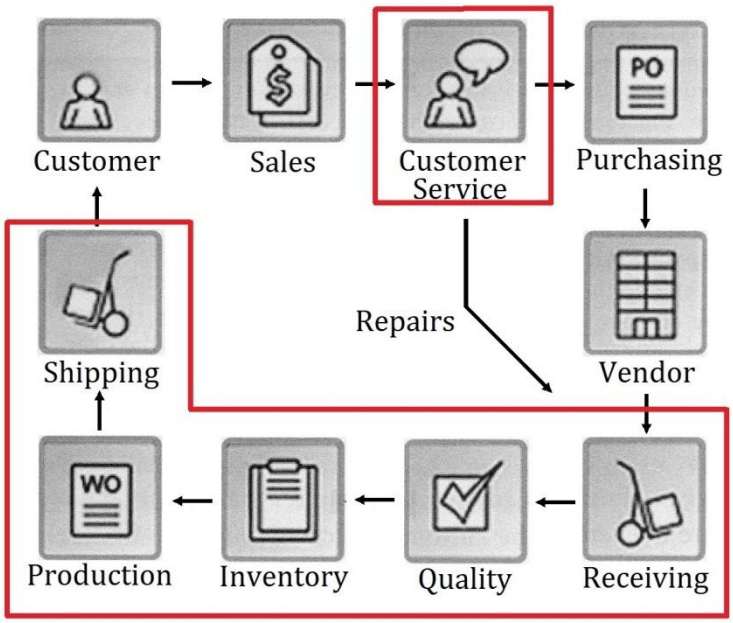

Figure 3. Elements of the Supply Chain (Adjusted version of the original found in Murray, 2009)

Various possibilities where DMC could play a role in improving the current business processes will be suggested. It needs to be assessed whether the implementation of the technology is efficient (amongst others, whether it saves time and whether it will prevent the poor data quality issues). It needs to be established which type of software and hardware is needed for making these codes and which departments in the company need to use this technology. More important, however, is which processes should change in order to get the desired improvement, which information should be contained by the DMC and how this information can be integrated with the ERP system. This will help to prevent errors and therefore lead to a more efficient usage of SAP.

It is possible to analyse the costs of the investments (hardware and software) that are needed in order to implement DMC. It is also possible to calculate potential time savings with this technology. The redesign will be on the basis of improvements found in literature and the current available technologies. It is not possible to take the exact development costs of SAP into account and how the exact changes needed to be programmed in SAP. These issues will be discussed in Chapter 7. This study will eventually be of a supportive nature for a decision regarding a possible investment in the identification technology.

1.3.3 Preconditions

It is important to set up preconditions for the design of a possible solution. Otherwise the possibility exists that solutions are designed that are not feasibly for a practical implementation. In consultation with XXXXX it is determined that the following preconditions should be met when designing solutions:

- The new technology should be integrated within SAP.
- The requirements for labels on internal and external purposes still need to be met.
- The new system should be user-friendly.

With user-friendly it is meant that the new system should be easy to use and logical, because otherwise the goal of improving data quality could overshoot its mark as a lot of time then will be lost in operating the new system.

1.4 Research Approach

Now that a practical problem statement is formulated, the next step is to formulate research questions which will be used to solve with the help of a certain research approach. First the research questions

will be formulated and secondly a research model with the methodology of choice will be presented. Finally, the prospected end results this study is supposed to deliver will be discussed.

1.4.1 Research Questions

In order to develop a valuable business case the following question needs to be answered:

'How can the AIDC technology Data Matrix Codes contribute to the performance of business processes conducted by Thales Electronic Systems GmbH in a cost-efficient way?'

With a possible contribution to the business processes, refer to the possible benefits (like decreasing time to finish a business process) that the DMC technology could bring. The possible contribution will be compared with the necessary costs and other disadvantages to determine whether an investment in DMC will be cost-efficient.

In order to acquire the information needed to answer this main question a number of sub-questions have been formulated which will be answered through a literature review, and a qualitative and quantitative research at TES.

Theoretical

- What exactly is a Data Matrix Code?
- Which possibilities are there to use a Data Matrix Code?
- How should the business case be developed?
- Which methods contribute to the development of a Business Case?
- Which indicators should be used in order to measure the benefits of the Data Matrix Code?

Analysis

- How are the current product flows organized (physical and in SAP) within TES?
- How are the current processes organized for the manufacturing of the current labels?
- How much products purchased or manufactured at TES need a Data Matrix Code for identification?
- How is the current time consumption in SAP of business processes within the selected scope?
    - How is the Business Process Diagram of the current situation?

Redesign

- What is necessary for manufacturing the labels with the new Data Matrix Codes (in terms of software and hardware)?
- What information should be contained by the Data Matrix Code?
- Which of the current processes will change due to the solution?
- Which actors will be affected by the possible changes and how does their role change?
- What are the costs of the potential solutions?

In order to structure the research (and the asked questions) a methodology for problem solving (described in subparagraph 1.4.2) will be used.

1.4.2 Research Model

As described in subparagraph 1.3.1 the goal is to develop a business case that will support a decision regarding the implementation of DMC with the purpose of improving the efficiency of input in SAP. The research will have the main structure of the methodology of the 'Algemene Bedrijfskundige Probleemaanpak (ABP)[5]' (Heerkens & Winden, 2012) in order to reach the described goal. The choice for this methodology results from the framework the ABP delivers, and since all phases this research needs are described in the ABP. The ABP distinguished two kinds of problems, namely a handling problem or a knowledge problem. In principal TES has a handling problem, because its management

[5] The English term for this methodology is the Management Problem Solving Method (MPSM).

has the feeling there is a discrepancy between norm and the reality in the context of the efficiency of input in SAP. The discrepancy is that too much time is spent in SAP than is necessary, but unknown is how large this discrepancy is. The norm would be that no time is lost in SAP due to errors, but the real question is whether this norm is really beneficial as described in previous sections. Therefore an answer is needed for the questions described in subparagraph 1.4.1, which can be identified as a knowledge problem and should be solved with a research cycle (Heerkens, 2010). This study will however differ from the usage of a research cycle and will use a more specific method in the phases 3, 4 and 5 of the ABP, namely the BC4IOP, which will be described in 2.3. A general overview of the structure of the research model can be found in Table 1.

Table 1. Structure of the Research Model

Phase	Description	Methods used	Chapter
1	*Problem Identification:* In this phase the problems will be inventoried and underlying causes will be laid. The end result will be a problem statement.	-	1
2	*Formulate a Research Approach:* The description of how this study will be executed in order to provide the needed answers to the questions asked.	-	1
3	*Problem Analysis:* A more detailed research of the problems described in which the knowledge problems will be answered and the impact of the problem will be disclosed.	BC4IOP -BPE -BMP SMART	2,3,4
4	*Formulate Possible Solutions:* Describe the criteria, which will be used to classify the possible solutions. Generate solutions in order to solve the problem and evaluate them with the formulated criteria.	BC4IOP -BPE -BMP SMART	5,6
5	*Choose a Solution:* Choose the solution, which is according to the criteria and the preconditions the most suitable for solving the problem	BC4IOP -BPE -BMP SMART	6
6	*Implementation:* Formulate a plan for the implementation in which activities and possible resistances will be described.	-	7
7	*Evaluation:* Compare the realized situation with the desired situation.	-	8

Although the ABP consists of seven phases only the first six will be executed. This is because it is not possible to overview the actual implementation and therefore evaluate it (due to the limited time available for this assessment in the current timeframe at TES).

In the table various methods are identified, which will be used to support the research and to generate the answers to the questions posed. A description of the methods used and how they will be implemented in our research approach are to be found in Chapter 2.

1.5 Outline of the Bachelor Thesis

Chapter 1 is the introduction to the problem and presents the motivation for this research. It also presents the framework in which this project is conducted. Furthermore it will describe the methodology used in the conduct of a cost-benefit analysis for this specific problem.

Chapter 2 describes the results of the literature research carried out. The findings in the available literature will be used for the analysis of the current business processes and the possible solutions

DMC could bring. It will also describe, in more detail, the methods to be used and how they will be used.

Chapter 3 will introduce the general framework used to measure the benefits of the introduction of a new AIDC technology. This general framework is based on the Simple Multi-Attribute Rating Technique (SMART).

Chapter 4 will give an overview of the current business processes (related to the in-house materials movements) and the time needed to conduct these processes. Both the actual movements and the information side will be analysed. Thereby the other questions asked (under analysis) in the subparagraph 1.4.1 will be answered.

Chapter 5 will present the application possibilities of the technology DMC and its potential disadvantages in the context of TES. It will also describe the current processes at Thales Transportation Systems GmbH in Arnstadt which already uses DMC. At the end of Chapter 5 a plan of requirements for the new solution will be provided and the criteria which will be used to assess the generated solutions.

Chapter 6 will describe the results of the redesign the current business processes with DMC. It will give an overview of the cost estimations and the potential savings/benefits (quantitative and qualitative) when using DMC (multiple solutions will be given, because the products and necessary hardware can vary). A final solution will be proposed.

Chapter 7 will provide an initial plan for implementation and will present the conclusions of the business case. This chapter will as well discuss the possibilities to implement the solutions at different locations of Thales.

Chapter 8 will provide a conclusion about the study conducted and discuss the shortcomings of study.

Chapter 2: Literature Review

In order to find which possibilities are available with DMC and which benefits they can generate, a review of literature has been performed. First, information will be provided about the DMC in general and about the possibilities created by the new technology, when DMC is chosen as a potential investment. Secondly, a business case for IT will be explained, and the potential benefits related to the investment in an IT project will be discussed together with how these benefits and values can be measured. Thirdly, theoretical bases will be sought in order to analyse current business processes and how to redesign them.

2.1 Data Matrix Codes: Description

Most people are familiar with the traditional one-dimension barcode which is the standard for most product identifications (see for example the products in a supermarket). However the need for storing more information within a barcode has led to the development of the two-dimensional barcode. Most people will know a variant of the two-dimensional barcode, namely the Quick Response-code, which is used for advertisement purposes and can be scanned with smartphones. The variant of two-dimensional barcode, which is considered for being implemented at TES, is the ECC200, which is possible to manufacture at TES.

The Data Matrix is defined as a square or rectangular symbol made up of individual squares and has an ordered grid of dark and light squares. Those squares are bordered by the so-called finder pattern, which is used to specify the orientation and structure of the symbol. The Data Matrix Code (ECC 200) is the data carrier, which represents data in a readable form (Benhaim, et al., 2011).

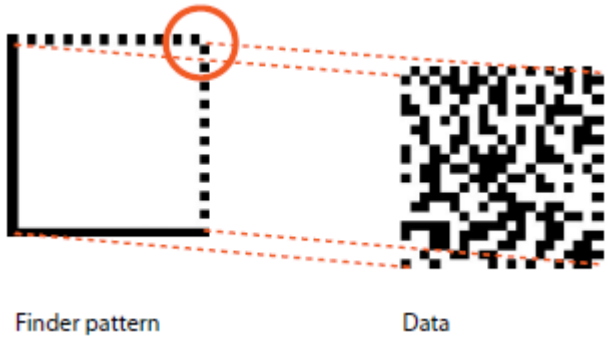

Figure 4. Finder Pattern and the Data (as found in Benhaim et al., 2011)

The size of the square (rectangle is also possible) can vary largely depending on the amount of data one would like to encrypt, but also other aspects have to be taken into consideration such as the size of the product on which the DMC will be placed. Also, it is necessary to determine if the DMC needs to be read by the customer (or supplier by returns etc.). At TES, some customers ('Bundeswehr') already demand these DMCs and the requirements have been established in the 'Technische Lieferbedungen' (BAAINBw, 2013). TES delivers those products corresponding to the GS1 Data Matrix, which are simply ECC 200 DMC, but places in the data have Application Identifiers (AIs) so when the codes are read out in a corresponding application, it recognizes the definition of the data (see Table 1, which shows the main GS1 element strings).

Table 2. GS1 Element Strings (as found in Benhaim et al, 2011)

AI	Data Definition	Format (AI/data)*
01	GTIN	n2+n14
10	Batch or Lot Number	n2+an..20
21	Serial Number	n2+an..20

*Meaning of the abbreviations used:

Table 3. Abbreviations GS1 Table (as found in Benhaim et al, 2011)

n	Numeric digit
an	Alphanumeric characters
n2	Fixed length of two numeric digits
an…20	Variable length with a maximum of 20 alphanumeric characters

It is possible however, to deviate from these GS1 ways of constructing a DMC. When these DMCs are used externally, it is the question of whether a customer agrees to deviating DMC since they could insist on standardized DMC from their suppliers (so that their system reads the information correctly).

2.1.1 Barcode: Possibilities

The usage of barcode technology is currently widely used and it can be stated that the barcode has reached a state of maturity. It has therefore become much more affordable to make it suitable for even small-scale niche applications (McCathie & Michael, 2005). The introduction of barcodes in manufacturing and logistics have reduced the error quote and increased the productivity at various companies (Varchaver, 2004). In order the read this barcodes it is necessary to be in the 'line-of-sight', in other words you need to see the code before you can scan the item. This means that only one item can be handled at a time. A correct usage of a barcode can provide better information for, among others, asset tracking, inventory management and quality control. The challenge for an organization is to determine what information should be put into the data carrier and to make clear for what further use the information is.

In construction management, a solution regarding the information input process is already being suggested due to the data input rework and the easiness of making mistakes in the information input process (Tserng, Dzeng, Lin, & Lin, 2005). The usage of a personal digital assistant (PDA) makes sure that one could work paperless and provide real-time information to the main office in order to improve the project planning. The barcode ensures an automated capture of the necessary data, which could lead to an increase of the accuracy and indirectly productivity. See subparagraph 1.2.2 for the impact of poor data quality.

2.2 Developing the Business Case

To get approval for a new IT project, one often makes a business case in which the costs and benefits of the project are rationalized and presented from a business perspective. In general, there are three views on the specific function of a business case, namely to get an investment approval for a single project, in the case of multiple projects to compose a project portfolio, and as a management instrument that can be used to manage the implementation process (Eckartz, 2012). The relevant view in this case is to get an investment approval for a single project, the DMC (and to find out whether this is cost-efficient). Although there is not a single template for all cases, it is possible to describe a general structure on which a successful business case is based (Schmidt, 2003). There are five general categories distinguished by Schmidt (2003) in which the essential building blocks of a business case lie, namely the following:

A. Introduction and Overview
B. Assumptions and Methods
C. Business Impacts
D. Sensitivity, Risks and Contingencies
E. Conclusions and Recommendations

In principal, a good business case should contain elements out of each category. Important is when proposing a new IT initiative or building a business case, it is necessary to put a value statement in a meaningful business context, as business users want improved business outcomes resulting from IT

initiatives (Hunter, et al., 2008). Hunter et al present a framework how to translate IT benefits into business value impact. They distinguish three investments categories, namely running the business, growing the business or transforming the business. In the case of TES, the possible implementation of DMC falls within the category of running the business, because the investment in the technology will potentially reduce costs and lessening the risks on errors. The value statements for running the business need to justify the investment in terms of price/performance. This can be in terms of improved accuracy, eliminate rework or unplanned downtime etc. DMCs are most likely to improve metrics in the supply management, in relation to operational efficiency, potential asset utilization and the number of errors. The aim of a business case should be in principal to express as many of the benefits as possible in financial terms, but that can also result in a number of issues (Ward, Daniel, & Peppard, 2008) such as overstating the financial benefits (or a creative way of calculating them) in order to get a project approved. Ward et al (2008) therefore suggests that organization should try to formulate business cases that include a variety of benefit types, instead of just those which can be ascribed to a financial value.

To support the development of the business case several methods are put into use, which are described in 2.3.

2.3 Business Case for Inter-Organizational Projects (BC4IOP)

As described, the goal of this study is to develop a business case for the DMC. The method BC4IOP, which is developed by the research project of Eckartz (2012), can be used to develop a business case. Although it is originally developed for the construction of a business case concerning multiple organizations, the structure of the methodology can still be used within a single organization like TES, because the DMC will have different impacts on various departments. In addition to this, the methodology will provide more structure to the development of the business case. The main structure of this method can be found in Figure 5.

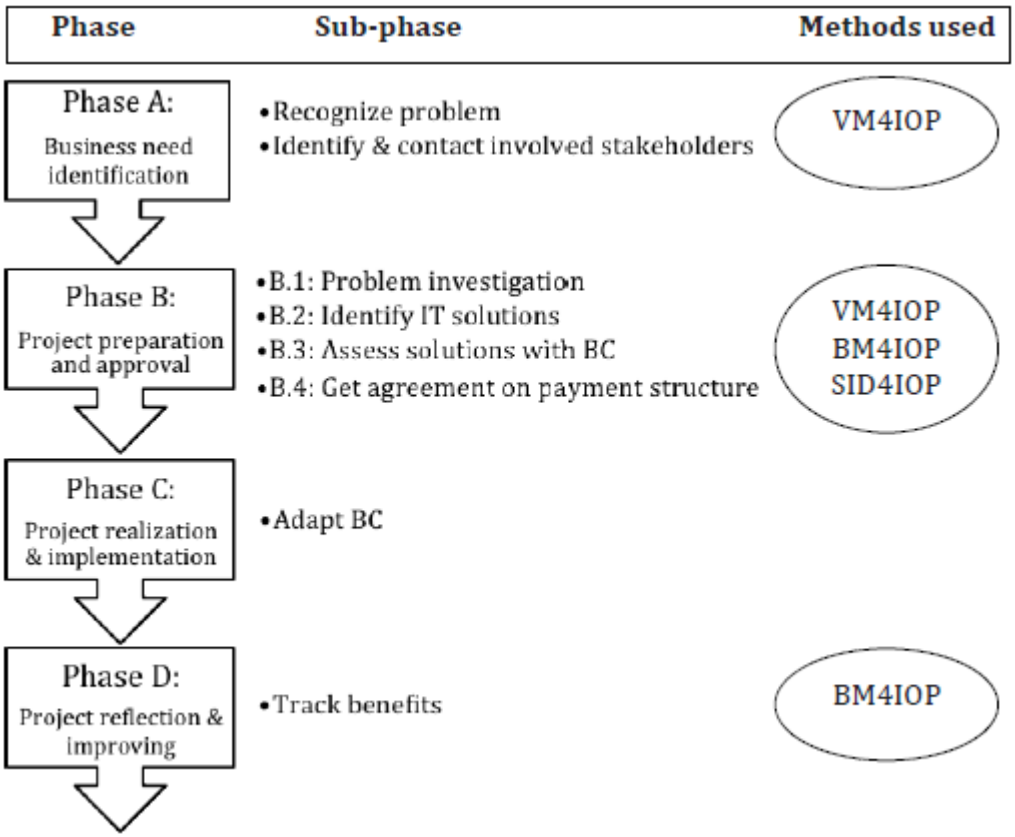

Figure 5. Meta-level overview of BC4IOP phases (as found in Eckhartz, 2012)

Due to the limited time window (approximately three months), it is not possible to conduct the whole method as described by Eckhartz. Only phase B of the BC4IOP method will be part of this paper. Phase A is already conducted in Chapter 1 with the structure of the ABP. The analysis of the current situation and identification of solutions with DMC will however be done in the structure of the BC4IOP, as this is more specific than the ABP in the context of this research. So steps B.1. through to B.3. will be conducted. An assessment of the potential costs and savings will also be made in order to support management on B.4. The actual decision for getting an agreement on the investment costs and the (degree of) adaption of the business case lies with management.

The methods needed to conduct the BC4IOP are as shown in Figure 5 the value model for inter-organizational projects (VM4IOP), benefits management for inter-organizational projects (BM4IOP) and structured information disclosure for inter-organizational projects (SID4IOP). Those supportive methods will, however, not be used in the current form, since other methods described in 2.3.1 and 2.3.2 are more suitable. For the phases B.1. through to B.3. the methods Business Process Engineering (BPE) and Benefits Management Process (BMP) will be used.

There is a difference between a Value Model (VM) and a Business Process Diagram (BPD), which follows from Business Process Engineering (BPE). The VM outlines the objects of value that are being exchanged by different parties and the BPD describes the way a VM is put into operation, namely by stating the activities needed, as well as their sequence to create, distribute and consume value (Gordijn, 2002). DMC only changes the way the data is carried and therefore current business processes can change, but the value created by the departments for other departments is not likely to change (but if they do so the changes are not radical). Therefore the choice has been made to only use the method BPE for which the book Business Process Engineering (van den Berg, Franken, & Jonkers, 2008) will be used as guidance in making the analysis. In order to make the analysis of the current business processes, and the new situation the software BiZZdesigner will be used.

The general model for BMP differs from the BM4IOP, but the latter is based on the BMP developed by Ward and Daniel, 2006. Some parts of the BMP were described as too complex by practitioners (Eckartz, 2012), but because this particular problem does not have the size characteristic of a large IT investment or with different organizations involved, the original method will be used.

The SID4IOP will not be used, because this concerns to process of the distribution of costs between organizations and negotiation processes which is not part of this study.

Phase B.1.
In this phase, a solid foundation will be built on which the business case will be developed. The situations (business process and stakeholders) that will be analysed will be those that are directly related to the problem (see Figure 1.). This will be done with a BPD. In order to compare the current situation with a new situation the added value of a business process will be quantified. In order to do so usage will be made of the SMART heuristic to develop a general framework in which the current situation and solutions can be quantified.

Phase B.2.
Although the choice for the computing platform has already been made, various solutions can be designed because the number of applications with DMC varies and the software and hardware can vary. Also the implementation of the solution will be taken into account. For those solutions, a BPD will be made and the method BM presented by Ward and Daniel (2006) and SMART (see Chapter 3) will be used to assess the benefits and these benefits will be quantified in Chapter 5.

Phase B.3.
Eventually, all the benefits (qualitative and quantitative), and the disadvantages of a solution, will be compared (together with the stakeholders) in order to choose a final solution based on the results of the SMART heuristic.

2.3.1 Business Process Engineering

In order to make a better assessment of the current business processes and to get a better understanding of these processes, the relevant processes will be put in a BPD model. The importance of a good understanding of the deliverables becomes clear when assessing the reasons why projects fail. A research showed that a weak business case was one of the common reasons for why projects fail, and where some of the respondents of the research commented that the complexity of the deliverables was not understood by the key users (Whittaker, 1999). In order to prevent that from happening, a clear overview of the current business processes and the deliverables with DMC needs to be presented in order to provide a clear understanding of the intended changes with the new technology.

The process can be viewed as a horizontal organizational form, which contains the interdependence of tasks, roles, people, departments and functions that are required to eventually provide a customer (internal or external) with a product or service (Earl, 1994). To model these business processes the software BiZZdesigner will be used (van den Berg, Franken, & Jonkers, 2008). This process modelling language makes it possible to compare the new situation with the current situation in which a clear understanding of the deliverables can be presented.

2.3.2 Benefits Management Process (BMP)

As previously described in 2.3 purely stating the benefits of a new IT technology in financial terms can lead to several issues (Ward, Daniel, & Peppard, 2008). This research will, therefore, exceed pure cost estimation of the new technology, due to the usage of Benefits Management (BM).

'Benefits management is an approach to identify, estimate, plan and manage the delivery of benefits.' (Eckartz, 2012)

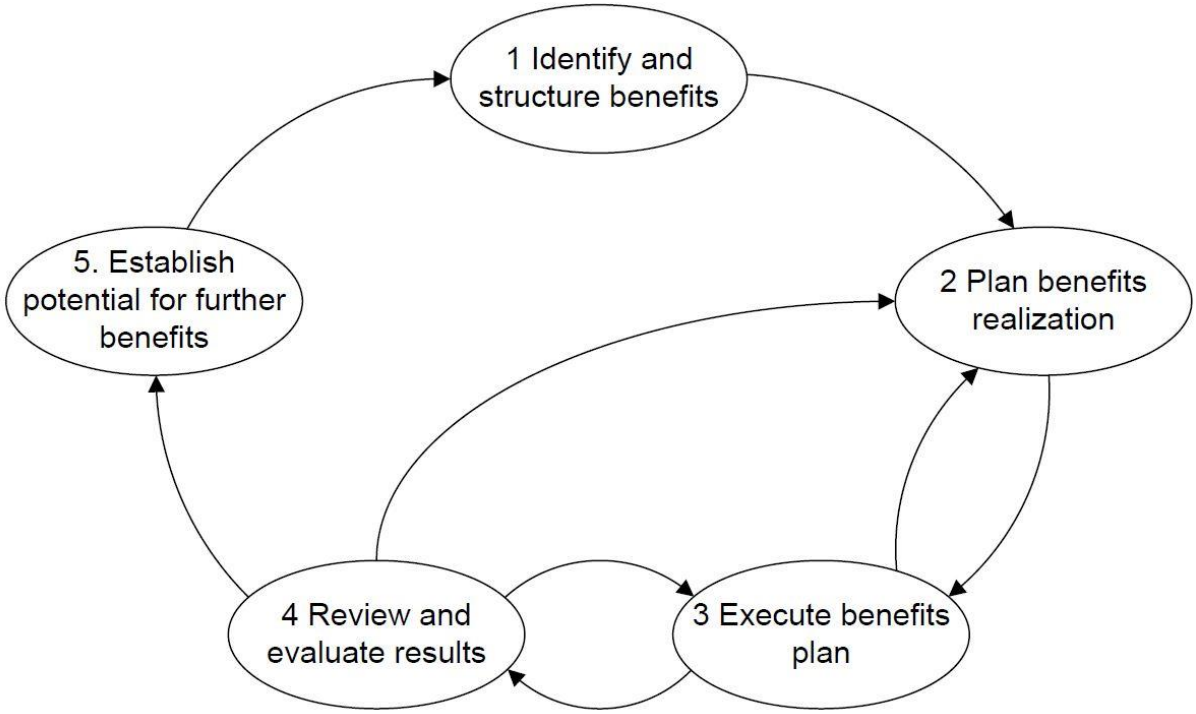

Figure 6. A Process Model for Benefits Management (as found in Ward & Daniel, 2006)

BM is more complex than pure cost estimation as the correct identification, quantification and realization of the benefits requires a more in-depth understanding of the business processes which are influenced by the new technology (Eckartz, 2012).

In order to manage the delivery of benefits provided by a new IT system, the Benefits Management Process (BMP) is developed (Ward & Daniel, 2006). This process should be, according to Ward & Daniel (2006), the driving mechanism behind the activities of change (in an organizational or a business context) for delivering benefits from IT investments. See Figure 6 for an overview of the steps conducted in the BMP. In order to develop the initial business case, the first stage of the BMP must be completed.

Identifying and Structuring the Benefits

In this step, the overall business rationale for the new/improved use of the technology the business contribution will be determined among others from the results of the BPE analysis and the literature review conducted. The nature of the investment also needs to be determined in order to find the possible and relevant benefits and to answer the question if they are achievable at all. For the possible natures of an investment see Figure 7.

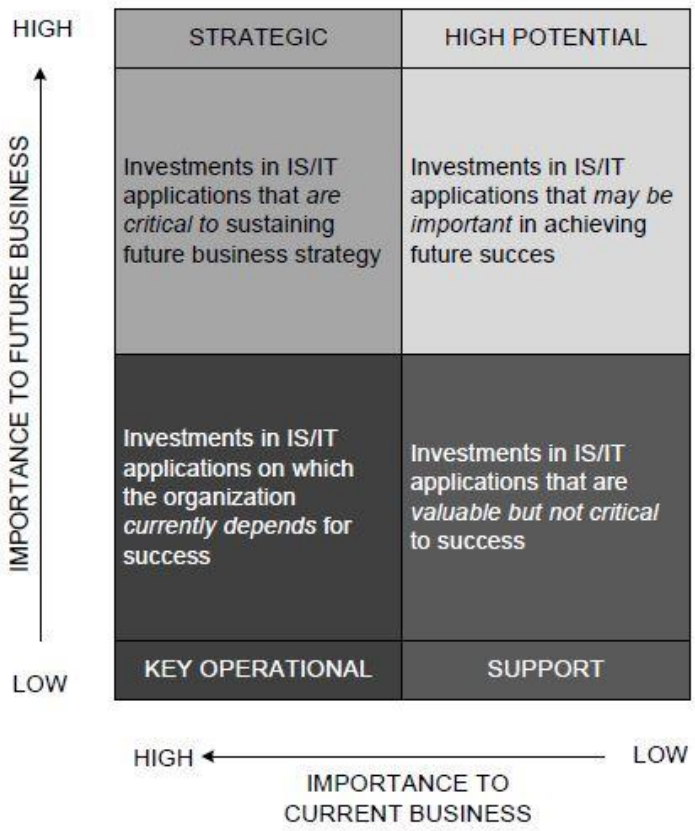

Figure 7. The Application Portfolio (as found in Ward & Daniel, 2006)

The purposes of this stage in the BPM process are as follow (according to Ward & Daniel (2006)):

- Establish agreed objectives for the investment related to the change drivers
- Identify all potential benefits, which are possible to obtain by achieving the established investment objectives
- The understanding of how the combination of the IT functionality and business changes will cause the potential benefits
- How to determine whether the possible benefits have been realized
- Identify possible issues or implications that could cause the project to fail

At the end of this stage, an outline business case will be generated, and this business case will help to decide whether to proceed further with the project developed or to stop the project prematurely. The end of this stage, in fact, marks the boundary of this study, because the assignment only requires finding out the possible contribution of the suggested technology to the organisation. Ward & Daniel

(2006) also states that benefits are 'owned' by individuals or groups who want to obtain value from the investment. It is also important to find out where this benefit is going to occur, how it will be possible to measure and who is responsible for delivering the respective benefit. This is relevant for identifying the possible benefits because if the benefit cannot be measured, it cannot be owned according to Ward & Daniel (2006). Some benefits are possible to measure directly and so it is possible to give an economical appraisement. Some benefits can be measured indirectly, such as an improvement of the employee satisfaction (which can be measured with surveys). This improvement of the employee satisfaction, can lead to a higher productivity, for instance, or improve the image of the firm involved.

Benefits Identification Matrix

Eckartz (2012) proposes a benefits identification matrix to structure and support the process of defining an extensive benefits list. The benefits are divided in five categories and where the benefit can be classified as operational, managerial, strategic, organizational and IT-infrastructure nature (see Figure 8).

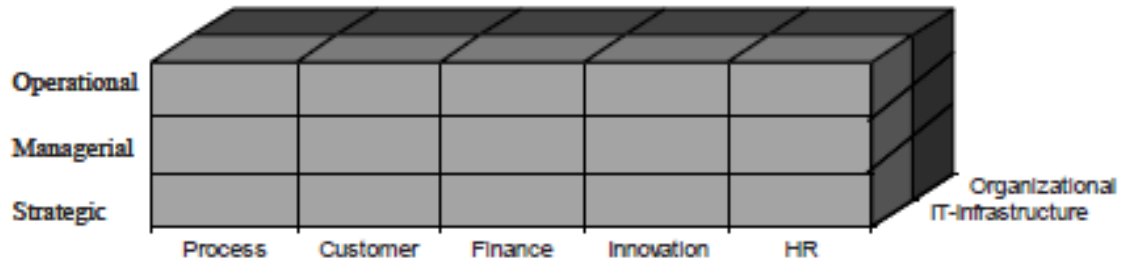

Figure 8. Benefits Identification Matrix (as found in Eckartz, 2012)

2.3 Possible (Dis-) Benefits and Risks

With the theoretical basis established for the build of the business case, the possible benefits that could be achieved using a new information system will be examined in more detail (relative to the investment project). Possible disadvantages will also be mentioned, and risks in order to establish a clear framework within which the potential value of the solution can be determined.

Lean management is already widely applied within supply chains. However, lean, in terms of information management, is less well known. The principles of lean (amongst others, eliminating waste) are applied to management of information by Hicks (2007). Waste within the context of information management is, in principle, not visible and not as clear as waste within a production process (Hicks, 2007). In his paper, Hicks (2007) establishes various forms of waste within information management, which could be reduced by improving the information quality. In the philosophy of lean in the context of information management, one should identify and realize focused improvements on various aspects of the information management such as sources of information or information for business processes, according to Hicks (2007). This is to eliminate waste and to improve the value of the information flow, which can lead to improvements in the efficiency, productivity and quality of the overall process. Waste in the area of information can be as follows (relevant for this problem): numbering and traceability of machines, assemblies and parts, information completeness and accuracy, information duplication.

Also, the improvement of the motivation of the employees could be a potential benefit. Spending time at work itself is a high motivator (Herzberg, 1987). By decreasing the time spend to administrative tasks and repairing errors could lead to more time spent on the actual job, such as repairing or analysing items. However, the administrative part is also a part of the job and making that job less challenging could demotivate employees. One should make a distinction between jobs in which the administrative work is a key part of the job itself or is of a supportive nature of the job.

As already identified in listing the possibilities of barcodes, using this technology may enable paperless work, improve project planning due to fast information sharing and an automated capture of

the necessary data, which, in turn, could lead to an increase of the accuracy and indirectly productivity (Tserng, Dzeng, Lin, & Lin, 2005). However, when implementing a new technology, it is expected that productivity will not increase or it is possible that it may even lead to a temporary decrease. Additionally, costs of organisational restructuring may be expensive, if groups resist to the change (Love & Irani, 2004). The time consumed by the management needed in guiding the project is usually experienced as costly (indirect costs). According to Love & Irani (2004), to leverage the benefits from IT one should also develop an expected IT benefits and cost management plan that will also anticipate potential indirect costs.

Based on the findings available in the literature and logical thinking, an initial table can be established (see Table 4 and 5) with possible benefits and disadvantages for the investment proposition. In Chapter 4 and onwards an assessment of the current situation will be made and an indication will be given whether the benefits are applicable to the suggested solution with DMC. The definitive benefits will then be described in the Benefits Identification Matrix (see Figure 9).

Table 4. Possible Benefits Found in Literature

Benefit	Explanation
Time reduction[6]	Less time is spent filling in the data input, therefore a job costs less time.
Information completeness and accuracy	Establish one standard way of putting in data (by scanning).
No information duplication	Due to DMC, there is one way to make an interpretation of the information.
Error reduction and less rework	Manual input is reduced and therefore no errors will be made due to typos.
Productivity increase (also see time reduction)	Since a job costs less time, more jobs can be done within the same time which leads to an increase of productivity. More jobs can potentially be accepted.
Decrease of the costs of a job (also see time reduction)	Since a job costs less time, the cost of the job decreases (salary of an employee is distributed on more jobs or the same number of jobs is done with less people).
Increase of motivation	More time can be spent on the work itself rather than administrative work.

Table 5. Possible Disadvantages and Risks Found in Literature

Disadvantages and Risks	Explanation
Decrease of motivation	Due to automation, work can be less challenging and therefore the employee can become demotivated.
Unforeseen costs	There is a risk that the implementation will cost more time than initially estimated and employees need to get used to the system which could lead to a decrease of productivity.
Employees resist the new system	There is a risk that employees will not see the benefit of the new system and therefore they will still use the old system, which will lead to higher costs.

[6] Time reduction can be monetized in different ways. For example an increase in productivity leads to a lower cost price, but is only valuable when the utilization of the employees is high. If it isn't possible to do more jobs (because the number of orders isn't sufficient) the amount of employees can be decreased in order to cut costs.

Chapter 3: General Framework

In order to make the added value of the new technology measurable with the current situation the benefits made possible due to the new technology will be quantified. This general framework will provide insight into whether the proposed investment is an improvement with respect to the current situation and a tool to compare different solution proposals. For this purpose, the ranking method of the simple multi-attribute rating technique (SMART) will be used. This will be slightly modified in order to make a general framework applicable at different locations of Thales, explained in section 3.2. The common denominator in determining whether the solution is cost-beneficial is the number of data inputs required to carry out the business processes. This aspect is closely related to the number of material movements carried out (due to the nature of DMC). The general framework should in the end provide a score, based on the benefits, disadvantages and risks and the number of data input, which can be compared with each other. This score could be used to support the decision for a certain investment propagated by the business case.

3.1 SMART Heuristic

The main difficulty of making a general framework for assessing different investments is the aspect of qualitative variables which need to be made measurable. Besides the large number of aspects taken into consideration for conducting such an analysis understanding the problem might be difficult. The central idea of the heuristic SMART is that splitting the problem into small parts and focusing on each part separately, it is more likely that the decision-maker acquires a better understanding of the problem (Goodwin & Wright, 2010).

The benefits and disadvantages described in paragraph 2.4 will be formalized as objectives, which can be maximized or minimized, and the score of an objective is determined by its attribute, which will be used to measure the performance (of a possible solution) in relation to its corresponsive objective. These numerical scores, derived from the attributes of an objective, will be used to rank potential solutions in order to select and justify a suitable solution for this particular problem.

Conducting the SMART heuristic consists of several stages as described in Goodwin & Wright (2010), namely the following:

- Stage 1: *Identifying the decision-maker(s)*.
- Stage 2: *Identify the alternative courses of action.*
- Stage 3: *Identify the attributes that are relevant to the decision problem.*
- Stage 4: *Measure the performance of the alternatives on the attribute.*
- Stage 5: *Determine a weight for each attribute.*
- Stage 6: *For each alternative, take a weighted average of the values assigned to that alternative.*
- Stage 7: *Make a provisional decision.*
- Stage 8: *Perform sensitivity analysis.*

The eventual goal of the general framework constructed with the SMART heuristic is that other location of Thales can use the template framework and fill them in with their own scores and make a decision supported with the results of the SMART heuristic whether or not the new technology is suitable for them.

3.1.1 Stage 1: Identifying the Decision-Maker(s)

In this case, the main decision-maker is senior management of the Materials Management at TES, because the general framework is only used to assess the current situation at the location in Kiel. In future analyses for other locations, their corresponsive management of Materials Management will be the decision-maker. If a solution involve multiple locations, then the general decision lies most likely in the headquarters of Thales Deutschland in Stuttgart.

3.1.2 Stage 2: Identifying the Alternative Courses of Action

Although the computing platform has already been decided (Data Matrix Codes), there are still different possibilities for reading these codes or standardizing the data input in order to prevent errors made or saving time for the data input. It is even possible that some solutions can co-exist, but that depends largely on the budget available.

In terms of reading devices (hereby referred to as technology), the choice is largely between three categories, namely:

- USB-corded 2D Barcode Scanners
- Wireless 2D Barcode Scanners with a Monitor
- Batch Barcode Scanners

An assessment of the technology will be made in Chapter 5, which technology will be suitable as a potential solution based on an evaluation of the current situation. Other possible solutions are limiting in the areas of data input (by making certain templates in SAP) in order to reduce the amount of errors and time needed in SAP.

3.1.3 Stage 3: Identify the Attributes & Stage 4: Measurement

The attributes that will distinguish the different solutions will be factors such as the benefits described in table 4 and 5 and those found in the analysis of the current situation. A value tree will be used to break down general attributes into specific attributes which can be given a numeric score. This makes it easier to compare the different solutions. The next step is to assess the scores of the solutions on different attributes.

3.1.4 Stage 5: Ranking the Attributes & Stage 6: Ranking the Solutions

It is unlikely that each attribute is equally important as any other attribute. Therefore it is necessary that the attributes will be ranked and will be given a weight in order to reflect which attribute is more important to the decision-maker. It is possible that a different decision-maker will make a different ranking of the attributes, which is not problem in the SMART heuristic. One can simply change the value of the weights in the calculation, which can lead to a different ranking of the solutions (which is a measure of how well the solutions perform over all the attributes).

3.1.5 Stage 7: Decision & Stage 8: Sensitivity Analysis

Based on stage 6, one should make a provisional decision, specifically, the solution that is going to be implemented. To see how robust the decision is to changes, the scores of different attributes are subject to a sensitivity analysis.

Once all stages are conducted for the problem at TES, the general framework will be complete and can be applied at different locations, because the only things likely to change are the cost-aspect (based on materials movement) and the weights of the attributes if the decision-maker has a different opinion. Scores on an attribute such as job satisfaction is likely to be the same.

Chapter 4: Analysis of the Current Situation (Phase B.1. of BC4IOP)

As described in paragraph 2.3 in this phase of the BC4IOP, the foundation of the business case will be built. The current situation, where the main problems related to the poor data quality occur, will be analysed. Before a more detailed view on specific departments (related to Figure 3.) and their internal business processes will be made, an overview of the business processes and how they interact with each other, a main business process diagram will be presented. The end results of this section should lead to a clear picture of where the AIDC technology, DMC, potentially could help to improve the business processes for which solutions could be designed. Before the business processes are analysed, some background information will be given about the current systems in use at TES.

4.1 SAP ERP ECC 6.0 and Legacy Systems

As the market and technology leader in client/server enterprise application software, SAP provides solutions for companies of all sizes and all industry sectors (Murray, 2012). The current client/server in use by TES is the version Enterprise Core Component (ECC) 6.0. This version integrates four core functional areas, namely Finance, HR, Corporate Services (i.e. Quality Management etc.) and Operations, which can be used for managing the available data.

It is possible to implement business suites alongside the core ECC 6.0. For the logistics side of SAP, for example, Materials Management (MM) the business suite SAP Supply Chain Management (SAP SCM) could have been implemented. This contains, among others, the functionality SAP Extended Warehouse Management (SAP EWM) in which, for example, order picking can be managed. However during the implementation of SAP in 2011, management chose not the implement this business suite. Legacy systems preceding the SAP-era are, therefore, still used at TES. In particular, this concerns two applications developed in Microsoft Access: **'Kommisionierungstool[7]'** which is a communication tool used (first in use on 21.2.2007) between the manufacture planners and the personnel who picks orders at the warehouse. The manufacture planners fill in a new order that needs to be picked and when it should be ready. The warehouse personal picks the order and they let the manufacture planners know that the order is ready via 'Kommissionierungstool'. The orders and the necessary labels for the order itself are, however, are brought to the warehouse personally by the manufacture planners. The application simply provides an overview of when an order is requested and to see whether it is ready or not.

'Versandtool[8]', which is in principal the same as the 'Kommisionierungstool', is used to provide an overview of all the shipments which need to be carried out. An employee who needs to ship something can make a shipping order. The goods and the delivery note are brought to the shipment department where an employee packs the goods and makes sure the paperwork is completed accordingly. The paperwork is scanned and attached to the shipping order in the application. The employee of the shipment department also has the possibility to attach pictures to the shipping order to be used in the event of liabilities should a package be damaged.

The principle in SAP (like any other ERP system) is that an employee can log in and conduct transactions within SAP. In these transactions, the necessary information is entered or information files are created by the employee. The information or files can be used by other employees. The employees can request this information directly after the transaction is saved. An employee will not have access to all the transactions, otherwise the system could be misused. Examples of transactions are receiving of goods, opening a project or placing an order for supplies.

XXXXX

[7] Order Picking Tool
[8] Shipment Tool

4.2 Overview of the Business Processes related to Material Management

This section will provide more insight in the current business process at TES. Due to the scope of this research (Figure 3.) only the logistics side (material movements etc.) will be taken in account. By making use of internal work instructions and interviewing employees it was possible to create a global overview of the logistical processes.

XXXXX

Two figures are presented that display the general processes of production and providing service (Figure 10 and 11). These figures display how different departments interact with each other. These two figures, however, do not take every possible exception into consideration, as these exceptions are not relevant for the purpose of this study.

Description of the General Business Processes

The Business Process Model found in Figure 10 provides a general overview of the business processes conducted at TES. The process starts when the requirements for a project have been established and the manufacture planners can determine which supplies need to be ordered. The manufacture planners can also make the technical product documents, which contains drawings, work instructions etc. The supplies are ordered in a so-called 'BANF' (BestellANForderung).

XXXXX

The supplies are ordered and are collected by the inward inspector, who checks the items for visible damages and controls whether the supply is in accordance with what was ordered. When the items are not correct or damaged, he will make a reclamation in SAP, which is also progressed by the Purchasing department. If the items are correct, then he will book the items in SAP with the transaction XXXXX. Although some supplies have serial numbers, which are also noted down, the serial numbers are not actually put in SAP. The serial numbers notes, together with the corresponding delivery note, are put in archives in case somebody needs them or when it turns out the supplies are defect. In this case, a reclamation needs to be written for the items.

XXXXX

The manufacture planners will make a picking order and communicate this via the 'Kommisionierungstool' where the deadline for such a picking order is also filled in. The 'Entnahmestückliste' (the picking order assignment) with the necessary labels are however brought personally by the manufacture planners. Booking the items out of the warehouse will be accomplished with the transaction XXXXX in SAP.

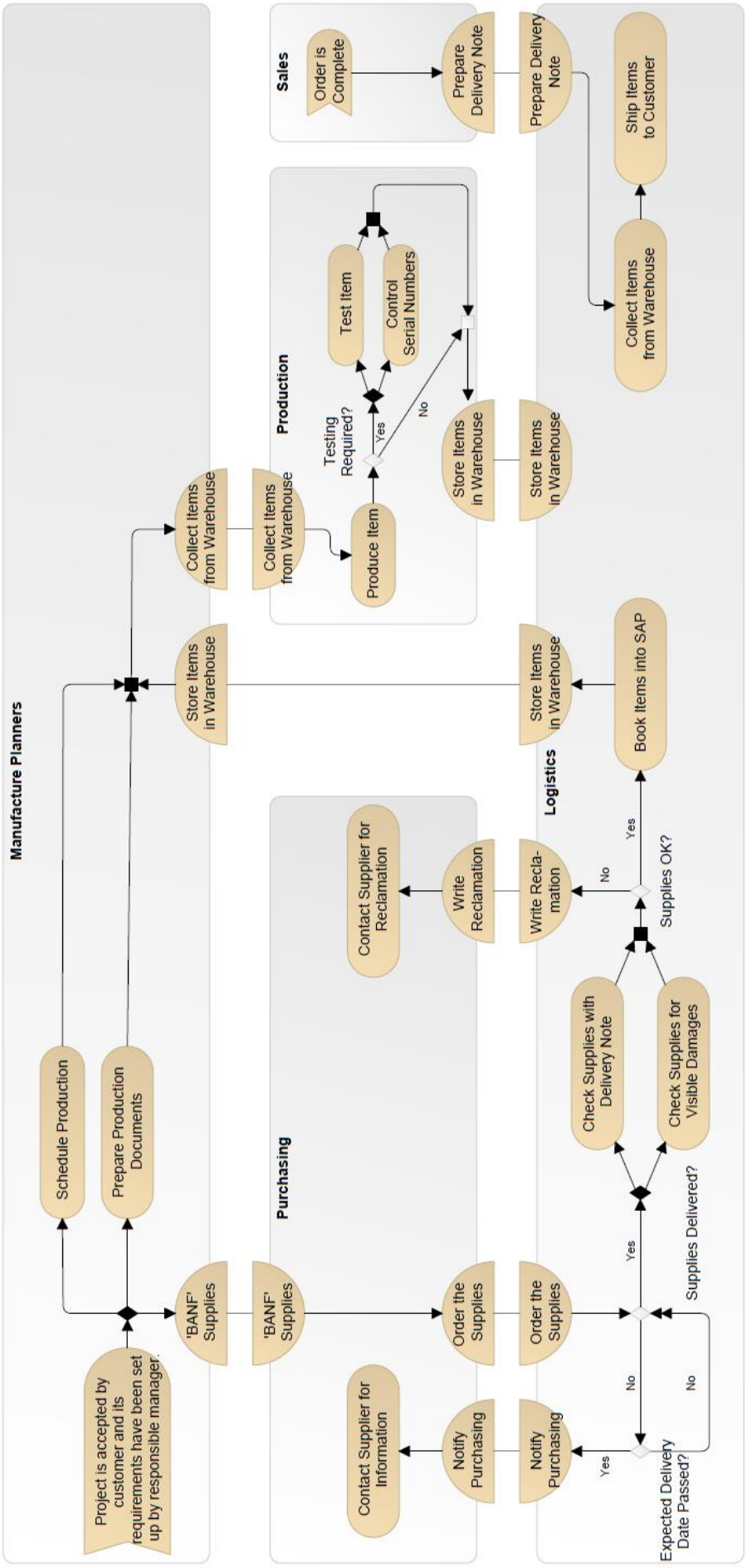

Figure 9. General Overview of the Production Process

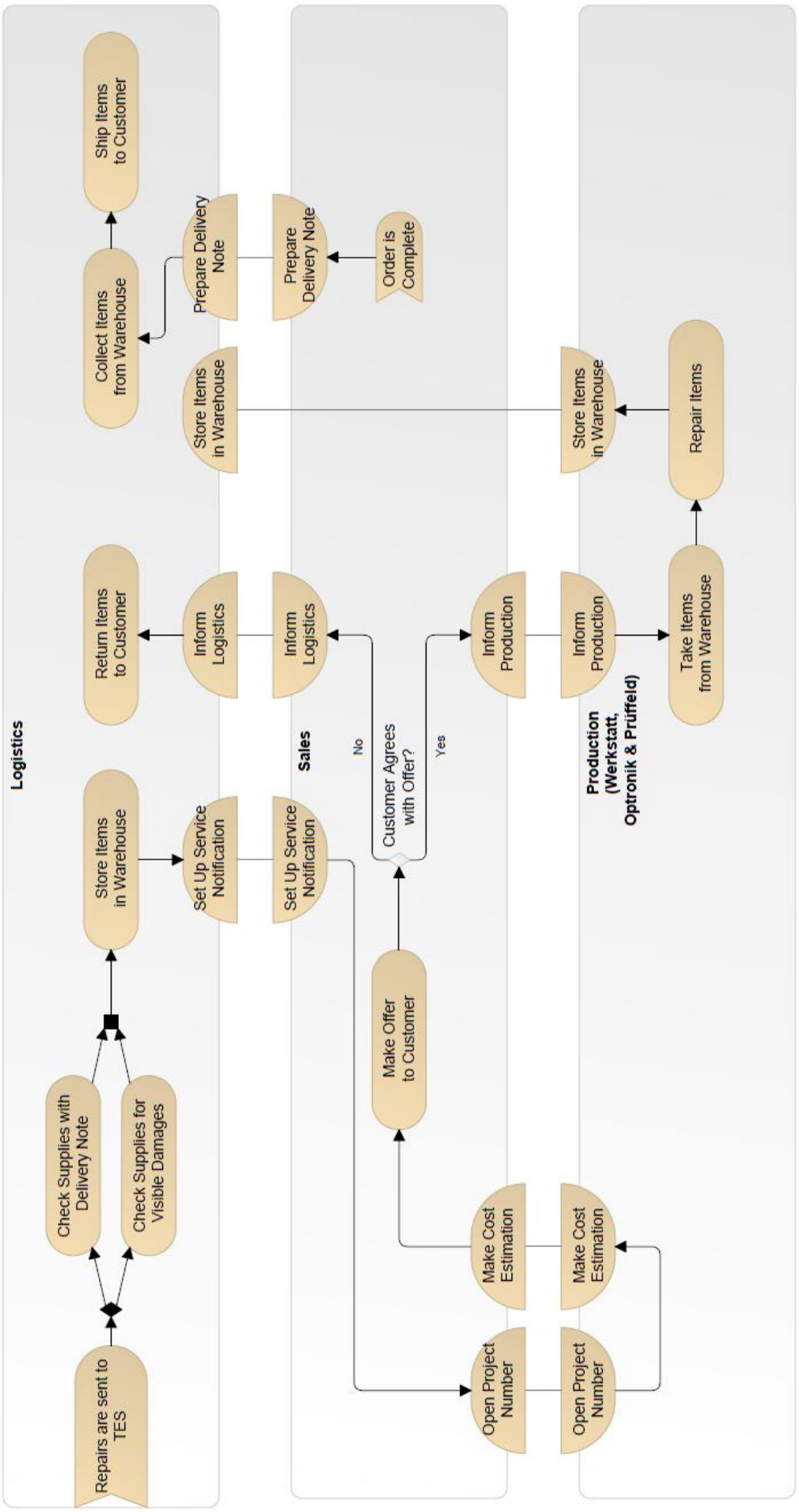

Figure 10. General Overview of the Service Process

The picked items are collected by the manufacture planners, who bring them along with the technical product documents to production, where the requested systems are produced. The items with a serial number (own components and suppliers components) are noted down. In-house produced components will get a serial number from the manufacture planners. When everything is built, then the system is transferred to the test field where the system and all its components will be tested. The notations of the production crew will be verified by having the system dismantled and checked whether the correct items (with the corresponding serial number) are built in the system. The system will be tested and build together again (sometimes together with someone from the production).

XXXXX

When the items need to be sent, then the employee, who is responsible for shipping the items, makes a notification in the 'Versandtool'. This tool, in Microsoft Office Access, provides an overview of all the shipment assignments. Additionally, all the delivery notes for shipments from TES are archived in this system.

XXXXX

When products are delivered for repairs at TES (see Figure 11), then the inward inspector opens a service notification with the transaction XXXXX. In the transaction XXXXX, he will fill in the corresponding data for the product, such as the company that sent the items and the serial number of the product. The sales department will open a project. The repair department ('Werkstatt') will make an estimate how much time they need and which materials (spare parts) they need. On the basis of this information, the sales department contacts the customer whether or not to conduct the repair. In the case of an acceptance, the products are booked from the warehouse to the repair department and repaired. When the products are finished, the goods are transferred to the shipment department which sends the items back to the customer.

With this general overview, it is possible to identify areas which are affected by the risks of putting wrong data within SAP (serial numbers). Incorrect serial numbers cause poor data quality which needs to be restored and this will cost additional time. The following areas have been identified:

- Warehouse: it is possible that items with wrong serial numbers have been booked out of the warehouse in SAP or it is possible to put in an incorrect storage location in SAP.
- Repairs: when making a service notification it is possible that wrong information has been put in SAP, which will lead to problems with warranty. The items are checked for warranty and, if the serial number is wrong, it will get a new warranty when it is repaired.
- Production and Test Field: when building components and building these components in a larger system, every serial number is noted and given to the Test Field. The Test Field then controls every component (and subparts) for serial numbers and location where it is built. This list is put in SAP and Excel, which can be subject to mistakes, because the input is entered manually.
- Shipping: needs to check whether the right components and serial numbers (which are on the delivery note given by the person who wants to ship something) are shipped. The shipping department also needs to make sure the right items are booked out of SAP.

If the poor data quality resulting from incorrect input is really a problem, a more detailed view of the previous described areas needs to be taken, which will be done in paragraph 4.2.1 through to 4.2.4.

4.2.1 Warehousing

Once the supplies have been checked by the inward inspector and determined to be OK, then there are several possibilities. Some supplies go directly to the project or the responsible person if needed and some will be stored in the warehouse when there is no immediate need for those supplies. Considering the inward process it would not be beneficial to add DMC in the process of booking the items in SAP via the XXXXX transaction, because the visual inspection and checking the supplies with the delivery

note is still necessary. The only data input which could be captured via a DMC is the order number, which can be seen in Figure 11.

Figure 11. SAP Menu of the Transaction MIGO

Problem is that every supplier should add a DMC to the delivery note, which means contacting every supplier and not every supplier will have the technology to produce such a DMC. Thereby the chance on errors is minimal, because when the order number is entered in the XXXXX transaction, a list is produced with the items contained by the order. The inward inspector would immediately spot a difference between the delivery note and the list produced by SAP, so he will notice that a wrong order number is filled in.

XXXXX

Once the supplies are booked in SAP, a 'WE-Schein' (Goods Entry Note) is printed, which provides information on for whom the supplies are, storage location etc. Considering the items that need to be stored in the warehouse, these will be picked up by an employee of the warehouse and he will put them at the right storage location. If no storage location is given in SAP or the current location is too small, then he will look for a new storage location. This new location will be noted down on paper and will later be added in SAP via XXXXX to the corresponding XXXXX (the Material Code at TES). Sometimes products will have serial numbers, these numbers will be noted down by the inward inspector on paper, but normally are not added in SAP. Although this is possible, this step is usually bypassed by the employees due to problems in the past when a reclamation is made for product. For the diagram of the current situation of booking items in SAP see Figure 12.

Figure 12. Booking Items as Stored in SAP / Current Situation

Summarizing the current inconvenience with booking items:

- Poor data quality can be created when incorrectly changing the storage location of items. Employees at the warehouse estimate changing a storage location occurs about XXXXX times a day, but hard data on this topic is not available.

Once the items are stored in the warehouse, the items can be requested by employees (commonly the manufacture planners). Via the 'Kommisionierungstool' described in paragraph 4.1, the order pickings are made available for the employees at the warehouse.

XXXXX

Figure 13. Order Picking / Current Situation

XXXXX

Summarizing the current inconvenience with order picking:

- XXXXX.
- Storage location not always available (although present in SAP) or wrong (exceptional).
- Chance of poor data quality when manually filling in the serial numbers in the transaction XXXXX.

Although there is a chance of poor data quality and losing valuable time within the warehouse processes, it is necessary to put these processes into context. Therefore a more refined view has to be taken to assess the amount of material movements and the duration of the processes. Due to the lack of hard data in some processes estimates based on opinions of employees will be used. The number of order pickings can be easily found due to the 'Kommisionierungstool'. All the order pickings for production at TES of the last 7 years are present in the application. After a few calculations, the data gives the following information about the order picking process (see Table 6 and 7).

Table 6. Information from the 'Kommisionierungstool'

XXXXX

In order to find out the duration of the different steps of order picking, a test has been made and conducted in order to make realistic assumptions about the needed time of the steps. The test was a simulation of the order picking process for which a 'fake' assignment was made consisting of real items and actual storage locations. There were items on the list that needed the notation of a serial number and some that did not. For the test a warehouse employee would carry out the assignment and time was measured during that process.

The first step of the test consisted of sorting labels. In order to find out whether the needed time for sorting the labels was linear or exponentially distributed the time was measured during this process

various times and with a different number of labels. The test results (rounded to complete seconds) can be found in Appendix B.

Figure 14. Test Results for Sorting Labels

XXXXX

4.2.2 Repairs

As shown in Figure 10 multiple departments are involved in handling the service process. Only the departments affected by the possible implementation of Data Matrix Codes are analysed. This involves the logistics department (in particular the inward inspector) and the production department (in particular the sector 'Optroniks').

Figure 15. Receiving of Products for Repairs / Current Situation

The process (see Figure 15) starts with the delivery of the items that need repair and the opening of a service notification in the transaction XXXXX in SAP. In this transaction, information about the customer is put in and a service number is made. The information about the customer put in SAP is hard to standardize (different lengths) and demands that customers send their items with a delivery note with a DMC. Additionally, once a customer is put in SAP, it is not necessary to put every detail in the next time because SAP will autocomplete it. The only current problem is that, for some reason, the customer cannot always be found in SAP although they were already in the system and which case the employee creates a duplicate file.

Once a service notification has been set up, the next step is to register to incoming goods in transaction XXXXX in SAP. In this transaction, the material numbers with the corresponding serial numbers are put into the system. It can be the case that a serial number is not yet available in SAP. In this case, the employee needs to register the serial numbers first in the transaction XXXXX in SAP.

XXXXX

Registering the goods in XXXXX was part of the problem described in paragraph 1.2. Typos were hard to correct due to restrictions in SAP and if the mistake was discovered late in the process, a lot of rework was required.

After the service notification has been set up, the sales department will open a project number (PSP-Element). Once the repairs are scheduled for a closer inspection, an employee of the 'Optronik' department will pick up the items from storage and the items will be booked accordingly in SAP to the 'Werkstatt'. The items will be inspected for their defects and the employee notes down the serial number of the item at this time. He also figures out which spare parts are needed in order to conduct the repairs. He will also note down missing accessories for which the customer will be asked if the accessories are needed by the sales department.

XXXXX

Sometimes a new label is needed for the product, because the old one is to badly damaged for which the employee has to walk to a different building to make new ones. The required equipment is added to the service notification in SAP via XXXXX, which is filled in per hand and quite often the same parts are filled in (see Figure 16 for an example of XXXXX).

Figure 16. Example of IW32

Figure 17. Repairing Products / Current Situation

An overview of the whole process of repairing products can be found in Figure 17. Since the introduction of SAP there have been almost XXXXX unique service notifications, although in the beginning notifications of the previous ERP system have been copied to SAP. In Figure 18 this can be noticed in the peak at the start. The trend line suggests that about XXXXX service notification are being made on a daily basis.

Figure 18. Number of Unique Service Notifications

A service notification can contain multiple items, but the larger part of the service notifications only contains one item as can be seen in Table 7.

Table 7. Item Frequency per Service Notification

XXXXX

The problem is not as large as previously assumed by senior management.

Summarizing the current inconvenience with the service process:

- Risk of rework, due to mistype's, which cost time and can be stressful.
- Time consuming administrative work at the repairs department.

4.2.3 Test Field

At TES most systems are built and tested there. The testing demonstrates whether they function correctly. Correct registration of the serial number of the systems and its components is important for providing after-sales services. Therefore, every serial number of a component built in a system is written down together with the position of where the component can be found in the system. These lists are passed to the test field (see Figure 19 for an example), that will check every position whether the list is correct. This also means partly deconstructing the system. If the list has been checked and, if needed, adjusted then the list is typed into SAP (via transaction XXXXX) and Excel, since, according to the employees, the list cannot be properly exported from SAP. The Excel list is sent to the customer along with all the building positions of the components.

Figure 19. Example Configuration List

Such a system contains more than XXXXX serial numbers, which means that errors could be made when filling in the list and typing it in SAP. Registering such a system at the test field cost an estimate of XXXXX hours, according to the employees. Registering such a system is lengthy in SAP, because every single time the XXXXX and subcomponents has to be added to the system, although the system is very similar every time (only serial numbers change). However, such a system is not built frequently and it is estimated that such a system is built on average only three times a year. Smaller systems have the same problem, but there are no hard figures about those systems.

Summarizing the current inconvenience with testing:

- Time consuming administrative process due to same input for SAP and Excel, deconstructing systems to check serial numbers and building the system in SAP (adding the XXXXX to the building group).

4.2.4 Shipping

When an assignment is completed at TES, then the order needs to be collected and packaged in order to be shipped to the customer. In principle, collecting the order follows the same process as collecting the items in the warehousing process (paragraph 4.2.1). Only in this process, the sales department will bring or fax the ‘Entnahmelieferschein’ that contains the items that need to be picked. If the items contain serial numbers, then these will be written down on the ‘Entnahmelieferschein’ and this is faxed back to the sales department. They will make the actual delivery note in Microsoft Word, which they bring to the shipment department along with the necessary labels for the packages. It is estimated that picking items for shipping is about one third of the size of the number of items picked in the warehousing process.

The employee responsible for the shipping makes sure that the items are correctly booked out of SAP (via an assignment number) in the transaction XXXXX. If necessary, the serial numbers are also put in. Reviewing the transaction in SAP, it became apparent that it was already possible to make a standard delivery note which also automatically added the items in the assignment with their corresponding serial numbers.

XXXXX

With regard to the label problem described in paragraph 1.2 XXXXX making it mandatory to scan items before shipment would prevent such an error in the future. The only control point at the moment is the employee who is responsible for the shipping.

Summarizing the current inconvenience with shipping:

- Storage location not always available (although present in SAP) or wrong (exceptional). Also see 4.2.1 Warehousing.
- Chance of poor data quality when manually filling in the serial numbers in the transaction XXXXX. If a non-existing serial number is put in, SAP will give an error in which case it is not possible to make the transaction. In this case the error will be noticed.
- XXXXX

4.3 Items Suitable for Data Matrix Codes

The areas in which the administrative workload is high and the chances of wrong input are all items with serial numbers. So, in principle, it would not be necessary to add a Data Matrix Codes to all the products and supplies at TES, but only those with a serial number. These are mainly the end products or semi-finished products. Nevertheless, it would provide an extensive extra workload, since every technical drawing has to be adjusted and would not be beneficial to apply new labels to all the current items in the warehouse. It is therefore suggested that only items that are newly produced should get such a label, because technical drawings are then made or used and labels should be printed anyway for the product. In this way no extra work will be created.

Current Label Manufacturing Process

As it has been described in paragraph 1.2.4, it is already possible to produce labels with a DMC at TES. There is a special printer for producing these codes and there is currently one of these available at TES located in the main building. The manufacture planners are responsible for coordinating that every product gets the right label. They will also create serial numbers for to be manufactured products in SAP.

4.4 Overview of Problems

The analysis has shown that there are risks and problems concerning the input of data in the described processes. These are as follows:

Warehousing

- Poor data quality can be created when incorrectly changing the storage location of items. Employees at the warehouse estimate changing a storage location occurs about XXXXX times a day, but hard data on this topic is not available.
- XXXXX.
- Storage location not always available (although present in SAP) or wrong (exceptional).
- Chance of poor data quality when manually filling in the serial numbers in the transaction XXXXX.

Repairs

- Risk of rework, due to mistype's, which cost time and can be stressful.
- Time consuming administrative work at the repairs department.

Test Field

- Time consuming administrative process due to same input for SAP and Excel, deconstructing systems to check serial numbers and building the system in SAP (adding the XXXXX to the building group).

Shipping

- Storage location not always available (although present in SAP) or wrong (exceptional). Also see 4.2.1 Warehousing.

- Chance of poor data quality when manually filling in the serial numbers in the transaction XXXXX. If a non-existing serial number is put in, SAP will give an error in which case it is not possible to make the transaction. In this case the error will be noticed.
- XXXXX

These problems and risks need to be addressed when designing a solution for the improvement of the current situation.

Chapter 5: Formulating Solutions (Phase B.2. of BC4IOP)

In this phase potential solutions will be formulated that will be ranked via the SMART method. For using the SMART method, it is necessary to indicate the criteria on which the alternative courses of action will be measured. The solutions will be formulated, in order to solve the problems described in the analysis of the current situation. The solutions will be designed in respect to the preconditions described in paragraph 1.3.3. The next step is to determine the criteria on which they will be ranked via the SMART method. For this purpose a value tree will be made. The first step however is to determine the standard DMC which will be used in the solutions.

5.1 Constructing the Standard Data Matrix Code

XXXXX

Figure 20. Example of a Label for the 'Bund'

XXXXX

5.2 Possible Solutions

It is necessary to identify the alternative courses of action possible for solving the described problems, according to stage 2 of the SMART method described in paragraph 3.1.2. As described in chapter 4, the data input in the various stages of the processes differ. This will therefore require different solutions to improve the data capture in those various stages. To improve the data input, different solutions for each stage will need to be designed. However, this does not mean that they are always mutually exclusive. In other words, it is sometimes possible that the solutions for that various stages can co-exist with each other. Distinctions and priorities of the solutions are dependent on budget constraints. For this situation, it will be necessary to apply the SMART method to determine the solution rankings. For designing the solutions the preconditions described in paragraph 1.3.3 have to be taken into account, namely:

- The new technology should be integrated within SAP.
- The requirements for labels on internal and external purposes still need to be met.
- The new system should be user-friendly.

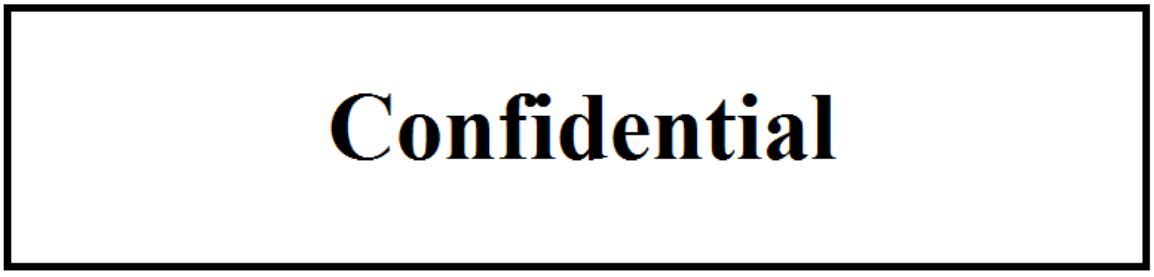

Figure 21. Security Solution for WLAN-Scanners (Internal Documents Thales)

In paragraph 3.1.2 three main categories have been described in which the reading devices could be divided, namely:

1. USB-corded 2D Barcode Scanners: These reading devices are relatively cheap (see Appendix C). These devices will be connected to a stationary computer and they will be the same in use as the current 1D Barcode Scanners at TES. The main problem with these devices is the ease of use when a lot of products need to be scanned, as an employee might struggle with the cable especially when it is not practical to bring all the items from the workbench to his desk. In order to solve this problem, a long cable is needed or an extra computer on the workbench needs to be installed. Programming costs in SAP are estimated around €500,-.

2. Wireless 2D Barcode Scanners with a Monitor: A lot more expensive scanner in comparison with the USB-corded scanners (see Appendix C), but easier of use because these scanners communicate wireless with the ERP system.

XXXXX

A sketch of the solution can be found in Figure 21.

The total cost of this solution at the moment is not clear, but an estimation (made together with the IT-department) is that it could be around €15.000,-. If more locations at TDS will use this solution, the cost for the data center can be shared. However, for further calculations, the amount of €15.000,- will be used. For this solution, only one type of scanner is allowed, which is determined to be the scanner from the brand XXXXX in the XXXXX series.

XXXXX

Nevertheless the cost of programming such devices for usage at TES is estimated to be €25.000,-.

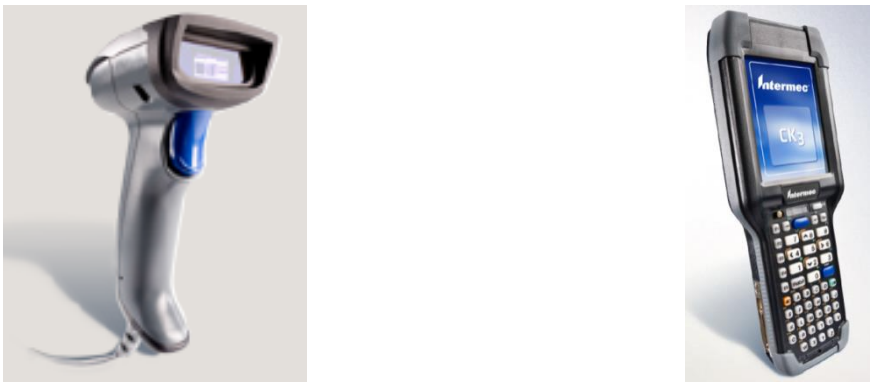

Figure 22. Left: USB-corded 2D Barcode Scanner; Right: Wireless 2D Barcode Scanner with Monitor.

3. Batch Barcode Scanners
These readers are battery powered and are used wireless. They can collect information and store it, which later, when connected to its docking station, can upload its stored data to, for instance, an ERP system. Although no WLAN infrastructure is needed for these readers, problems tend to occur when the data is uploaded to SAP (which uses real-time information). When somebody already has made changes to a certain file in SAP and the batch barcode scanner will upload outdated information, the possibility exists that the data will become corrupted, which will have a negative effect on data quality. For this reason the batch barcode scanners are not considered as a solution for TES.

5.2.1 Solution A: Scanning Serial Numbers via Corded Scanner

In order to prevent wrong data input and risking rework, the serial numbers for items should be scanned via the USB-corded 2D barcode scanner. This would apply for the process of order picking (also for collecting items for shipment) and for data entry when making a service notification. In the

case of making a service notification it is not possible to bring every item to the desk of an employee the cable should be considerably long in order to reach the workbench (5 meters). At the warehouse all the items are collected on a trolley, so the employee does not need to note down the serial numbers, but he can scan them once he collected the order and is doing the administrative work in SAP. The current process does not radically change and will almost be the same as in Figure 13 and 15.

The necessary hardware for this solution would be:
-2 USB-corded 2D Barcode Scanners

Solution A+: Scanning Serial Numbers via Corded Scanner (extra PC)
The solution A+ is almost the same as solution A, but in this version an extra PC is installed at the workbench for making the service notification. In this case a long cable is not needed and makes it easier to work for the employee.

The necessary hardware for this solution would be:
-2 USB-corded 2D Barcode Scanners
-1 PC

5.2.2 Solution B: The Wireless 2D Barcode Scanners with a Monitor

In order to reduce the risk of poor data quality, the input in SAP should be standardized where possible. Therefore the wireless scanner should be used. The processes tend to change in comparison with the current situation. Also an application for the wireless scanner should be developed. An user should log in on its account via the wireless scanner, because every user has specific rights for certain transactions (see Figure 23). The next step is to choose the right transaction as displayed in Figure 24.

Figure 23. Login Screen for Wireless Scanner.

Figure 24. Transaction overview.

Once a transaction is chosen the employee has to walkthrough certain steps of the transaction and scan necessary items. Once the transaction is complete the employee has to save the transaction in order to update the SAP system. This will change the procedures for the processes of warehousing, registering repairs, registering systems and shipping. The new standards for these processes have been worked out in Appendix D. With the change of procedures also the roles of some actors will change.

XXXXX

The production should register a new system via a scanner while building it. The only role for the test field is to test it, and spot check the configuration list made by production. Also the shipping department has to scan the items in order to book them, which would make sure that every item will have a Thales label (otherwise it could not be scanned).

XXXXX

The necessary hardware for this solution would be:
-4 Wireless 2D Barcode Scanners with a Monitor

5.2.3 Solution C: Optimization of the Administrative Part for the Repairs

Currently the spare parts needed for a repair are all written down by an employee and put in SAP later. It would be a lot quicker when the employee puts in the information directly in SAP, when making the inspection of the defect item. The spare parts are often the same, which makes it possible to make some kind of catalogue, which can be scanned (just like in a supermarket). Currently only one catalogue of all the spare parts exist for the product XXXXX, which is also two third of the items repaired by the 'Optronik' department. Adding a DMC code to the spare parts, which can be scanned in the process, would save a lot of time. An example of this process can be found in Figure 25.

Figure 25. Example of Catalogue DMC.

XXXXX

Normally the employee does the administrative work at his desk, and the inspection of the defect items is done in the workplace. For this solution it is necessary to add a computer with a scanner to the workplace. Also a printer should be installed, so the employee does not have to walk to a different building to print new labels for the products (see Figure 26).

The necessary hardware for this solution would be:
-1 USB-corded 2D Barcode Scanners
-1 PC
-1 Printer

The estimated programming costs will be around €500,-.

Figure 26. Overview 'New' Layout for the Optronik

5.2.4 Solution D: Master File in IQ02

It should be made possible in SAP to create a template of a complete configuration (some kind of master file). Once such a template is created an employee only has to add the serial numbers of the items build into a new system. This solution would save a lot of time for the engineers at the test field in registering a new system. In comparison with the current situation two thirds less entries have to be made in SAP. This solution is not beneficial if solution B is chosen, because then the production will already register the system. The estimated programming costs will be around €1000,-.

5.2.5 Solution E: Control Point for Shipping

XXXXX

The necessary hardware for this solution would be:
-1 USB-corded 2D Barcode Scanners
-1 PC

5.3 Value Tree

Solutions have been designed and the next step of the process is setting up the criteria on which the solutions will be measured. For this process the BMP will be used in order to determine the potential benefits of the solutions, which will be formulated as criteria to measure the solutions. The described solutions are all of a supportive nature (see Figure 7), and are on an operational level (see Figure 8). To sort the benefits the categories of the Benefits Indication Matrix will be used, namely:

- Process
- Customer
- Finance
- Innovation
- HR

Because the solutions are only pointed at internal processes and no potential benefits or disadvantages are created for the customer, this category will not be taken over in the value tree.

Based on the analysis of the literature and the current situation, the following criteria (benefits, disadvantages and risks) have been set up:

- Process
    - Time Reduction: A solution can possibly save time, which could be spent differently, which potentially lead to an higher productivity. Measurements on this criterion will depend on the number of material movements and compared with the time needed for the current situation.
    - Improvement of Data Quality: Due to more standard input, the chance on errors is reduced resulting in an improvement of the data quality. Measurements on this criterion will depend on the number of material movements.
    - Prevention of non-SAP related errors: Solution introduces extra control points, which reduces the risk on errors (XXXXX), which are not related to data input in SAP.
    - Implementation Time: How quickly can a solution be implemented?
- Finance
    - Investment Costs: the amount of money which is needed to introduce the solution (hardware and programming costs).
    - Investment Payback Time: the time needed to repay for the investment costs, which are the investment costs divided by soft savings (derived from the time reduction). Measurements on this criterion will depend on the number of material movements.
    - Investment Risk: the chance that a solution will not meet its potential, due to the uncertainty about the costs and soft savings of a solution.
- Innovation
    - Growing Potential: the potential that a solution can be applied or used in other processes not covered by this study.
- HR

- Chance Solution Gets Resisted: Solution could be impractical or difficult to use, in which case an employee will conduct the process on the old way.
- Job Satisfaction: Due to the solution more time can be spend on the actual job itself (for instance repairing items) or less stress for an employee due to the reduction of errors.

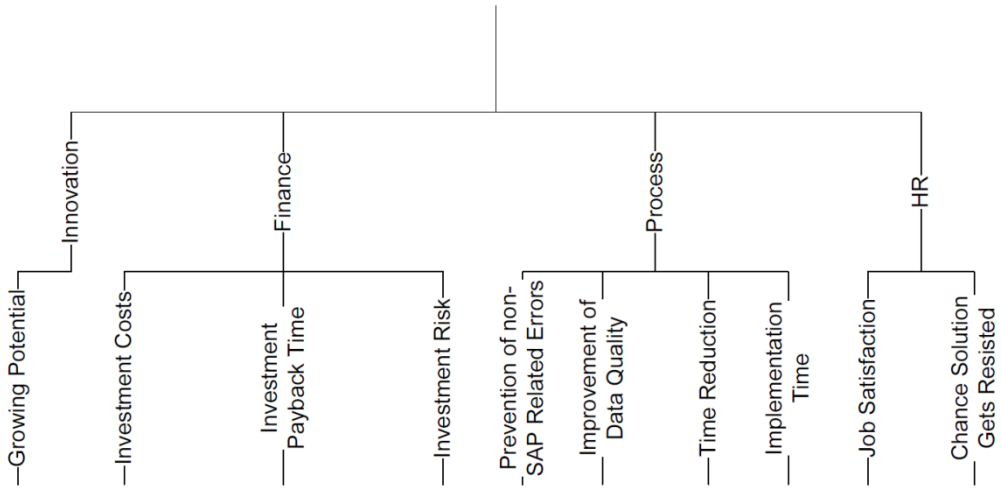

Figure 27. Value Tree

An overview of the value tree can be found in Figure 27. In chapter 6 the performance of the solutions on these criteria will be measured and weights will be added to each criteria.

Chapter 6: Assess the Solutions (Phase B.3. of BC4IOP)

In this chapter the solutions will be measured on the attributes (criteria) set up in the previous chapter. The next step is to determine the weights of the attributes, because the attributes are not equally important to the decision-maker. These weights are based on observations and interviews with employees and management. Once that step is complete, it is possible to rank the solutions. To see how robust the ranking of the solutions is a sensitivity analysis will be conducted.

The model developed via SMART can also be used by different locations of Thales or decision-makers for an assessment in which it is easy to add attributes or change to weights of the attributes. The measurements may also change, because some are based on the number of material movements. One should also notice that these measurements can sometimes rely heavily on the opinion of the decision-maker and a different decision-maker can come to different conclusions.

6.1 Measuring the Solutions on the Attributes

Some attributes are easily measured by quantifiable variables such as money or time. However some attributes cannot be represented by such a quantifiable variable. For those attributes the technique direct rating will be used. It will rank the solutions on such an attribute from most preferred to the least preferred. The most preferable solution will get a score of 100 and the least preferable solution will get a score of 0. The solutions between the most and least preferable will be rated on values that represent the preference for one solution over another in terms of the attribute. It is not necessary that the values have to be very precise, because it often requires quite substantial changes in the scores of an attribute before the ranking of the solutions change (Goodwin & Wright, 2010). The measurements on these attributes are based on data following from the tests described in Appendix A (also calculated with the labour costs in Appendix E) and data given by retailers of barcode scanners (see Appendix B). Some measurements on the attributes are based on the opinions of the employees who will eventually work with these solutions, because is not possible to always conduct a quantifiable measurement.

6.1.1 Process Attributes

Time Reduction

The time reduction of each solution has been calculated in Appendix E. Since an hour saved in the production is not the same as an hour saved in the test field, the time savings will be multiplied by the salary costs of a department.

Table 8. Attribute Time Reduction

Improvement of Data Quality

For this attribute the amount of potential errors made in SAP will be used as variable. Since not every error is equal. An error in serial numbers for a service notification can cost a lot of rework, but an error at the test field can quickly be recovered. For that reason the direct rating method will be used. Solution E will not change the data quality and for that reason it is the least preferable on this attribute. Solution B will score the best at this attribute because at embodies the same improvement of solution A(+) and it improves the data quality at the test field more than solution D. Since in solution B all the input in SAP will be done via scanning DMC and solution D only reduces the amount of manual input

in SAP. Solution C will also reduce possible wrong input, but these are quickly noticed and easy to fix. Therefore its improvement of the data quality is considerably low in comparison with the current situation.

Table 9. Attribute Improvement of Data Quality

Solution	A	A+	B	C	D	E
SMART	70	70	100	20	40	0

Prevention of non-SAP Related Errors

There are only two solutions that really prevent non-SAP errors and that are solution B and E. The main reason is that both solutions make sure that the items that are planned to be shipped are checked for labels (because these are supposed to be scanned). Such an extra control point could possibly prevent a problem like the label-issue described in paragraph 1.2.1.

Table 10. Attribute Prevention of non-SAP Related Errors

Solution	A	A+	B	C	D	E
SMART	0	0	100	0	0	100

Implementation Time

The time needed to benefit from a solutions full potential is the variable measured for this attribute. Since nobody knows the implementation time of solutions certain direct rating is used. Some solutions can be implemented directly once they have been programmed and set up, such as solution C, D and E. The main reason for this is that those solutions do not depend on labels on the products with DMC. As stated previously it is only beneficial to give products a label with DMC if they are new products (otherwise every technical drawing has to be adjusted) or returned via repairs. Due to the high lifespan of the products it could take years before repairs returned at TES can be scanned (which concerns solution A(+) and B). However the main problem with solution B is that programming the application for the wireless devices could be complex. At Thales Arnstadt, which has experience with programming, a comparable application it took at least two years to work properly. For that reason solution B is the least preferable.

Table 11. Attribute Implementation Time

Solution	A	A+	B	C	D	E
SMART	25	25	0	100	100	100

6.1.2 Finance Attributes

Investment Costs

The necessary investments have been described in chapter 5 and appendix C. This leads to the following figures in Table 12.

Table 12. Attribute Investment Costs

Solution	A	A+	B	C	D	E
Investment Costs (€)	960	1960	43.500	2730	1000	1230
SMART	100	95	0	94	98	97

Investment Payback Time

The investment payback time is the soft savings of the solutions divided by the investment costs. In Table 13 values on the attribute investment payback time can be found, whose values are based on the current amount of material movements.

Table 13. Attribute Investment Payback Time

Investment Risk

For this attribute direct rating will be used, because there is not an exact (quantifiable) variable on which the investment risk can be estimated. Since there were observations about the data input during the repair process and hard figures about the material movements were available solution C is the most preferable solution. Solution B is the least preferable solution, because its costs are highly uncertain. Besides it is not clear when its full potential can be met as described by the attribute 'Implementation Time'. The same goes for solution A(+), but the costs can be estimated with more certainty. The cost of solution D is expected to be in the right range, but its savings are an estimate of employees and not based on hard figures therefore it is not the most preferable solution. Solution E is pretty riskless as well, because its costs and (no) savings are pretty fixed. However there is no guarantee that solution E will fully prevent non-SAP related errors in shipping (related to for instance the label-issue).

Table 14. Attribute Investment Risk

Solution	A	A+	B	C	D	E
SMART	20	20	0	100	75	60

6.1.3 Innovation Attributes

Growing Potential

For this attribute direct rating will be used, because there is not an exact (quantifiable) variable on which the growing potential can be estimated. Solution B will be the one with the highest growing potential, because it can easily be used in different processes, for instance making the year-end inventory, which is currently done by noting every down on paper. Other solutions cannot be used for those processes, because they are not wireless. The least preferable would be solution E, because it only has one purpose for preventing non-SAP errors for the shipping department. Solution A(+) has the same problem, because the scanners are fixed and there is not a lot of different data in those processes that can be standardized. That will make the solution A(+) also less preferable. Solution C and D have the same potential. They can probably not be used in different processes, but within the process there is growing potential. In the case of solution C this would mean making additional catalogues for different products and for solution D it would mean applying the same principal for smaller systems.

Table 15. Attribute Growing Potential

Solution	A	A+	B	C	D	E
SMART	0	0	100	60	60	0

6.1.4 HR Attributes

Chance Solution Gets Resisted

For this attribute direct rating will be used, because there is not an exact (quantifiable) variable on which the attribute can be estimated. After assessing the solutions with the employees an estimate can be made how they will handle the solutions and if they will use them. There remains a chance that employees bypass the solutions and will still conduct processes the old way. The greatest chance that

will happen is with solution E, because it only sets up an extra barrier. Therefore solution E is the least preferable solution. The most preferable solutions are C and D, which clearly reduces the amount of work to be done. The opinions about solution A(+) and B are mixed. Solution A+ has a greater ease of use than solution A, and both are considered of great use in the repair process (registering the serial numbers). For the order picking process they are not considered as an added value. Solution B is preferred over A(+) by the employees, but then the employees have to learn to handle the new devices and working in SAP (for instance production employees currently do not use SAP).

Table 16. Attribute Chance Solution Gets Resisted

Solution	A	A+	B	C	D	E
SMART	40	50	70	100	100	0

Job Satisfaction

For this attribute direct rating will be used, because there is not an exact (quantifiable) variable on which the job satisfaction can be estimated. The least preferable solution is E, because as previously stated it is more likely to be an extra barrier. Solution A(+) and B tend to reduce stress due to the prevention of errors made, but as the analysis has shown the amount of errors made are considerably low. Solution C and D will also prevent wrong input (although these are relatively easy to fix), but the workload of the administration is reduced and can be spend differently. Because B embodies elements of D it is perceived that solution B is the most preferable, closely followed by C and D.

Table 17. Attribute Job Satisfaction

Solution	A	A+	B	C	D	E
SMART	60	60	100	80	80	0

6.2 The Weights of the Attributes

In order to add weights to the different attributes to express to importance of an attribute the technique of swing weights (described in Goodwin & Wright, 2010) will be used. For this technique the decision-maker has to imagine a solution with all the attributes at the least preferred levels. The next step is to question which attribute would be preferred if only one of the attributes could be improved to its most preferred level. For the remaining attributes the same question will be asked until all the attributes have been ranked. The attribute on rank one will be given a score of a 100. Based on the opinion of the employees and observations made during the analysis the following ranking has been made:

1. Investment Costs
2. Investment Payback Time
3. Implementation Time
4. Time Reduction
5. Chance Solution Gets Resisted
6. Growing Potential
7. Investment Risk
8. Prevention of non-SAP Related Errors
9. Job Satisfaction
10. Improvement of Data Quality

An improvement on the investment costs would be extremely preferable, because the least preferable solution B scores very badly in comparison with the other solutions. Although the reasons for this study is based on the presumed problems with data quality, the real impact of the problem turned out to be considerably small, which is the reason the attribute is ranked low.

The next step is to compare a swing from the least preferred level to the most preferred level of the attribute on rank 1 with the other attributes. For example a swing on the attribute 'Investment Payback Time' is considered to be 60% as important as a swing from the 'Investment Costs' and therefore will lead to a weight of 60. Conducting this step for all the attributes leads to the weights in Table 18, which are also normalized so that the total sum of the weights is 100.

Table 18. The Weights of the Attributes

Attribute	Original Weights	Normalized Weights
Investment Costs	100	25
Investment Payback Time	60	15
Implementation Time	55	14
Time Reduction	50	13
Chance Solution Gets Resisted	40	10
Growing Potential	30	7
Investment Risk	25	6
Prevention of non-SAP Related Errors	25	6
Job Satisfaction	10	3
Improvement of Data Quality	5	1
	400	100

6.3 Ranking the Solutions

The only step remaining before a ranking of the solutions is made is multiplying the weights of the attributes with the SMART scores of the solutions. The results can be found in Table 19.

Table 19. Total Value of the Solutions (via SMART)

		Solutions					
Attribute	**Weight**	*A*	*A+*	*B*	*C*	*D*	*E*
Time Reduction	13	17	17	100	41	32	0
Improvement of Data Quality	1	70	70	100	20	40	0
Prevention of non-SAP related errors	6	0	0	100	0	0	100
Implementation Time	14	25	25	0	100	100	100
Investment Costs	25	100	95	0	94	98	97
Investment Payback Time	15	87	72	0	83	100	0
Investment Risk	6	20	20	0	100	75	60
Growing Potential	7	0	0	100	60	60	0
Chance Solution Gets Resisted	10	40	50	70	100	100	0
Job Satisfaction	3	60	60	100	80	80	0
Total Value	100	**5146**	**4896**	**3700**	**7808**	**7916**	**4785**

On the basis of the SMART method the solutions are ranked as follows:

1. Solution D: Master File in IQ02
2. Solution C: Optimization of the Administrative Part for the Repairs
3. Solution A: Scanning Serial Numbers via Corded Scanner
4. Solution A+: Scanning Serial Numbers via Corded Scanner (extra PC)
5. Solution E: Control Point for Shipping
6. Solution B: The Wireless 2D Barcode Scanners with a Monitor

As one can conclude from Table 19 is that solution B scores badly, because it scores poorly on the attributes in the category finance. The other solutions score a lot better at those attributes. For that reason, a sensitivity analysis will be conducted to examine how robust the choice of a solution is to changes in weights used in the analysis. Therefore the weight on finance will be varied on a scale of 0 to 100 to see when the ranking of the solutions will change. If the weight on Finance is 0 this means that all the attributes in this category are zero as well. When the weight is adjusted to 100 (meaning that all the other attributes have a weight of zero) then the normalized weight of the attributes in the category Finance will be 'Investment Cost' = 54, 'Investment Payback Time' = 32 and 'Investment Risk' = 14. The results of the sensitivity analysis for weight placed on finance can be found in figure 28.

Finance			
Weight	0	46	100
Solution A	22,16	51,46	84,64
Solution A+	24,06	48,96	77,14
Solution B	69,3	37	0
Solution C	66,23	78,08	91,32
Solution D	64,56	79,16	95,42
Solution E	37	47,85	60,78

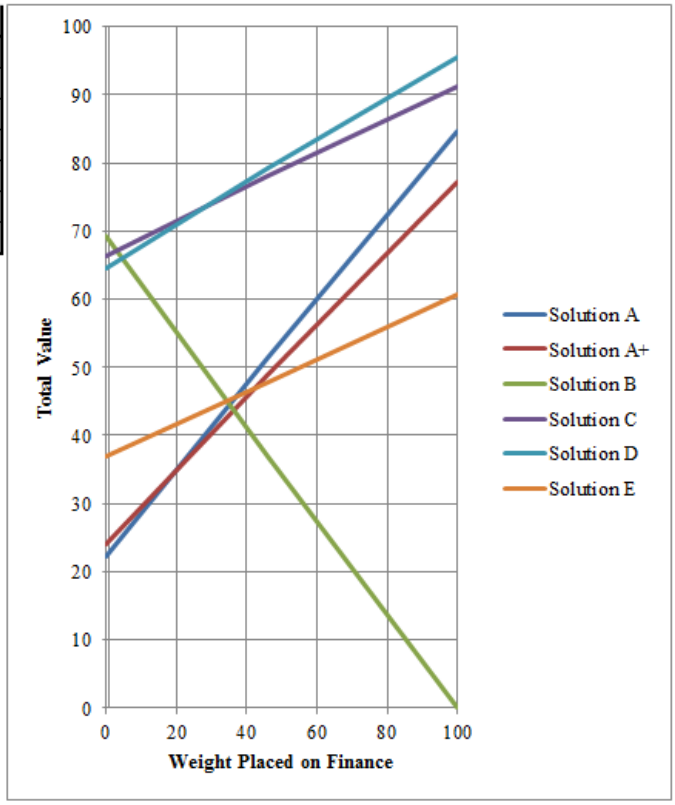

Figure 28. Sensitivity Analysis for Weight Placed on Finance

The sensitivity analysis shows that the solution B will only be the best, when the weight on finance is almost zero, which shows that even when the cost of this solution are drastically decreased (making finance less important and therefore less weight will be placed on finance) the solution will not preferred over solution C or D. Solution C and D are basically even preferable and if the budget allows it they can both be implemented.

Chapter 7: Business Case Conclusions

Questions have been asked at TES about the data quality and the efficiency of data input in SAP. Due to the lack of insight in the consequences of poor data quality at TES and the possible contribution of an AIDC technology in the form of Data Matrix Codes to the current business processes an analysis have been conducted to address these questions.

7.1 Answering the Research Question

The goal of the study conducted was to develop a business case for the DMC technology in order to find out if investing in the new technology is worthwhile for improving the efficiency of data input in SAP. To achieve this goal a modified version of the BC4IOP has been used together with BPE and SMART. Scope of the analysis has been narrowed to the supply chain at TES in which the presumed problems occurred and the research question asked is as follows:

'How can the AIDC technology Data Matrix Codes contribute to the performance of business processes conducted by Thales Electronic Systems GmbH in a cost-efficient way?'

By analysing the current processes via observations, tests and interviews, it turned out that the amount of errors made in SAP were very small. The main reason for this conclusion is the number of material movements conducted at TES, which is relatively small in comparison with other locations of Thales, like Arnstadt. Although the number of material movements is small, areas are still indicated for improvement largely in the field of data input efficiency. However these areas of improvement are not always related to the AIDC technology of Data Matrix Codes. The added value of materials with labels containing a DMC was too little to make such a solution cost-efficient. The proposed solutions were either too costly or risky and the benefits received by the solutions were too small due to the number of material movements at TES.

Two solutions were perceived to be cost-efficient and are therefore proposed to be implemented at TES. The first concerns the making of a catalogue for the spare parts of the products repaired at TES. This mainly affects the department 'Optronik'. All the necessary information of the spare parts will be stored in a DMC, which can be scanned by an employee when entering data in SAP. This leads to a reduction of time needed for this process. On a yearly basis this will approx. save €2700,- (soft savings). The second concerns the making of a standard master file in SAP in which systems build more often, can be registered. Applying such a master file will reduce the amount of data entries required for registering a system in SAP. This will reduce time and errors made. On a yearly basis this will approx. save €2100,- (soft savings).

These solutions can be implemented very quickly. Programming these solutions is not complex and once the hardware is bought and the catalogue has been made the solutions are ready to go. The solutions are not perceived as risky due to low investment costs and the clear benefits received by the solutions. Since the savings are generated by time reduction, there has to be different work to do for the employees (in other words an higher productivity has to be realised) otherwise the savings are not beneficial. An overview of the costs are presented in table 20.

There is some growth potential with solution C and D. In the case of solution C more catalogues can be made for different products. Currently one standard catalogue is available, which is provided via Thales Agnénieux for which in the solution TES only has to add the described DMC from the proposed solution (paragraph 5.2.3). In the case of solution D also smaller systems could be registered which will lead to higher soft savings (there is no clear image how great the number of smaller systems is).

If these solutions provide the benefits described and are successful at TES, it can be researched if they are suitable for other Thales locations. If that is the case then the realized soft savings can be considerably higher.

Table 20. Overview of the Investment Costs

Software and Hardware Investments*			
Department / Application	#	Solution C & D	
Dispatch (WE) / USB-Barcode Scanner	0	€	-
Dispatch (WE) / WLAN Barcode Scanner	0	€	-
Dispatch (WE) / Computer	0	€	-
Warehouse / USB-Barcode Scanner	0	€	-
Warehouse / WLAN Barcode Scanner	0	€	-
Optronik / USB-Barcode Scanner	1	€	230,00
Optronik / WLAN Barcode Scanner	0	€	-
Optronik / Computer	1	€	1.000,00
Optronik / Printer	1	€	1.000,00
Production / WLAN Barcode Scanner	0	€	-
Test Field / WLAN Barcode Scanner	0	€	-
Total Basic Hardware Investment		€	**2.230,00**
Estimate Programming Costs (adjusting SAP)		€	1.500,00
Total Investment		€	3.730,00
*Prices excluding value-added taks (VAT)			

7.2 Limitations

The focus of the study was mostly narrowed to the situation at TES. Although Thales Arnstadt has been visited, it is not clear if the proposed solutions (C & D) are already introduced at different Thales locations.

The literature used during this study was helpful in providing information about the subject of benefits management and the realization of a business case, but the real added value of the literature remains a bit unclear due to the relative small impacts of the new technology. Little specific literature was found concerning the introduction of an AIDC technology in small project-based organisations.

The problem with the use of SMART is that its results really depend on the views of the decision-maker. This is due to the weight given to the attributes and the measurements on non-quantifiable variables. Therefore it is difficult to provide a general framework with SMART for which only a few adjustments have to be made. For future decisions concerning the problems of data quality and SAP errors, it is possible to use the criteria used by this study, but the scores will vary in comparison to the results of this study a lot due to a different number of material movements. The weights on the attributes will also need some re-evaluation, because due to the changes of the measurements some attributes can become more or less important.

7.3 Future Work

If multiple Thales locations will implement the designed solutions in chapter 5 this conclusion can change. The general framework set up with the SMART method can be used to re-evaluate the new situation. The same attributes can be used and the calculations in Appendix E can be adjusted to the new amount of material movements (the weights on the attributes have to be re-evaluated because they can change due to the new information). The new amount of material movements will change the measurements on the attributes, which can eventually make solution A, B or E attractive. Especially solution B is more likely to become more attractive, because the highly uncertain programming costs will be divided among multiple locations. Since this type of a solution may be possible in the future it

is recommended that every newly produced product will get a label with an added DMC as described in chapter 5. This does not cost additional time or money, but will reduce the time implementation time of such a solution, because the products with a DMC will already be in circulation.

7.4 Recommendation

It is recommended that TES makes a catalogue of all the spare parts for its products (starting with the LUCIE device) in which a DMC can be scanned for the data input in SAP (Solution C). The investment costs are € 2.730,-, which is paid back (soft savings) in the first year. The implementation time is short and the difficulty is not complex. The necessary hardware needs to be ordered and the reading of a DMC in SAP needs to be programmed in which Thales Arnstadt already has experience.

It also recommended that TES allows the creation of a master file in IQ02 (Solution D) for complete systems (with a certain 12NC). The programming costs are estimated on € 1.000,- and the implementation time can also be relatively short. Once the changes have been programmed it can be put into use when a new system needs to be registered.

It is possible to have both solutions implemented within a month, when there are no difficulties concerning the programming of the changes in SAP.

As stated in paragraph 7.3 it is also recommended that every newly produced product will get a label with an added DMC. This does not cost additional time or money, but will reduce the implementation time of various solutions (A and B) for when these solutions become feasible (depends if other locations also implement the DMC, see paragraph 7.3).

Bibliography

aimuk.org. (sd). *Automatic Identification and Data Capture*. Opgeroepen op November 22, 2013, van www.aimuk.org: http://www.aimuk.org

BAAINBw. (2013). *Technische Lieferbedingungen.* Koblenz: BAAINBw.

Benhaim, M., Houlette, C., Ilteris Oney, L., Buckley, D., Dentes, D., van Eeghem, M., et al. (2011, Juni 6). *www.gs1.org/services/publication/online.* Opgeroepen op November 12, 2013, van www.gs1.org: http://www.gs1.org/docs/barcodes/GS1_DataMatrix_Introduction_and_technical_overview.pdf

Earl, M. J. (1994). The New and the Old of Business Process Redesign. *Journal of Strategic Information Systems*, (Vol. 3) 5-22.

Eckartz, S. M. (2012). Managing the Business Case Development in Inter-Organizational IT Projects: A Methodology and Its Application. In S. M. Eckartz. Enschede.

Goodwin, P., & Wright, G. (2010). *Decision Analysis for Management Judgement.* West Sussex: John Wiley & Sons Ltd.

Gordijn, J. (2002). *Value-based Requirements Engineering: Exploring Innovative e-Commerce Ideas.* Amsterdam: Vrije Universiteit.

Heerkens, H. (2010, February 12). Methodologische Checklist. Enschede.

Heerkens, H., & Winden, A. v. (2012). *Geen Probleem.* Van Winden Communicatie in opdracht van Business School Nederland.

Herzberg, F. (1987). One More Time: How Do You Motivate Employees? *Harvard Business Review*, (September-Oktober) 5-16.

Hicks, B. (2007). Lean Information Management: Understanding and Eliminating Wasete. *International Journal of Information Management*, 233-249.

Hunter, R., Audrey, A., McGee, K., Handler, R., Dreyfuss, C., Smith, M., et al. (2008). A Simple Framework to Translate IT Benefits into Business Value Impact. *Gartner Research*, 3-11.

Lankhorst, M., Proper, H., & Jonkers, H. (2009). The Architecture of the Archimate Language. In T. Halpin, J. Krogstie, S. Nurcan, E. Proper, R. Schmidt, P. Soffer, et al., *Enterprise, Business-Process and Information Systems Modeling* (pp. 367-380). Amsterdam: Springer-Verlag Berlin Heidelberg.

Love, P. E., & Irani, Z. (2004). An exploratory study of information technology evaluation and benefits managment practices of SMEs in the construction industry. *Information & Management*, 227-242.

McCathie, L., & Michael, K. (2005). *Is it the End of Barcodes in Supply Chain Management?* University of Talca, Chile: Proceedings of the Collaborative Electronic Technology and Research Conference LatAm.

Murray, M. (2009). Elements of the Supply Chain. In M. Murray, *Discover Logistics with SAP ERP* (p. 30). Bonn: Galileo Press.

Murray, M. (2012). *Materials Management with SAP ERP: Functionality and Technical Configuration.* Boston (MA): Galileo Press Inc.

Redman, T. C. (1998). The Impact of Poor Data Quality on the Typical Enterprise. *Communications of the ACM*, Vol.41, No. 2, 79-82.

Schmidt, M. (2003). Business Case Essentials: A Guide to Structure and Content. *Solution Matrix Ltd. White Paper*, 1-31.

Smith, A. D., & Offodile, F. (2002). Information management of automatic data capture: an overview of technical developments. *Information Management & Computer Security*, 109-118.

Tayi, G. K., & Ballou, D. P. (1998). Examining Data Quality. *Communications of the ACM*, Vol. 41, No. 2, 54-57.

Tserng, H. P., Dzeng, R.-J., Lin, Y.-C., & Lin, S.-T. (2005). Mobile Construction Supply Chain Management Using PDA and Bar Codes. *Computer-Aided Civil and Infrastructure Engineering*, 242-264.

van den Berg, H., Franken, H., & Jonkers, H. (2008). *Handboek Business Process Engineering (Academische uitgave, versie 7).* Enschede: BiZZdesign.

Varchaver, N. (2004, May 31). *Scanning the Globe*. Opgeroepen op November 13, 2013, van CNNMoney: http://money.cnn.com/magazines/fortune/fortune_archive/2004/05/31/370719/

Ward, J., & Daniel, E. (2006). *Benefits Management: Delivering Value from IS & IT Investments.* West Sussex, England: John Wiley & Sons Ltd.

Ward, J., Daniel, E., & Peppard, J. (2008). Building Better Business Cases for IT Investments. *MIS Quarterly Executive*, 1-15.

Whittaker, B. (1999). What went wrong? Unsuccessful information technology projects. *Information Management & Computer Security*, Vol. 7 23-29.

Appendix A: Entnahmestückliste used for Time Measurements

Confidential

Appendix B: Time Measurements of Sorting Labels and Entnahmestückliste

Confidential

Appendix C: The Cost of Hardware

Confidential

Appendix D: Standards for Wireless Scanner

Appendix E: Calculations for Time Reduction

Confidential