SLOVENSKÁ TECHNICKÁ
UNIVERZITA V BRATISLAVE
FAKULTA ELEKTROTECHNIKY
A INFORMATIKY

Ing. Andre Gleser

Autoreferát dizertačnej práce

CHALLENGES FOR AUTO-ID SYSTEMS IN MANUFACTURING
VYUŽITIE AUTOMATICKÝCH ID SYSTÉMOV VO VÝROBE

na získanie akademickej hodnosti doktor (philosophiae, PhD.)

v doktorandskom študijnom programe:	**Rádioelektronika**
v študijnom odbore	**5.2.13 Elektronika**

Miesto a dátum: Bratislava, júl 2016

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Dizertačná práca bola vypracovaná v externej forme doktorandského štúdia na Ústave elektroniky a fotoniky FEI STU Bratislava, Ilkovičova 3, 812 19 Bratislava.

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ABSTRACT

Key words: Automatic identification and data capture (Auto-ID), Radio frequency identification (RFID), Glauto process, process analysing tools

Automatic identification and data capture (Auto-ID) refers to the methods of automatically identifying objects, collecting data about them, and entering that data directly into computer systems.

Short product life cycles and a constantly decreasing amount of repeated orders in the area of industrial engineering require an adaptation of existing IT concepts like EDM (Engineering Data Management) as well as PDM (Product Data Management). Auto-ID can help to counteract to that development. The aim is to regenerate the loss of productivity again considering a wide range of production environments ranging from small batch productions to bulk applications.

Essential for profound process analysis of case studies are the available process-analysing tools. Existing process-analysing tools can only be used for a rough process understanding for Auto-ID applications. The problem is that the existing methods are not designed for Auto-ID applications and crucial information are missing. Therefore the new and original Glauto (**Gl**eser + **Auto**-ID) process chain paradigm was developed. It is a specialised process-analysing tool for Auto-ID applications, which offers also the possibility to calculate key figures.

Glauto process chain paradigm is applied to two different case studies: one small batch production and one bulk application. The concepts are analysed considering technical as well as financial aspects. With the help of Glauto process chain paradigm and financial calculations open rationalisation potential is recognised.

One of the hardest questions to answer for the implementation of a new technology is the balance or the compromise of technical possibilities and financial reasonableness. Improvements of the possibilities to academically answer this question are offered by generating functions for costs and benefits for the two considered case studies.

This procedure gives the possibility to become acquainted with the economic aspects starting from the technical options. A more and more quickly changing market requires real time data respectively analysis for decision makers to react flexible to a changing inquiry situation, new trends or delivery problems.

For the two considered case studies it has to be stated that the most important part when applying Auto-ID technology to an existing system is to profound question the design of the desired system and consider the important interfaces and influences for an optimum realistic financial calculation.

ABSTRAKT

Kľúčové slová: Automatická identifikácia a zber dát (Auto-ID), vysokofrekvenčná identifikácia (RFID), Glauto proces, nástroje procesnej analýzy

Automatická identifikácia a zber dát (Auto-ID) sa vzťahuje na metódy automatického zisťovania objektov, zhromažďovanie údajov o nich, a spracovanie týchto údajov pomocou počítačových systémov.

Krátke životné cykly výrobkov a sústavne klesajúci počet opakovaných zákaziek v oblasti priemyselnej výroby vyžadujú úpravy existujúcich IT konceptov, ako napríklad EDM (Engineering Data Management) alebo PDM (Product Data Management). Auto-ID aplikácie môže byť protiváhou tohto vývoja. Cieľom je regenerácia klesajúcej produktivity pri zohľadnení širokej škály výrobných prostredí, od malosériovej výroby až k hromadnej produkcii.

Pre procesnú analýzu prípadových štúdií majú podstatný význam nástroje procesnej analýzy, ktoré sú k dispozícii. Existujúce nástroje procesnej analýzy je možné použiť iba pre základné pochopenie Auto-ID aplikácií. Problém spočíva v tom, že existujúce metódy nie sú navrhované pre Auto-ID aplikácie a chýbajú v nich podstatné informácie. Z toho dôvodu bol vyvinutý pôvodný a originálny model postupového reťazca Glauto systému (**Gl**eser + **Auto**-ID). Je to špecializovaný nástroj procesnej analýzy pre Auto-ID aplikácie, ktorý súčasne ponúka možnosť kalkulácie kľúčových číselných hodnôt.

Systém Glauto bol aplikovaný na dve rôzne prípadové štúdie: jedna sa týka malosériovej výroby, druhá hromadnej produkcie. Pri analýze jednotlivých konceptov sú zohľadnené jednak technické a jednak finančné aspekty. Pomocou systému Glauto je možné rozpoznať potenciál racionalizácie finančných kalkulácií.

Jednou z najzložitejších otázok, na ktorú je treba pri rozhodovaní o zavedení novej technológie nájsť odpoveď, je nájdenie vyváženosti alebo kompromisu medzi technicky realizovateľnými možnosťami a primeranosťou nákladov, ktoré sú s tým spojené. Zlepšenie možností pre akademické zodpovedanie týchto otázok je cesta generovania funkcií pre náklady a prínosy, ako to je uskutočnené vo dvoch prípadových štúdiách, ktoré sú prezentované v práci.

Tento postup umožňuje zoznámiť sa s hospodárskymi aspektmi, ktoré vyplývajú z technických možností. Stále rýchlejšie nastupujúce zmeny trhu si vyžadujú dostupnosť dát v reálnom čase a vypracovanie analýz pre vedúcich pracovníkov tak, aby mohli flexibilne reagovať na meniace sa výsledky prieskumov, na nové trendy alebo na problémy, ktoré sa týkajú dodávok.

Pre dve uvažované prípadové štúdie je potrebné konštatovať, že najdôležitejšou časťou pri aplikovaní Auto-ID technológie na daný systém je návrh designu požadovaného systému a vytvorenie dôležitých prepojení a vplyvov pre dosiahnutie optimálnej a reálnej finančnej kalkulácie.

CONTENTS

1 INTRODUCTION

Auto-ID has gained more and more usage and attention in the last few years. The goal for industrial applications is slightly different than for access control applications. Chip cards and biometrics are mainly used for access control applications. This dissertation thesis deals with RFID in manufacturing. Therefore the focus will be on the industrial applications. Chip cards and biometrics will not be considered in the further development of this thesis.

In common it can be stated that especially the RFID sector is supposed to grow enormous from 7,6 US$ billions in 2012 9 US$ billions 2013 to 10 US$ billions in 2014, which is one indicator that this technology gains more and more usage in the industry but also in our everyday life [1].

The Auto-ID technologies magnetics stripes and smart cards suffer from mechanical wear and need contract to the reader while being read. Machine vision systems, barcodes and RFID do not undertake any mechanical wear. Thus these three technologies get used in the industry. Machine vision systems are mainly used when there is a need to compare a product with a picture for a certain decision of a machine. Equally to barcodes they need a line of sight to be read. RFID systems do not have that disadvantage [2]. In addition to that many studies state that there is much more development potential for RFID transponders (compare Fig. 1.1). In contrast the barcode technology has reached its maximum usage level.

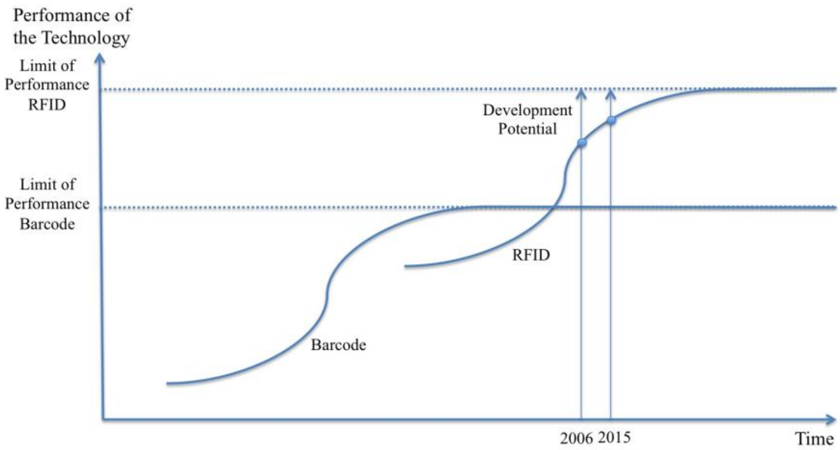

Fig. 1.1: S-curves of the barcode and RFID technology [3]

But also the RFID technology has its limit, which is not defined by the technology itself. Problems are recognised as below.

- „cost/insufficient ROI,
- lack of knowledge and understanding,
- maturity of the company,
- perceived maturity of the technology/ marketplace“ [4].

This represents one side, the other are concerns regarding data security. With the invention of RFID systems in 2003 a widespread discussion regarding privacy has started and is still on going. The US consumer protection CASPIAN (Consumer Against Supermarket Privacy Invasion And Numbering) wanted customers to boycott Wal-Mart, Benetton and Gillette at that time because they announced the use of RFID. At that time the use of RFID was criticised in Germany too. Since then representatives of the economy, representatives for data security, representatives of the states of Germany, EU committees, data security associations and employees of scientific institutes express their opinions to

social and data security laws. There has not only been an announcement of point of views. Nevertheless first requirements for the use of RFID regarding data security have been stated [5].
Nowadays RFID transponders are widely spread among different sectors. The first applications are to be recognised around 1944 in military applications – Fig. 1.2. After this Stockmans followed with his peer-to-peer communication and then approximately 25 years later with smaller and cheaper transponders mass applications started – anti theft applications and the identification of farm animals.

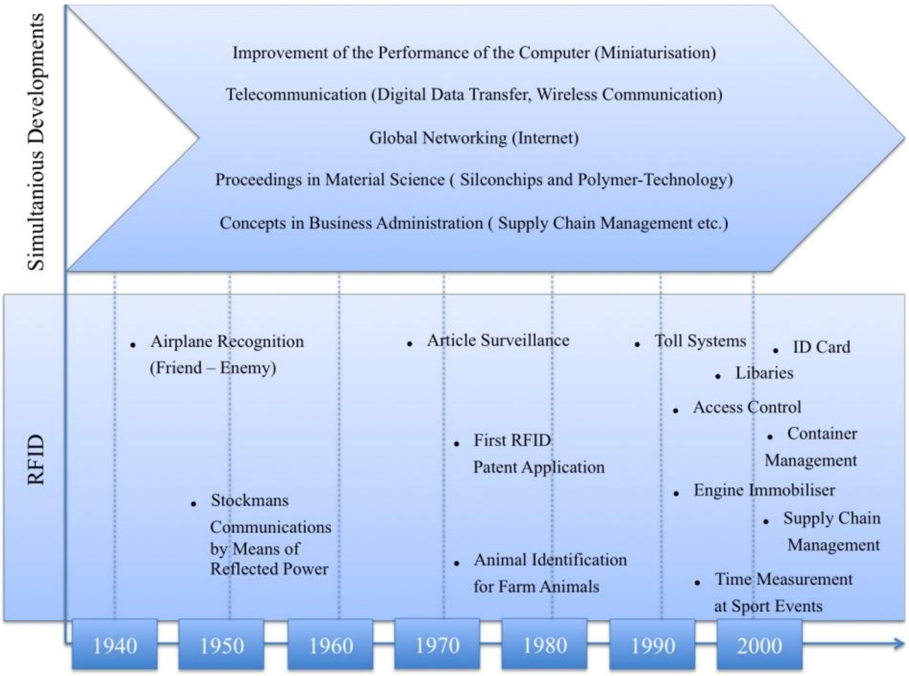

Fig. 1.2: Milestones of the RFID development [3]

Based on cumulating the sales from 1944 to 2005 the main sectors for RFID usage are to be found in Fig. 1.3.
In this thesis some of the case studies are situated in the manufacturing sector but are at the same time partly suppliers for the automotive industry which gathers 42% of the sold transponders. Thus it can happen and happened to the considered small batch production that automotive customers require their ordered products equipped with RFID transponders (Fig. 1.3).

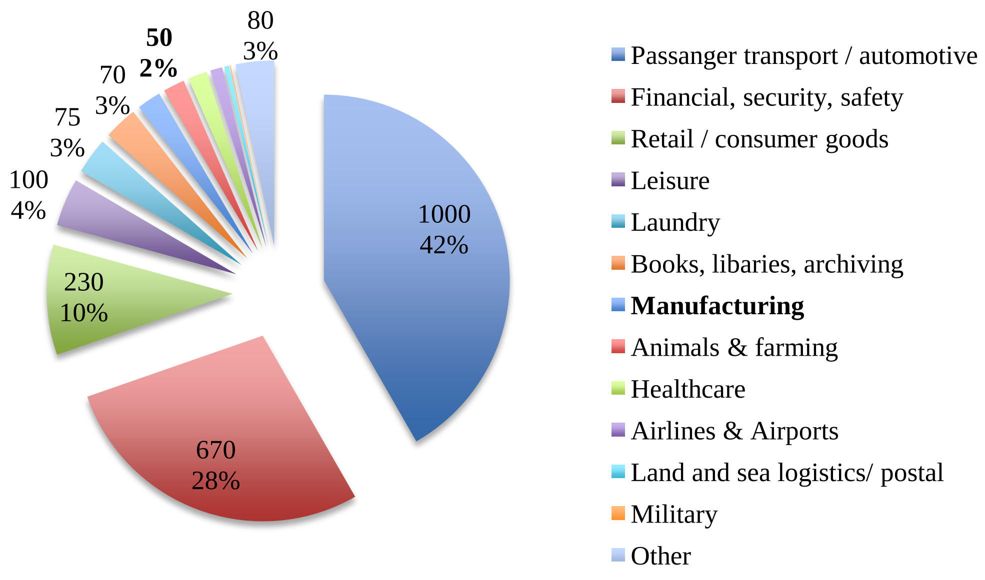

Fig. 1.3: Cumulative number of tags 1944 to end 2005 (millions) [6]

2 AIMS OF THE DISSERTATION THESIS

The challenges in the area of industrial engineering caused by turbulent production environment (shorter product lifecycles and a constantly downsizing amount of repeated orders) require an adaption of existing IT concepts like EDM (engineering data management) as well as PDM (product data management). The costs of implementation, problems with data security but also the need to improve the handling of complex processes to operate profitable as a company require the synthesis in an integrative engineering process.

Auto-ID Concepts respectively Auto-ID applications offer the possibility to create analysis in real time with simultaneously recorded data. Especially in global operating companies data have to be accessible immediately at different locations - not only for the controlling department. That can be data, which directly concern the production planning and control or on the other hand data from the maintenance respectively inventory.

Implementation costs and the effort of implementation respectively duration are factors, which decision makers in the industry partly lead to cancel Auto-ID projects at early stages. The gathering of personal data and personal times to create post calculations in real time, doubtless contain risks regarding data privacy.

The objectives of the dissertation thesis are summarised in the following points.

- **Development of a universal method for process recording specialised for Auto-ID applications**

Essential for profound process analysis of case studies are the available process-analysing tools. Existing process-analysing tools can only be used for a rough process understanding for Auto-ID applications. The problem is that the existing methods are not designed for Auto-ID applications and crucial information is missing. Therefore the “Glauto process chain paradigm” is developed. It is a specialised process-analysing tool for Auto-ID applications, which offers also the possibility to calculate key figures

- **Development of requirements for different Auto-ID case studies in manufacturing.**
    - **Design and analysis of the case study Auto-ID in small batch applications**

The analysis of the case study small batch application should contain two main parts:

- Technical aspects,
- financial aspects.

In order to understand the process of the case study correctly the Glauto process chain paradigm will be used. This tool is designed to analyse, design and optimise process chain elements especially for Auto-ID applications.

The expertise of the small batch application should be completed with the financial aspects. It will include a cost benefit calculation executed by the net present value method. The reason for choosing this method is that the main part of series of cash flows for Auto-ID investments are enlarged to a time period of several years. The net present value method considers the discount factor, which makes it possible to compare payments done at different dates.

- ### Design and analysis of the case study Auto-ID in bulk applications

Analogue to the previous case study this analysis of the case bulk application study should also contain two main parts:

- Technical aspects,
- financial aspects.

Due to higher quantities of products being handled a more productive Auto-ID system has to be invented which is able to do more scans/ reads in a shorter time period. Concluding this there are on one hand other requirements on an Auto-ID system and on the other hand higher quantities, which should result also in more interesting cost benefit calculation. Like the "small batch application" chapter this chapter will also be based on a case study, which will be a European logistics centre for the textile industry situated in the southern part of Germany.

- ### Development of the discrepancy regarding Auto-ID requirements between mass - and small batch production

In this section all technical- and financial details of the two case studies will be compared and the discrepancy between the two case studies will be presented.

- Comparison of technical aspects

The comparison will include the used frequency, type of system (active or passive system), type of coupling, reading rate and speed, the sensitivity against electromagnetic interfering fields, the influence of humidity and metal, the possibility of reading transponders in bunch, the design of the transponder and the storage capacity. Beside the comparison of the hardware the comparison of the two processes of the two case studies will be executed via the Glauto process key figures. The structure of the processes as well as the degree of automation will be compared.

- Comparison of financial aspects

For both case studies the net present value method is executed in the belonging chapters. This makes it possible to compare the results.

- ### Development of the reasonable degree of visibility

Especially for logistic applications visibility is a frequently discussed topic in the management level of companies. According to some expert's opinion 30 % of the core data, which are used to manage the supply chain are not correct. Thus it is difficult to make the right decision for logistic managers. Auto-ID will improve the visibility. But what is reasonable degree of visibility? The optimal degree of visibility would be optimal financial solution but for the reasonable degree additionally non-quantifiable aspects will be considered.

- ### Develop the reasonable degree of visibility for the two case studies

One of the hardest questions to answer for the implementation of a new technology is the balance or the compromise of technical possibilities and financial reasonableness. Improvements of the possibilities to academically answer this question are given in the chapter "The reasonable degree of visibility" by generating functions for costs and benefits for the two considered case studies.

Summarising the purpose of the dissertation is to create concepts respectively analyse already implemented applications of the Auto-ID technology for „factories of the next generation" as well as examine the realisability based on profitability [7].

3 RESEARCH METHOD

This chapter is dealing with the research method. In the following is to be found first the fundamentals of the Auto-ID technology, which is followed by the problem description. In chapter 3.2 a new and original method for the structured analysis of Auto-ID applications will be developed and described.

3.1 Auto-ID Fundamentals

In the last few years the Auto-ID technologies got widely spread which caused the raise of the competitive pressure among other things. Mainly in procurement, production and outbound logistics but even in the trade business this technology reached the status of carrying a great weight. To offer structured data is the main task as well as the goal of the Auto-ID technology. Automatic data collection in comparison to manual data collection has significant advantages: It is less error-prone, faster as well as more efficient. Even experienced users do not have a good overview of the market because of its many available components. There are four different Auto-ID systems that are mainly used nowadays: optical character recognition (OCR), chip cards, RFID and biometrical systems [8]. In the following the systems from Fig. 3.1 are shortly described to offer an overview of the different Auto-ID technology. More details of the particular technologies are to be found in their respective chapters.

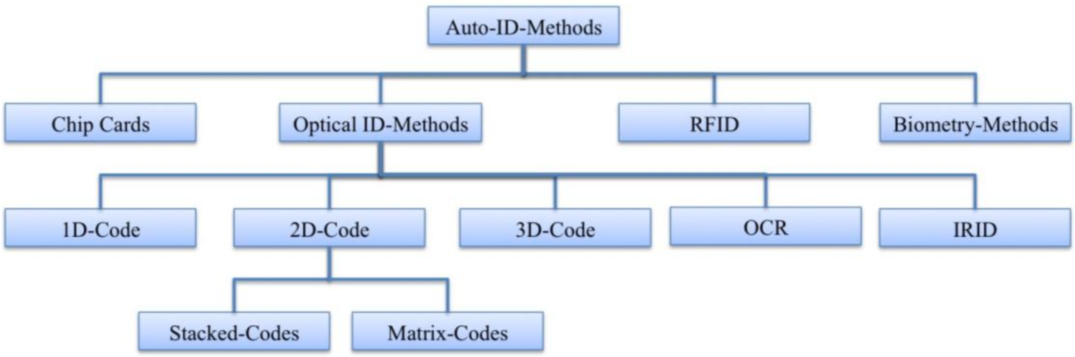

Fig. 3.1: Mainly used Auto-ID Methods [9]

In the following the systems from the above figure are shortly described to offer the interested reader an overview of the different Auto-ID-Technology. More details of the particular technologies are to be found in their respective chapters.

- Chip cards

Electronic data storage can be found in common chip cards. To prevent the chip from loss or failure caused by impacts it is integrated in a plastic housing in check card size. If it is necessary an addition with a microprocessor is possible. By adding this component the card changes its name. It is not called memory card as before without a microprocessor, it is now called chip card. With the invention of static callbox 198 the first mass application started on the German market. To activate the chip card respectively the processor it has to be supplied with energy and a work cycle. The supplier for this is the data collection device. This is also in connection with the main disadvantage of chip cards: It is very susceptible against dirt, abrasion and corrosion. A usage in logistics is questionable because a direct contact between chip card and data collection device is mandatory [9].

- Optical ID systems

Since the seventies the 1D-Barcode is used. Parallel-arranged stripes are the basis for this code. Optical laser sampling decrypts the codes. Different reflexions on the dark and bright parts of the codes offer the possibility of mechanical processing. The widest spread in the area of 1D-Codes is the European

Article Number (EAN). Beside this code, which was designed in 1976, we have 2D-Codes, which can be divided in Stack- and Matrix-Codes. Stack-Codes consist of many 1D-Codes, which are situated one below the other. Matrix-codes look like a matrix and its elements can be boxes or points [9].

- Optical Character Recognition (OCR)

OCR belongs to the optical ID procedures. A main advantage of this technology is that the information can also by read by the human eye. At the same time the high information density is an advantage. On the other hand the high acquisition costs for the OCR hardware relativize it. The complex data collection devices are mainly responsible for the high price of these systems. Nowadays the technology has become much cheaper but for logistics it is not the first choice. The technology is often applied in letter sorting machines at postal service operators [9].

- Infrared identification systems (IRID)

IRID systems use optical recognition for data transmitting. These infrared waves are situated around 300 THz. The detection range is exactly defined respectively directed. Equally a line of sight between transponder and reader is necessary. The IRID systems are mainly used where RFID systems have their boundaries: This can be caused by incompatibility against fluids and/ or metals. This technology is to be found in logistics especially identification processes of metal container or cases, process automation as well as safety relevant applications [9].

- Radio Frequency Identification Systems (RFID)

RFID-Systems consist of a reader and a transponder. The transmitting of data and partly the energy supply is done over the air interface. Magnetic or electromagnetic fields are used to transmit. The biggest advantage compared to other Auto-ID technologies is that there is no need to have a line of sight between reader and transponder to transmit data. [8] This low sensitivity against outer influences makes this technology highly interesting for many logistic processes [9].

- Biometrical methods

Biometrical methods for identification are processes for identifying unique human body parts. This can be for example a fingerprint scanner, retina scanner, speech recognition or face recognition. For logistic processes these methods are not the first choice.

3.2 Development of the Glauto Process Chain Paradigm

In order to design the optimal solution for a process and/ or improve existing solutions for a specific process the following subchapter will feature the state of the art regarding process visualisation methods, which are useful tools to understand a specific process, and more even define critical process areas.

At the moment no process visualisation method exists which allows a complete process recording taking into account material and information flow, assistive equipment, resources as well as IT interfaces. Normally existing methods are focussing on a later process modelling which make them complex. Thus the complexity and necessary deep understanding of the process are obstructive for a process recording, which should be fast, and time efficient. In addition to that the risk of recording an incomplete actual state, which can cause time and money consuming repeating recordings to record all information exists [10], [11].

A new method for process visualisation will be developed which is called “Glauto Process Chain Paradigm” (hereafter mentioned as Glauto process). It will feature an integral process recording with respect to material and information flow, assistive equipment, resources as well as IT interfaces, which makes it more, specialised for Auto-ID processes. It will also feature logical and conditional correlations because information deficits are a problem for planning and controlling of processes [12].

Glauto process will additionally feature interfaces to IT systems as well as material- and information flow and the “flow of help” which mainly is in industrial environment transportation with different vehicles. Especially Glauto process chain paradigm will focus on the combination of material and information flow together with existing IT systems in order to use the full potential of the Auto-ID technology which can only be used when backend systems combines all in and outputs to a powerful system.

Glauto process will be developed as a standardised method. It will mainly be based on the visualisation of (sub) processes with a few logical operators for material- and information flow. The name “Glauto” consists of a combination of the first two letters of “**Gl**eser “and the “**Auto**” to describe its aim to be specialised for Auto-ID applications.

Fig. 3.2 shows a diagram with three aspects namely “Logistics & Production”, “Business Process Management” and “IT Soft- & Hardware”. The diagram describes common used process modelling and/ or process analysing tools. The goal of the Glauto process is to position it as a universal tool for all Auto-ID interfaces in the middle of all three considered aspects as there is a need to record processes, consider interfaces to existing IT systems as well as being able to rate processes in the sense of economical aspects. More information about the existing methods for process visualisation can be found at several sources e.g. [13], [14], [15], [16], [17], [10].

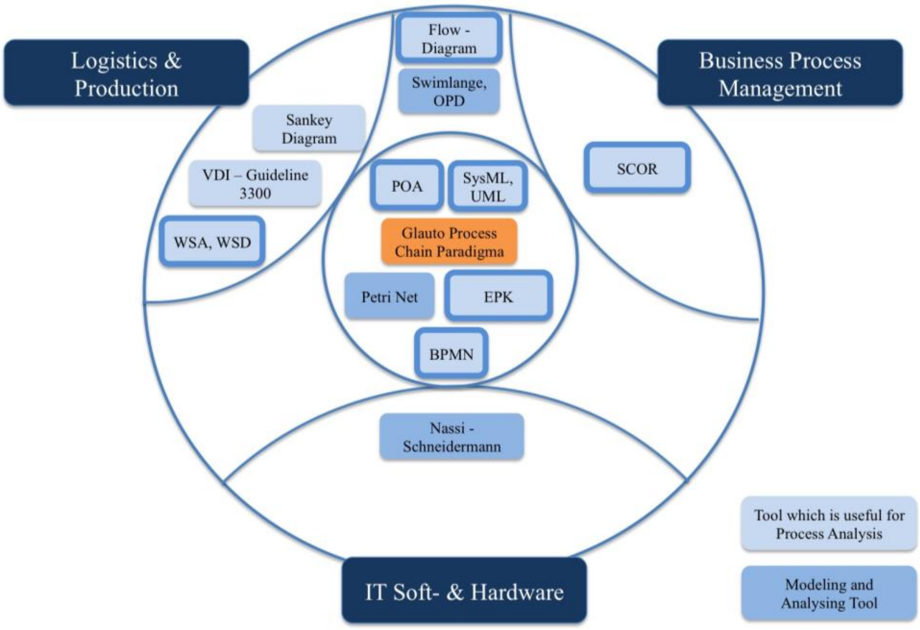

Fig. 3.2: Classification of methods for process visualisation [11]

Glauto Process Chain Paradigm Procedure

Next is to be found the procedure how the Glauto process paradigm should be applied on a specific process

1. Step of process recording

In order to get a first overview about the observed process it is very helpful to start the process recording with a hierarchic process level model. It shall include the main processes numbered with 1,2,3… and subprocesses belonging to a main process numbered with 1.1, 1.2, 1.3… - see Fig. 3.3 [10].

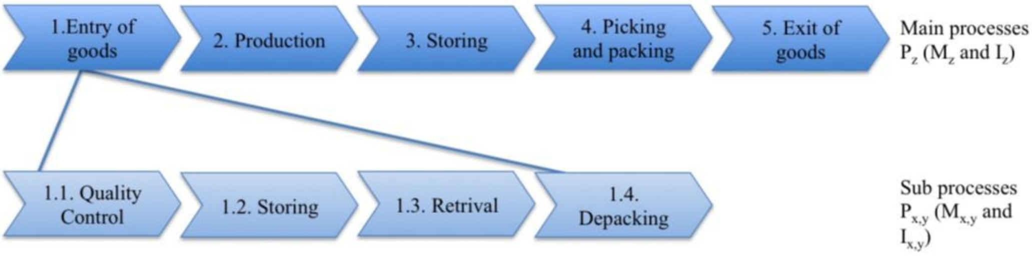

Fig. 3.3: Hierarchic process level model

Every single block arrow can be understood as a mixture between material flow, information flow, used recourses and IT interfaces – compare Fig. 3.4.

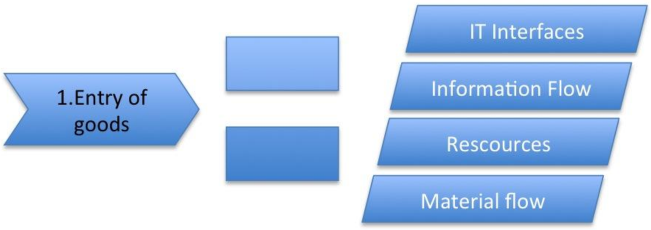

Fig. 3.4: Sample of divided contents of a block arrow

2. Step of Process Recording

Glauto process chain paradigm will use four different process types. Every process type is defined with a certain value, which will be used to calculate process key figures.

Definition of Basic Symbols

Next the symbols used in the top left corner of the operation block diagram are descripted. It is differentiated between basic operations for material flow and basic operations for information flow [10].

Tab. 3.1: Overview of basic operations for material flow [11]

Basic operation	Explanation
Handling	Handling operations at the beginning or end of production, transport, warehousing operations without any change of the goods itself or the location [18]. Examples: drop something, loading or unloading something.
Moving	Purposive in- or out house movement of goods between processing steps or warehousing [18] without any change of the goods itself. Examples: transporting, conveying, picking up, carrying.
Resting	(Un) purposive interrupting of the material flow without any change of the goods itself. Normally the goods are resting in a defined area. Examples: warehousing, buffering, saving, waiting.
Processing	Every process that brings the product closer to the state in which it should leave the factory [18]. Examples: producing, mounting, packing.

Tab. 3.2: Overview of basic operations for information flow [11]

Basic operation	Explanation
Gathering	Processes at the beginning or ending of transmission or processing or identification. Analogue to handling in material flow. Examples: entering, identifying, visualising.
Transmitting	Purposive change of location of information respectively data (referring to moving in material flow Examples: sending, receiving, information or data exchange.
Storing	Stockpiling of information regardless of maturity and type of information (referring to resting in material flow). Examples: laying in inbox, status of system, activating, saving.
Processing	Changing, transforming and interpreting of input information according to specific rules for generating of output information Examples: checking, controlling, comparing, booking, generating of new information.
Marking	Connecting of material and information flow by mounting an information carrier respectively information on the good. Examples: labelling, tagging.

In Tab. 3.3 the connecting and logic symbols are listed which are used to connect operation block diagrams with each other in a process visualisation.

Tab. 3.3: Connecting and logic symbols [11]

Symbol	Explanation
⟷	Unloose the link between two objects
→←	Marriage of two objects
∧	Logical “AND” (all inputs respectively outputs have to exist)
X	Logical exclusive “OR” (exactly one input or output has to exist)
∨	Logical “OR” (minimum one input or output has to exist)
2.1	Link to subprocess 2.1
A	Link to alternative process (A) or to support process (S)
⟶	Connection of the material flow respectively inputs from material flow to information flow
⇢	Connection of the information flow respectively inputs from information flow to material flow

Next is to be found an example for process visualisation with Glauto process. It contains the operation block diagrams as well as basic operations and connecting and logic symbols. On the bottom of this diagram is the flow of material situated, above the resources which means here should be situated all supporting processes and resources. Above is to be found the flow of information, which is often triggered, by the flow of material but sometimes it can be the other way round. On the top of the diagram (Fig. 3.5) is the IT interface situated, which is kind of similar to the resources but is meant to be filled by supporting IT processes or IT resources [10].

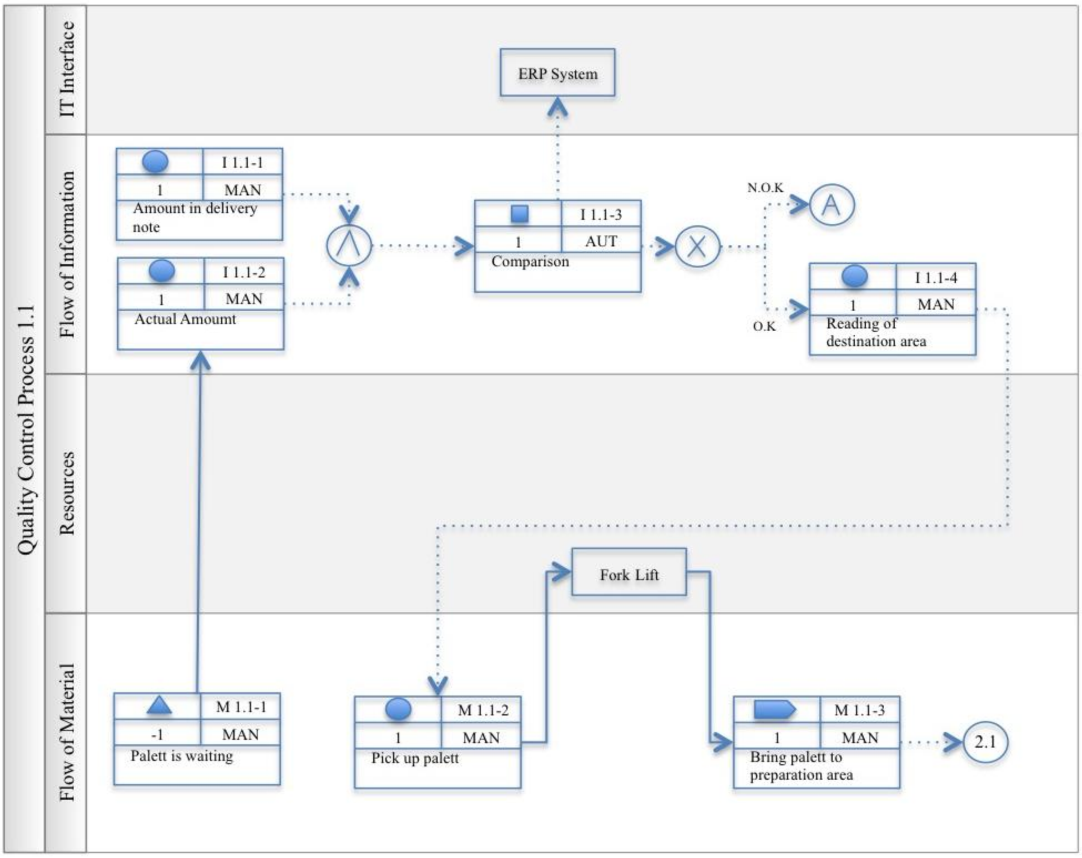

Fig. 3.5: Example for process chain plan: checking of goods at arrival [11], [19]

Definitions of Glauto Process Key Figures

The following key figures are defined. Some chosen main figures are presented here. More details are to be found in the dissertation thesis.

- Glauto quality for material flow $GQM_{x.y}$ for subprocess $M_{x.y}$ is defined

$$GQM_{x.y} = \left[\sum_{j=1}^{n} Y_{x,y-j} \right] \Big/ n \;; x, y = const \tag{3.1}$$

$$GQM \in \mathbb{Q} \;; Y \in \{-2, -1, 1, 2\} \;; j, n, x, y \in \mathbb{N}_{>0}$$

where

$M_{x,y}$	submaterial flow process,
$GQM_{x.y}$	Glauto quality for material flow and subprocess $M_{x.y}$,
$Y_{x,y-j}$	value of the block diagram,
n	number of counted block diagrams,
j, x, y	counter variable.

If $GQM_{x,y}$ is > 1 the material flow process contains many subprocesses, which add value.

If $GQM_{x,y}$ is between 1 and -1 the material flow process contains subprocesses which add value, but contains also sub processes, which add no value.

If $GQM_{x,y}$ is < -1 the material flow process contains many subprocesses, which add no value.

- Glauto quality for information flow $GQI_{x.y}$ for subprocess $I_{x.y}$ is defined

$$GQI_{x.y} = \left[\sum_{j=1}^{n} Y_{x,y-j} \right] \Big/ n \; ; x, y = const \tag{3.2}$$

$$GQI \in \mathbb{Q} \; ; Y \in \{-2, -1, 1, 2\} \; ; j, n, x, y \in \mathbb{N}_{>0}$$

where

$GQI_{x.y}$	Glauto quality process for information flow and subprocess $I_{x,y}$,
$I_{x,y}$	subinformation flow process,
$Y_{x,y-j}$	value of the block diagram,
n	number of counted block diagrams,
j, x, y	counter variable.

If $GQI_{x.y}$ is > 1 the information flow process contains many subprocesses, which add value.
If $GQI_{x.y}$ is between 1 and -1 the information flow process contains subprocesses, which add value, but contains also subprocesses, which add no value.
If $GQI_{x.y}$ is < -1 the information flow process contains many subprocesses, which add no value.

- Glauto quality GQ is defined

$$GQ = \left[\left[\sum_{x=1}^{a} \sum_{y=1}^{b} \sum_{j=1}^{c} YM_{x,y-j} \right] \Big/ m + \left[\sum_{x=1}^{d} \sum_{y=1}^{e} \sum_{j=1}^{f} YI_{x,y-j} \right] \Big/ n \right] \Big/ 2 \tag{3.3}$$

$$GQ \in \mathbb{Q} \; ; YM, YI \in \{-2, -1, 1, 2\} \; ; a, b, c, j, d, e, f, n, m, x, y \in \mathbb{N}_{>0}$$

or

$$GQ = [GQM + GQI]/2 \tag{3.4}$$

$$GQ, QGM, QGI \in \mathbb{Q}$$

where

$GQI_.$	Glauto quality for information flow,
GQM	Glauto quality for material flow,
$YM_{x,y-j}$	value of the block diagram for information flow,
$YM_{x,y-j}$	value of the block diagram for material flow,
a	maximum number of main processes for material flow,
b	maximum number of subprocesses for material flow,
c	maximum number of block diagrams for material flow,
d	maximum number of main processes for information flow,
e	maximum number of subprocesses for information flow,
f	maximum number of block diagrams for information flow,
GQ	Glauto quality,
m	number of counted block diagrams for material flow,
n	number of counted block diagrams for information flow.

If GQ is > 1 the process contains many subprocesses, which add value.
If GQ is between 1 and -1 the process contains subprocesses, which add value, but contains also subprocesses, which add no value.
If GQ is < 1 the process contains many subprocesses, which add no value.

- Degree of automation DoA is defined

$$DoA = \sum_{j=1}^{n} Z_j \;/n \;[\%] \tag{3.5}$$

$$DoA \in \mathbb{Q}\,;\, Z \in \{1, 0\}\,;\, j, n \in \mathbb{N}_{>0}$$

where

DoA	degree of automation,
j	counter variable for information flow,
Z_j	value of the operation for automated / manual operation,
n	number of counted block diagrams.

If DoA is > 50% the process contains many automated operations.
If DoA is < 50% the process contains many manual operations.

4 RESULTS AND DISCUSSION OF THE STUDY

Next are to be found different case studies from different areas, which should cover a wide area of application for verifying practical application of the Glauto process.

4.1 Auto-ID in Small Batch Productions

The first case study is a worldwide operating company, which produces tools for metal cutting. Standard products are produced at other locations in the world. The German subsidiary does produce special tools. As it is special the average order quantity is one or two. Before the product goes into the production department it has to be designed and the work preparation department has to set the order of working steps and has to choose the type of raw material. After these steps the product goes into production where the following RFID systems should add benefit and minimise as well as prevent errors. Fig. 4.1 shows the primary goals for this case study

Fig. 4.1: Primary goals for an Auto-ID introduction for the small batch production

The first case study is a worldwide operating company, which produces tools for metal cutting. Standard products are produced at other locations in the world. The German subsidiary does produce special tools. As it is special the average order quantity is one or two. Before the product goes into the production department it has to be designed and the work preparation department has to set the order of working steps and has to choose the type of raw material. After these steps the product goes into production where the following RFID systems should add benefit and minimize as well as prevent errors.

The goals for this case study are mainly:

- Time savings
    - integral process acceleration resulting in shorter delivery time,
    - improvement of delivery reliability.
- Cost reduction
    - reaching a payback period of max. 5 years,
    - cost savings intermediate-term and long-term.
- Improvement of quality
    - preventive error proofing,
    - increase of the degree of automation,
    - more transparency.

Next is to be found the possible and the chosen technology for this application. The chosen technology is marked in yellow.

Table 4.1: Conception summary

Frequency	LF	HF	UHF	MW
Energy Supply	Passive	Semi passive	Active	
Data storage	Read-only	EEPROM	FRAM	RAM
Type of coupling	Capacitive	Inductive	Backscatter	
Design	Disc transponder	Glass transponder	Smart label	Chip card
Reader	Handheld	Gate	Tunnel	Table integrated

Application of the Glauto Process Chain Paradigm

Next is to be found the hierarchic process level model for this case study (Fig. 4.2). The considered part for this case study is the complete process

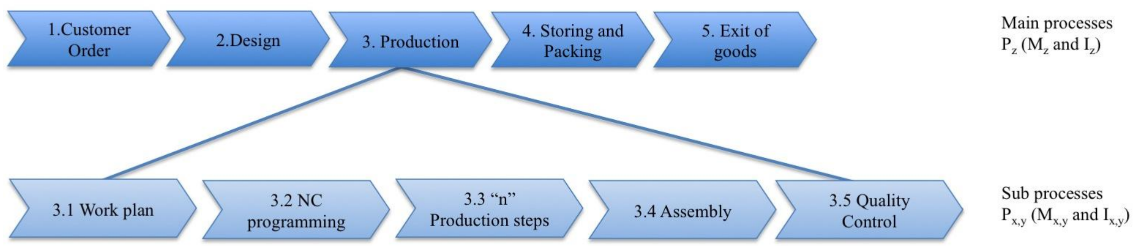

Fig. 4.2: Hierarchic process level model for the small batch production

This "overview" leads to the detailed process chain plans for each process. Next is to be found a chosen process chain plans for this case study as an example (Fig. 4.3).

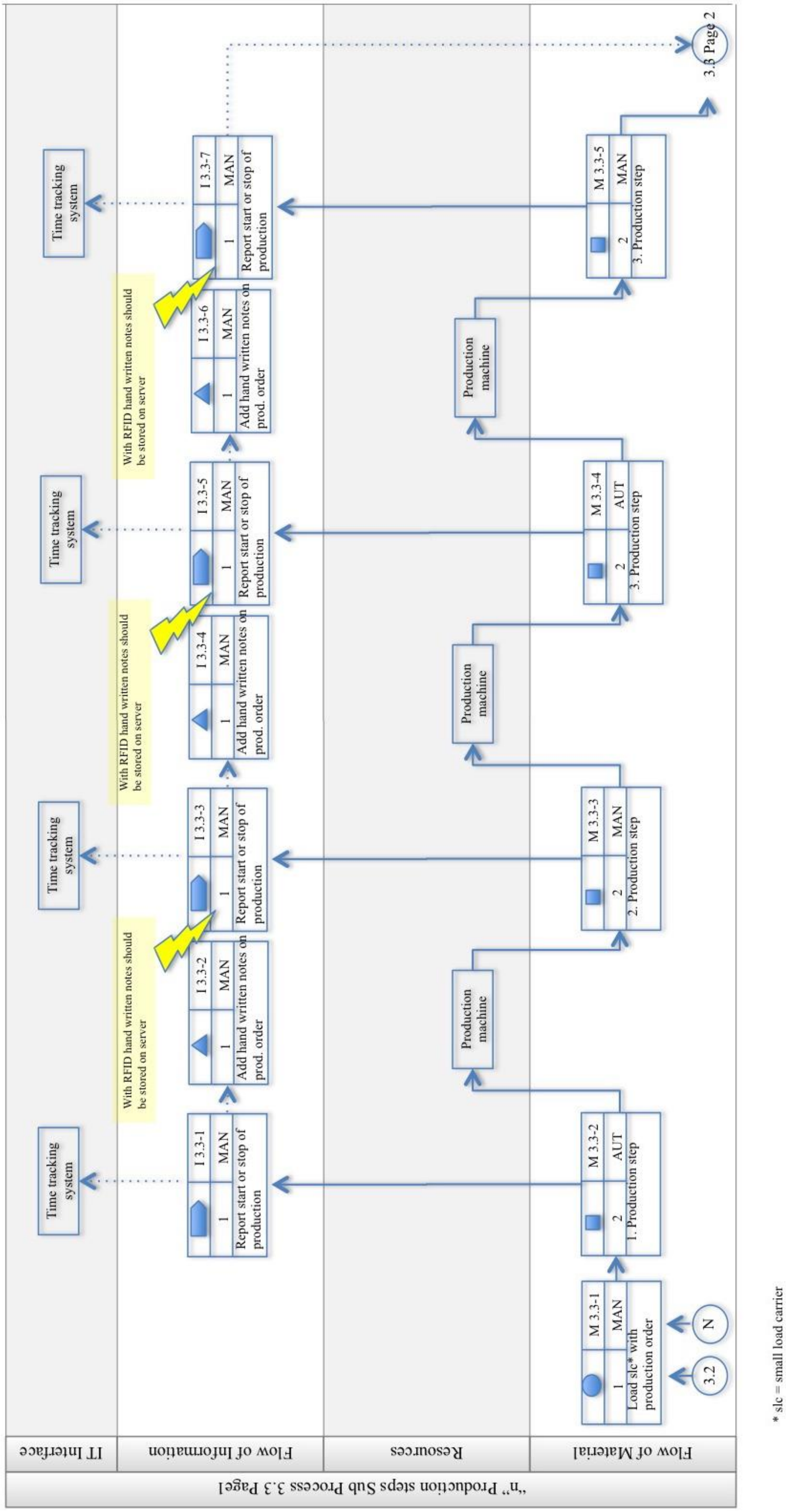

Fig. 4.3: Process chain plan for the subprocess 3.3 "n" production steps page 1

Fig. 4.4 presents the quality of material- and information flow as well as the Glauto quality combined in one figure for a better overview. It is obvious that 4. storing and packing has the highest quality of material flow which is owed to the simple short process. It takes the product one step closer to being delivered to the customer with simple, short work.

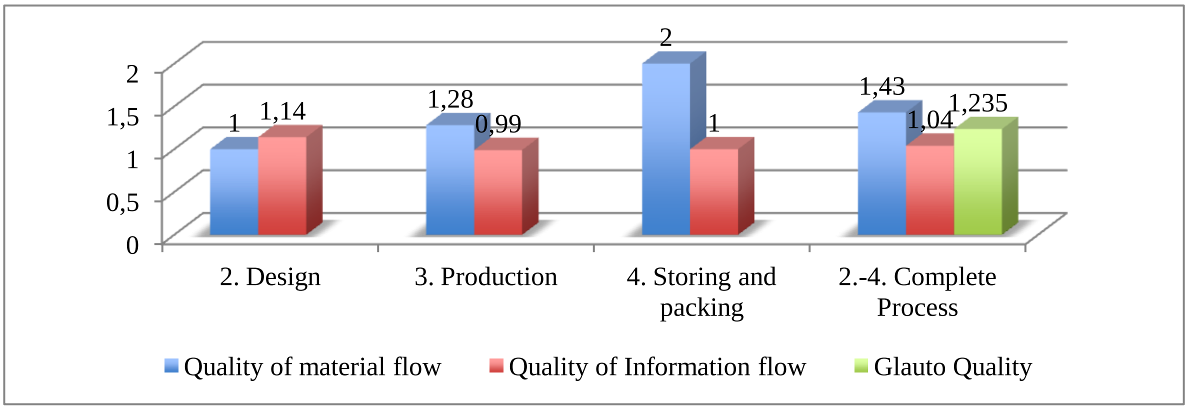

Fig. 4.4: Several process key figures for the main process and the complete process for the first case study: small batch production

Fig. 4.5 features the comparison of the development of the net present value for both systems. It is remarkable that the net present value after five years only differs about 3.000 € despite different acquisition costs and different benefit per year. One reason is that there are only small differences between the barcode and the RFID system. The difference is 4,6% (RFID 42 min. savings, barcode 40 min. savings) more time savings per each production order, e.g. the manual job of picking, using, and putting back the barcode reader is not required for the RFID system [20], [7].

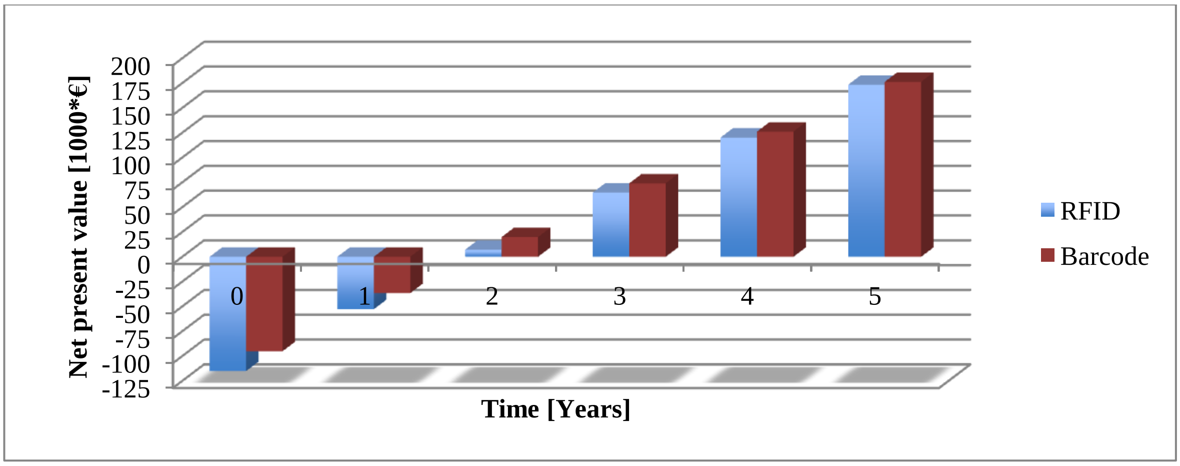

Fig. 4.5: Development-comparison of the net present value for a barcode and an RFID system [20], [7]

4.2 Auto-ID in Bulk Applications

The considered company is a Swiss company, which produces outdoor and mountain clothing and -equipment. The company is specialised in the high quality, premium sector and is trying to be the technology leader. 55% of the products are produced in Asia or in Europe. The considered site in Germany is the European Logistics Centre. The complete logistic is orientated on the on time provision on commissioned and packed goods for the customers. The core of the logistic system is the Dematic multi-shuttle storage system. Cartons and cases are stored in it for commissioning. When they are needed they are delivered automatically to the picking places. An automatic small parts storage, which is constructed as a high-bay warehouse, is the replenishment for the multi-shuttle storage [7].

Fig. 4.6: Primary goals for the Auto-ID introduction for the bulk application [24]

Next is to be found the possible and the chosen technology for this application. The chosen technology is marked in yellow.

Table 4.2: Conception summary

Frequency	LF	HF	UHF	MW
Energy Supply	Passive	Semi passive	Active	
Data storage	Read-only	EEPROM	FRAM	RAM
Type of coupling	Capacitive	Inductive	Backscatter	
Design	Disc transponder	Glass transponder	Smart label	Chip card
Reader	Handheld	Gate	Tunnel	Table integrated

Application of the Glauto Process Chain Paradigm

Next is to be found the hierarchic process level model for this case study (Fig. 4.7). The considered part for this case study is storing and packing. It is the first step of the Glauto process chain paradigm.

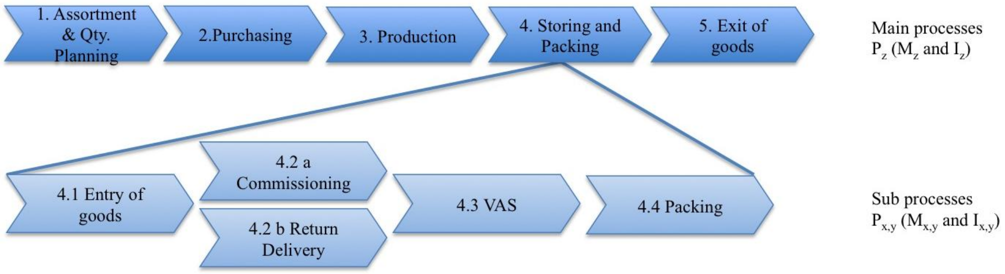

Fig. 4.7: Hierarchic process level model for bulk application

This "overview" leads to the detailed process chain plans for each process. Next is to be found a chosen process chain plans for this case study as an example (Fig. 4.8).

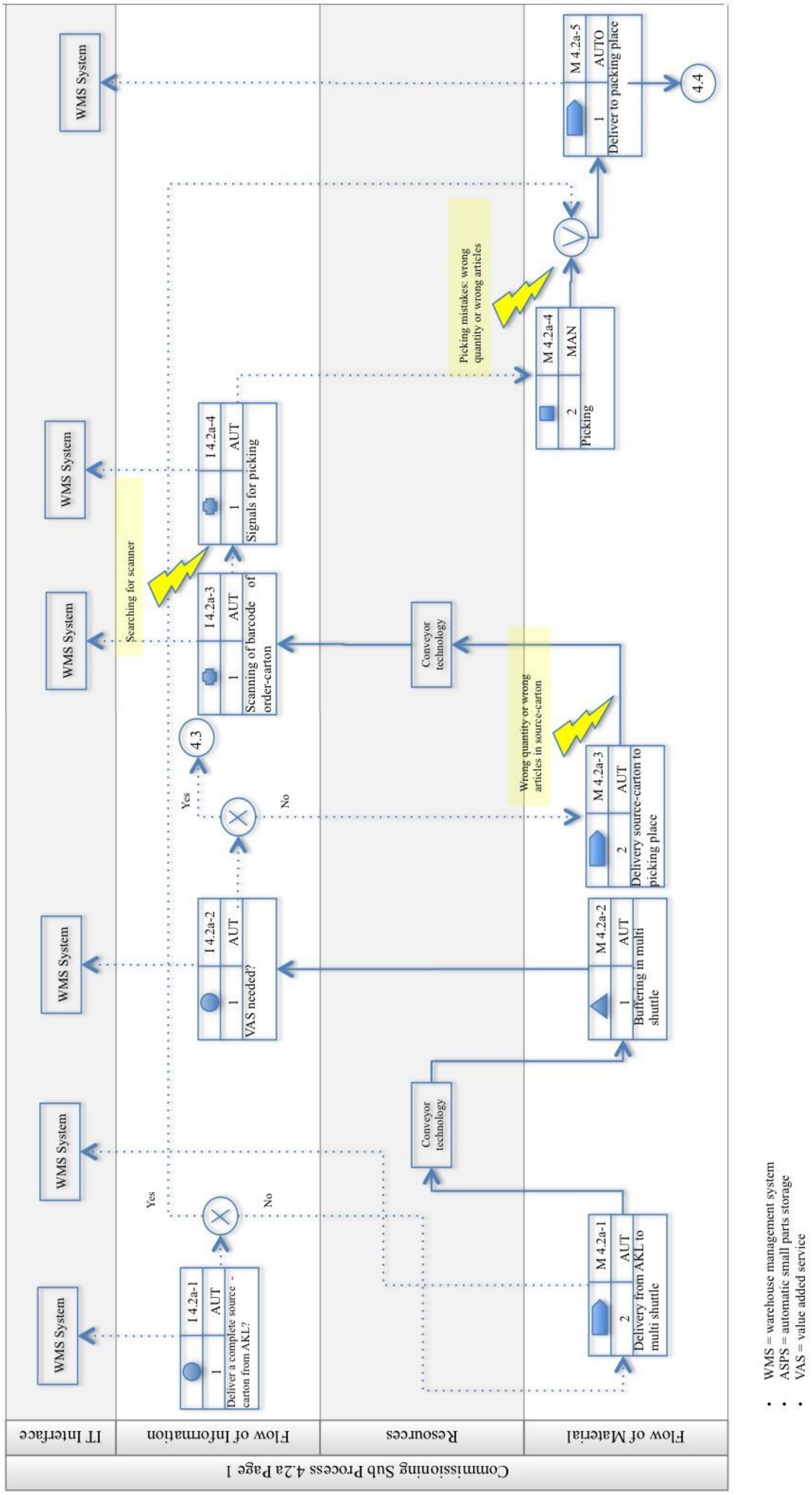

Fig. 4.8: Process chain plan for the subprocess 4.2a commissioning

Next are to be discussed the key figures for the quality of material. Fig. 4.9 presents the quality of material- and information flow as well as the Glauto quality for each subprocess for 4. storing and packing as well as the main process 4. storing and packing combined in one figure for a better overview. It is obvious that 4.2b return delivery has the lowest quality of material- and information flow. Due to its natural structure manual unpacking, checking, identifying and giving input in the IT-systems define the process. In contrast to that 4.2a commissioning and 4.3 value added services have a high quality of material flow, which is owed to structured movement of the handled goods, which leads a step closer to delivering the products to the customer.

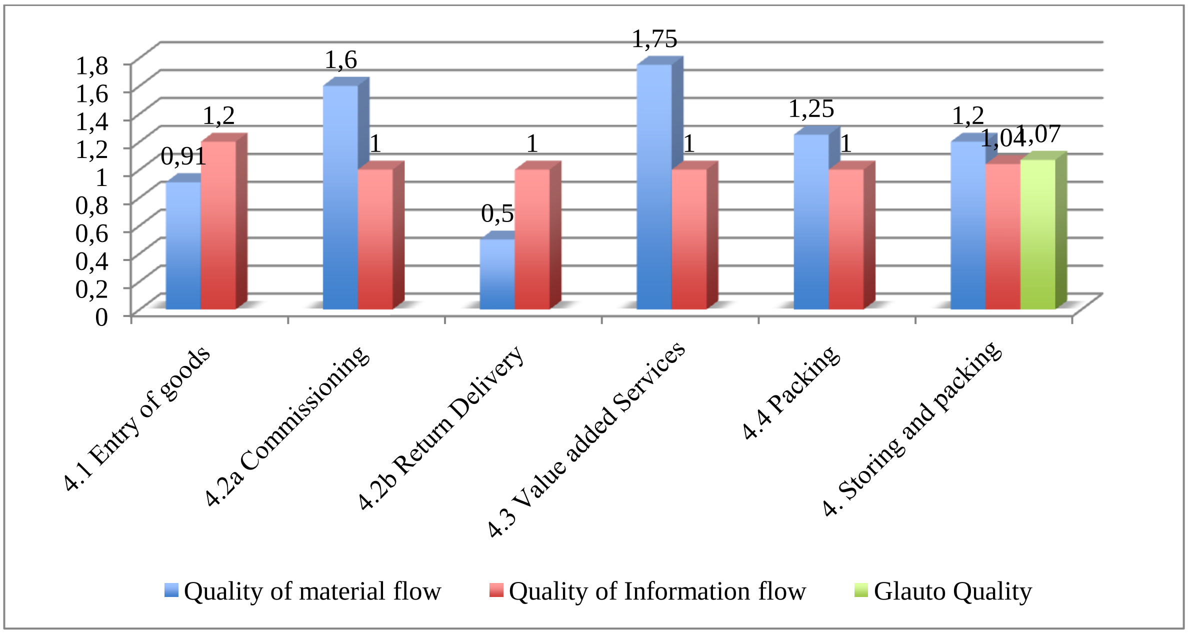

Fig. 4.9: Several process key figures for the main subprocesses and the main process 4 storing and packing for the second case study: bulk application

Fig. 4.10 clearly states no economical use of RFID in the near future. The main problem is that the prices for transponders are too high and the factory already has a high degree of automation – 21,22% process storing and packing.

But it has also to be considered that the company expects a sales increase of 5% due to higher product availability. That means an extra yearly benefit of 300.000 €, which is not considered in the above calculation. It would totally change the calculation, e.g. it would mean a payback period of less than two years.

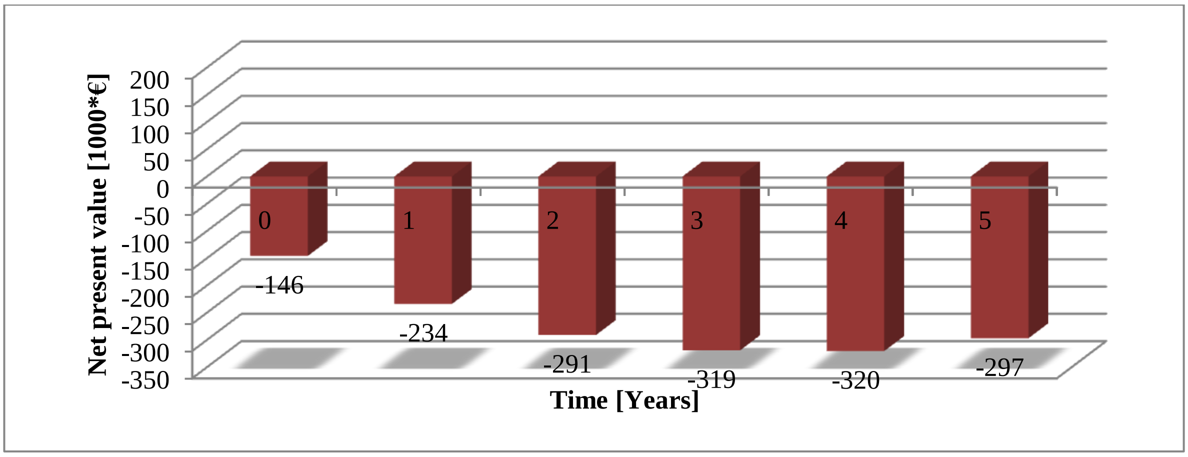

Fig. 4.10: Development of the net present value of an RFID system [24]

Both case studies are designed to reach different goals. Also the structure of both systems is quite different. The first case study is working with a closed system (reuse of the transponder) and the second case study is working with an open system (receiving transponder from supplier and sending transponder to customer). Both are also based on different frequencies with their pros and cons. Ultra high frequency (UHF) offers a larger reading distance than high frequency (HF) but also is strong influenced by humidity and metal. Due to cost savings both systems are based on passive, read only, smart labels. The acquisition costs differ by 27 % (year 0). This means the system for the BA costs 31.000 € more than the system for the SBP. In the first year and afterwards is where the gap between the two systems is getting bigger. In the first year the gap is about 181.000 € and it increases even to 470.000 € in the fifth year. It is obvious that ether the design of system has to be changed, the prices of the transponder have to decrease or the consideration of other influences has to be added to the cost benefit calculation for the BA to make it economical useful. In contrast to that the system for the SBP has a much shorter payback period and gains more benefit that costs per year.

4.3 The Reasonable Degree of Visibility

In contrast to the optimal degree of visibility, which may be understood as the best technical solution the reasonable degree of visibility should be understood as the compromise between best technical solution and best financial solution. The technology RFID offers many possibilities but for a certain application the question will always be “Is the achieved result worth the invest?”

At first generalities and definitions are to be found and afterwards the two case studies will be analysed for defining the reasonable degree of visibility for each case study.

Schwaninger offers the opportunity to define the reasonable degree of visibility in three management levels: Normative, strategic and operative. With respect to the technical approach of this thesis, only the operative level is considered, which is to be found below. [21] The reasonable degree of visibility is reached when increasing the visibility causes more costs than saving costs respectively than generating benefit [22]. Fig. 4.11 shows graphically the situation to be analysed. Formally known cost function is used for the cost function $c(x)$. For the benefit function $b(x)$ a logarithmical function is used. The logarithmical function is chosen because visibility normally has a certain maximum and the benefits are higher in lower degrees of visibility. E.g. locating a transponder with an accuracy of 0,1 m normally does not increase the benefit more than locating an object with an accuracy of 0,5 m but it increases the costs for a certain application.

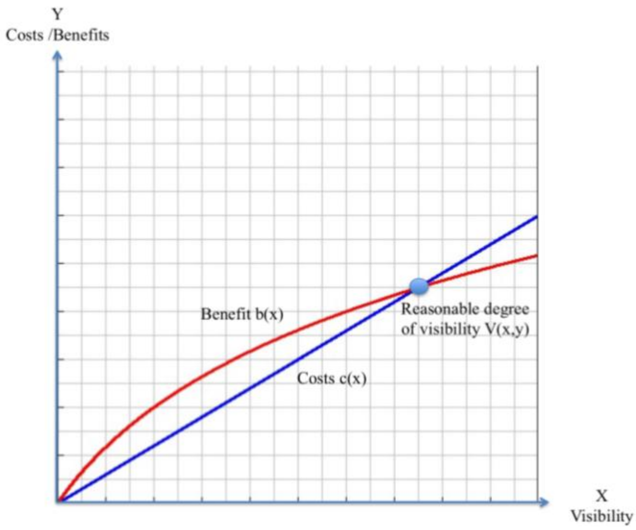

Fig. 4.11: Qualitative visualisation of the reasonable degree of visibility

Fig. 4.12 shows the comparison of values, which are calculated for the two case studies. Yearly costs are always to be seen in relation to acquisition costs. This is why the BA reaches a lower value than the SBP on the y-axis. As it takes a long time until the payback period is reached the costs have a strong influence on decreasing the y value. Along with this is to be seen the x value for the BA. It is 3 to 4 points lower than for the SPB. This can be explained also with the long payback period, which results in better having a lower visibility for more cost savings. Comparing the barcode system and the RFID system for the SBP it is obvious that both values for the barcode system are higher. One reason is lower costs at nearly same benefits, which results in higher reasonable degree of visibility.

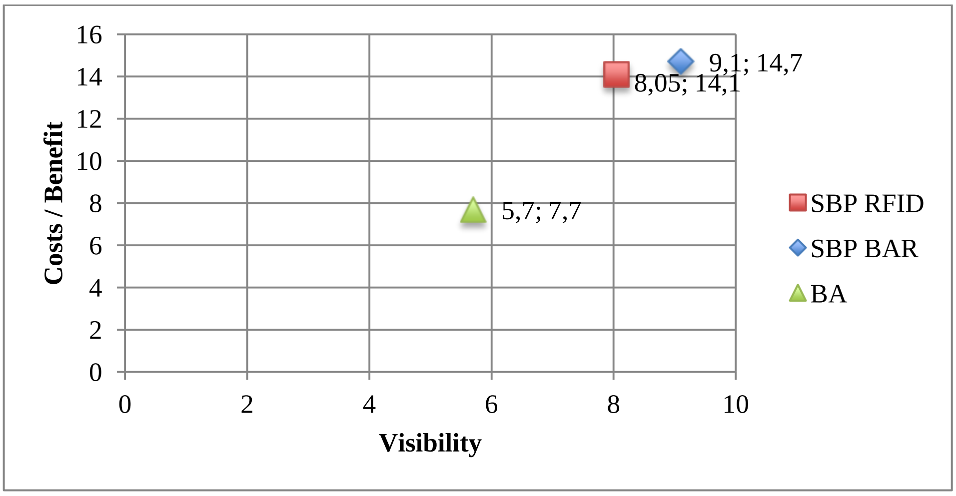

Fig. 4.12: Graphical comparison of the reasonable degree of visibility

5 SUMMARY OF RESULTS AND FUTURE ORIENTATIONS

The main scientific contribution of the thesis may be summarised in the following points:

- **Development of a specialised process analysing tool for Auto-ID projects**

At the moment no process visualisation method exists which allows a complete process recording taking into account material and information flow, assistive equipment, resources as well as IT interfaces. Normally existing methods are focussing on a later process modelling which make them complex. A new method for process visualisation is developed which is called “Glauto Process Chain Paradigm”.
Glauto process chain paradigm is a standardised method. It is mainly based on the visualisation of (sub) processes with a few logical operators for material and information flow. Glauto process chain paradigm is positioned as a universal tool for all Auto-ID interfaces in the middle of all three considered aspects as there is a need to record processes, consider interfaces to existing IT systems as well as being able to rate processes in the sense of economical aspects
In addition several key figures are developed to be able to rate and compare Auto-ID projects. Glauto process key figures do not measure the input or output of a system more they describe the system and the quality of a process itself. This is how they differ from conventional logistics key figures. They are focused on the process itself and the improvement of it. The key figures are mainly describing the quality of material flow, the quality of information flow and the degree of automation.

- **Development of Auto-ID concepts for two case studies**

The first case study is a worldwide operating company, which produces tools for metal cutting. Standard products are produced at other locations in the world. The German subsidiary does produce special tools. One change that has to be made for this case study is that the job ticket on a paper is left away. Another change, which has to be made to implement a barcode or an RFID system, is the preparation of the small load carriers (SLC). In order to identify the SLC (=work piece) not the working process as it is done right now, a SLC has to be equipped for both systems with a unique number and either with a barcode or an RFID transponder.
The second case study is a Swiss company, which produces outdoor and mountain clothing and equipment. The company is specialised in the high quality, premium sector and is trying to be the technology leader. In the European Logistics Centre the complete logistic is orientated on the on time provision on commissioned and packed goods for the customers. Due to an existing high degree of automation and automated scanning of barcodes, mainly the scanning of barcodes should be replaced with scanning of RFID transponders.

- **Analysis of two case studies with the new developed process analysing tool**

For both case studies the hierarchic process level models as well as the process chain plan from Glauto process are modelled. This allows an easy understanding how the processes are proceeding. With the modelled process chain plans the key figures can be calculated for an easy comparison of both case studies. The key figures also offer the possibility of seeing and planning for improvements of the processes and afterwards the verification of the taken actions.
Opposite to first guesses all values for the SBS are higher or equal than for the BA. It can be seen in connection with the development of the net present value, which offers a much quicker ROI for the SBP. The quality of material flow for the SBP is 19 percent higher than for the BA. One reason is that the SBP is a production, not a logistics centre. Nevertheless the quality of information flow for the SBP

and the BA are equal. In total, the Glauto quality differs than about 15 percent between the two case studies. The degree of automation is strongly different for both case studies. The main reason is that the handled quantities of goods are strong different. Written in values this means a difference of 20 percentage points.

- **Analysis of two case studies with respect to financial aspects**

The net present value method is used in order to economically quantify the use of the Auto-ID technology for the two case studies.

The acquisition costs differ by 27 % (year 0). This means the system for the BA costs 31.000 € more than the system for the SBP. In the first year and afterwards is where the gap between the two systems is getting bigger. In the first year the gap is about 181.000 € and it increases even to 470.000 € in the fifth year. It is obvious that either the design of system has to be changed, the prices of the transponder have to decrease or the consideration of other influences has to be added to the cost benefit calculation for the BA to make it economical useful. In contrast to that the system for the SBP has a much shorter payback period and gains more benefit than costs per year although the handled quantities of goods are much lower.

- **Development of the reasonable degree of visibility**

In contrast to the optimal degree of visibility, which may be understood as the best technical solution the reasonable degree of visibility should be understood as the compromise between best technical solution and best financial solution. The reasonable degree of visibility is reached when increasing the visibility causes more costs than saving costs respectively than generating benefit [22]. This general statement is converted into mathematical functions. The point of intersection of the cost function and the benefit function can be understood as the reasonable degree of visibility. The functions are well defined and the methods for calculation the point of intersection are given.

- **Analysis of two case studies with the new developed reasonable degree of visibility**

The developed functions for the reasonable degree of visibility are applied of the two case studies. This makes it possible to compare the costs respectively the benefit at the same time with visibility.

Yearly costs are always to be seen in relation to acquisition costs. This is why the BA reaches a lower value than the SBP in costs/ benefits. As it takes a long time until the payback period is reached the costs have a strong influence on decreasing the costs/ benefits value. Along with this is to be seen the visibility value for the BA. It is 3 to 4 points lower than for the SPB. This can be explained also with the long payback period, which results in better having a lower visibility for more cost savings.

This work can be classified as a progressing step in the analysis of Auto-ID applications. With the developed method it is possible to deeply describe and understand the processes as well as analyse the realisability of a certain application based of economical aspects. A possible future development of the system can be described by the following.

- Analyse of more case studies for further verification of Glauto process chain paradigm and especially to verify the values for the reasonable degree of visibility.
- Define more detailed functions for costs and benefits to avoid calculation offsets on the results e.g. define more steps for formula (3.13 dissertation thesis), (3.14 dissertation thesis), (3.16 dissertation thesis) and (3.17 dissertation thesis).

- Remodel the case study BA with the consideration of chapter 3.1.5 (dissertation thesis) and 3.1.6 (dissertation thesis). Recalculate the technical and financial aspects as well as the reasonable degree of visibility.
- Remodel of both case studies with the identified improvements (blizzards on the process chain plans) and recalculate key figures and reasonable degree of visibility.
- Design real time localisation systems for the two case studies. Analyse if this is economically useful and results in a higher degree of visibility.

6 CONCLUSION

Auto-ID Technologies, especially the RFID technology, are without doubt a quite interesting technology, which can be adapted to many applications in manufacturing. Due to the steady sinking prices of transponders the technology will escort us in our everyday life and also in the industry - also with the risks regarding data security.

At nowadays technology standard beside the RFID technology there are some other interesting Auto-ID Technologies that are worth looking at. For example the barcode technology is a profitable technology for identifying goods. It is really cheep and simultaneously easy to adapt to a certain good – it can be printed on labels or directly on the goods. In comparison to RFID there are some advantages (like the costs or the spreading etc.) but on the other hand many disadvantages (line of sight needed, dirt influence, reading possibility etc.) that gave and gives the RFID technology an enormous boom in the last few years and nowadays. The IRID technology is something in between the “big players” RFID and barcode. A line of sight is needed but it is not susceptible against dirt or most material, which it can be situated on. The other Auto-ID Technologies that depend on biometrical characteristic technologies for identifying or verifying persons certainly have potential for giving persons access to certain areas or verifying a person to do something. But in comparison to RFID or barcode the potential in the manufacturing area is quite low because the biometrical technologies cannot be used for identifying goods, which certainly are higher amounts than persons and need to be identified more often than humans.

With the development of a specialised process visualisation method for Auto-ID projects is now possible to quantify and compare different projects with each other. Another big advantage for the “Glauto process chain paradigm” is the structured way or workflow of noting down each subprocess. With its logical connectors it is close to the thinking when programming something, which should make it easier for IT experts to program the IT structure for an Auto-ID application especially in large projects. The key figures themself help to recognise potential for improvement whether it to be found in the material- or in the information flow. In addition to that the key figure degree of automation might also help for discussion if more automation should be invented in a company.

For the analysed small batch production the implementation of the Auto-ID technology is a big challenge because the company produces so many different products, which makes it hard to design a suitable IT-backend. There are ideas for a barcode- and an RFID system. There is no big difference between these two systems for the small batch production in the design of the software/ IT back end. With some small changes regarding drivers etc. the software could be used for a barcode- and an RFID system or for a combination of the two technologies. The main difference is really the used technology itself. Also when thinking about times and handling these two systems are close to each other – for a small batch production. Another difference for these two systems is the price – the barcode-technology is certainly cheaper in acquisition- and yearly costs than the RFID technology but the time savings with an RFID system compared to a barcode-system are about 4,6% quicker. The reason is that an RFID system is a little but quicker in the handling also for smaller quantities. This is also verified by financial calculation, especially with the net present value method where after five years the difference is only about 3.000 €. The main point is to create a useful, time-effective concept for a small batch production is not the Auto-ID technology itself, it is more the structure of the system and what/ where it is identified. There is a need for more intelligence in the system design than benefit for a modern “fancy” technology.

Every identifying process for an RFID transponder saves some seconds in comparison to reading a barcode or even makes it possible to identify something that is not orientated and not quite clean for scanning a barcode with a barcode reader. So mostly the preventing factor from not buying an RFID system as an open system (without reuse of the transponder, often bulk applications) are the running costs as the prices for transponders are too high nowadays to economically identify all goods as it has been identified in the case study bulk application. But on the other hand it has to be very carefully taken into consideration the influencing factors for the financial calculation e.g. loss or theft of goods, which has not been considered for the second case study. Without considering loss or theft of goods and without considering marking of superior goods the case study does have a longer payback period than five years. With consideration of both aspects it will be probably much shorter.

Nevertheless in general the Auto-ID technology can generate more benefit when a company is handling larger numbers of goods and the existing degree of automation is not as high as it is for the considered bulk application. Also the marketing aspects can be something to look at- for both case studies- you can show your customers being a modern and innovative company. E.g. with the created concept for the small batch production you can offer your customer real-time data about their ordered products – if you want to of course. The customer could view over the Internet with logging in for example in which status his/ her ordered product is. For the two considered case studies it has to be stated that the most important part when applying Auto-ID technology to an existing system is to profound question the design of the desired system and consider the important interfaces and influences for a optimum realistic financial calculation.

One of the hardest questions to answer for implementation of new technology is the balance or the compromise of technical possibilities and financial reasonableness. Improvements of the possibilities to academically answer this question are given with the chapter “The reasonable degree of visibility” by generating functions for costs and benefits for the two considered case studies. The bulk application reaches a lower value of visibility than the small batch production. Along with this is to be seen the cost/ benefit value for the bulk application, which results in better having a lower visibility for more cost savings. The values for the BA will dramatically change with the consideration of loss or theft of goods and tagging only of superior goods. Comparing the designed barcode system and the RFID system for the small batch production it is obvious that both values for the barcode system are higher. One reason is lower costs at nearly same benefits, which results in higher reasonable degree of visibility.

Concluding this the discrepancy between different Auto-ID projects can be made visible with the two developed tools. First of all with the help of the Glauto process chain paradigm for useful, effective process analysis. The mathematical approach for the reasonable degree of visibility further more enhances the transparency of effectiveness for Auto-ID projects. Visibility (technical aspect) as well as costs/ benefits (financial aspect) are considered in the algorithm.

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RESUMÉ

V priebehu posledných rokov získava automatická identifikácia a zber dát (ďalej Auto-ID) stále viac pozornosti a možností využívania. Ciele priemyselných aplikácií sú od aplikácií prístupovej kontroly mierne odlišné. Pre aplikácie prístupovej kontroly sa vo väčšine prípadov používajú čipové karty a biometria. Keďže v dizertačnej práci sa zaoberáme vysokofrekvenčnou identifikáciou (RFID) vo výrobnom procese, zameriavame sa predovšetkým na jej priemyselné využitie. Samotná problematika čipových kariet a biometria nie je v tejto práci rozoberaná.

Technologické postupy Auto-ID, ktoré využívajú magnetické pásky a čipové karty, podliehajú mechanickému opotrebeniu a pri čítaní musia byť v kontakte s čítačkou. Systémy strojového videnia, čiarové kódy a RFID sa mechanicky neopotrebovávajú. Tieto tri technológie sa používajú v priemysle. Systémy strojového videnia sa používajú predovšetkým tam, kde je potrebné porovnávať výrobok s obrazom, aby príslušný stroj uskutočnil potrebné rozhodnutie. Rovnako ako systém čiarových kódov potrebujú pre svoju funkciu priamy pohľad na výrobok. Systémy RFID túto nevýhodu nemajú. Okrem toho sa v mnohých štúdiách uvádza, že ešte stále existuje veľký potenciál pre ďalší vývoj RFID transpondérov. Oproti tomu technológia, ktorá využíva čiarové kódy, už dosiahla najvyššiu úroveň použiteľnosti. Spoločnosti, ktoré zavádzajú RFID, sledujú predovšetkým nasledovné ciele:

- zlepšenie výrobných postupov,
- zlepšenie dát pre analýzu,
- dodávanie svojich výrobkov s údajmi,
- udržať svoje postavenie ako spoľahlivý výrobca.

V protiklade sú k tomu nasledovné dôvody, kvôli ktorým spoločnosti nechcú implementovať RFID:

- náklady/nedostatočná návratnosť investícií,
- nedostatočné znalosti a pochopenie,
- vyspelosť spoločnosti,
- vyspelosť technológie/trhu.

Náročné úlohy v oblasti priemyselného inžinierstva, ktoré sú spôsobené búrlivým výrobným prostredím (kratšie životné cykly výrobkov a stále klesajúci počet opakujúcich sa zákaziek) vyžadujú prispôsobenie už existujúcich IT koncepcií, ako je napríklad EDM (Engineering Data Management) a PDM (Product Data Management). Výdavky spojené s implementáciou, problémy s bezpečnosťou dát, ale aj nevyhnutnosť zlepšenia využívania komplexných postupov pre ziskovú prevádzku si vyžadujú syntézu výrobných procesov.

Koncepcie resp. aplikácie Auto-ID postupov umožňujú tvorbu analýz v reálnom čase so súčasne zaznamenávanými údajmi. Predovšetkým pre spoločnosti s celosvetovou pôsobnosťou je nevyhnutný bezprostredný prístup k údajom získaným v rôznych miestach. To neplatí iba pre úseky, ktoré sa zaoberajú kontrolou kvality. Môžu to byť údaje, ktoré sa bezprostredne týkajú plánovania a kontroly výroby, alebo na druhej strane aj údaje z oblasti údržby alebo skladového hospodárstva.

Implementačné náklady a namáhavosť, respektíve trvanie implementácie patria k tým faktorom, ktoré niekedy vedú riadiacich pracovníkov v priemyselných podnikoch k rozhodnutiu zastaviť Auto-ID projekty už v počiatočnom štádiu. Zhromažďovanie osobných údajov a dát o výrobných časoch za účelom vytvárania následných kalkulácií v reálnom čase je nepochybne spojené s rizikami, ktoré sa týkajú ochrany údajov.

Účelom dizertácie je vytvoriť respektíve analyzovať už zavedené aplikácie Auto-ID technológií pre „firmy nasledujúcej generácie“, ako aj preskúmať ich realizovateľnosť na základe ziskovosti.

Ciele a prínosy tejto dizertačnej je možno rozdeliť do nasledovných troch skupín.

1. **Návrh a vývoj**
   - Špecializované nástroje procesnej analýzy pre Auto-ID koncepty.
   - Auto-ID koncepty s vyvinutými nástrojmi pre dve prípadové štúdie.
   - Primeraná úroveň viditeľnosti.
2. **Analýza**
   - Technické a finančné aspekty pre dve prípadové štúdie.
   - Dosiahnutie krátkej doby návratnosti výdavkov pre dve prípadové štúdie.
3. **Porovnanie**
   - Technické a finančné aspekty pre dve prípadové štúdie.
   - Primeraná úroveň viditeľnosti pre dve prípadové štúdie.

V súčasnosti neexistujú žiadne vizualizačné metódy výrobných postupov, ktoré by poskytovali možnosť kompletného zaznamenávania výrobného procesu a ktoré by účinne zohľadňovali tok materiálu a informácií, pomocnú výbavu, zdroje a IT rozhrania. Bežne existujúce metódy sa zameriavajú na následné modelovanie postupov, ktoré ich dopĺňa. Komplexnosť a nevyhnutné hlboké pochopenie procesov je však obštrukčným činiteľom pre zaznamenávanie výrobného procesu, ktoré by malo byť rýchle a časovo nenáročné. Okrem toho existuje aj nebezpečenstvo, že bude zaznamenaný neúplný aktuálny stav, čo by mohlo viesť k časovo a finančne náročným opakovaniam záznamových postupov za účelom zaznamenania naozaj všetkých existujúcich informácií.

Z týchto dôvodov bola vyvinutá nová a pôvodná metóda vizualizácie pracovných postupov, ktorú sme nazvali „Model Glauto Procesu (Glauto Process Chain Paradigm). Názov "Glauto" sa skladá z kombinácie prvých dvoch písmen priezviska **Gl**eser" a **Auto**, ktorý naznačuje, že systém je špecializovaný na Auto-ID aplikácie. Tento postupový reťazec je charakterizovaný zaznamenávaním integrálneho procesu toku materiálu a informácií, pomocnej výbavy, zdrojov a IT rozhraní, ktoré ho vo vyššej miere prispôsobuje postupom Auto-ID. Umožňuje aj logické a podmienené korelácie, pretože informačné deficity vytvárajú problémy pre plánovanie a riadenie pracovných postupov. Okrem toho Glauto proces podporuje rozhrania k IT systémom, tok materiálov a informácií, ako aj pomocný tok, ktorý predstavuje predovšetkým dopravu v priemyselnom prostredí uskutočňovanú rôznymi prostriedkami. Glauto proces sa zameriava predovšetkým na kombináciu informácií týkajúcich sa toku materiálov a informácii s údajmi existujúcich IT systémov, aby bolo možné plne využívať potenciál technológie Auto-ID, ktorý je aplikovateľný iba vtedy, keď podporný systém vytvára zo všetkých dostupných vstupov a výstupov výkonnú zostavu.

Postup Glauto procesu je vyvíjaný ako štandardizovaná metodika. Je založený predovšetkým na vizualizácii (sub) procesov a na niekoľkých logických operátoroch toku materiálu a informácií.