Techniques for Analysis of Auto-Id Applications for sustainable Development

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Abstract— This paper deals with techniques for analysis of Auto-ID applications for sustainable development. The design of a new method for process visualization specialized for Auto-ID projects is to be found after the introduction and the problem formulation of this paper. Existing process visualization methods are not taking into account all aspects, which need to be considered for a complete process recording. Especially Auto-ID projects often have many interfaces and connections to other IT-systems, which result in the need for a complete and easy-to-understand process visualization. Also key figures for quantification and comparability among different projects are developed. Afterwards the new development method is applied on two strong different case studies to cover a wide range of application to test if the developed method is versatile usable. The second presented technique in this paper is the reasonable degree of visibility, which is defined mathematically as well as applied on the two case studies. The goal with reasonable degree of visibility is to find the point where increasing the visibility causes more costs than saving costs respectively than generating benefit.

Keywords— Auto-ID case studies, process visualization method, process chain paradigm, radio frequency identification system, reasonable degree of visibility.

I. Introduction

AUTO-ID and sustainable development is this something, which can go along with each other, or can it not exist simultaneously? First the definition for sustainable development has to be considered in order to take a closer look:

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:

the concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given; and

the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs." [1].

Auto-ID is not considering any need of the world's poor but it is saving trees and paper if it is used in closed system, e.g. the transponder can be used several times. An example for this system can be found in the first case study.

On the other hand (second part of the definition) Auto-ID should meet the present and future needs. Reducing mistakes and accelerating the output of goods by the help of Auto-ID technology is certainly something, which is underlining this idea. An example for these kinds of improvements is given in this paper by the second case study.

II. Preliminaries and Problem Formulation

How can an Auto-ID project, here a case study completely be described? A certain tool or method is needed to record all information and make the information be quantifiable and comparable – this can be achieved by a process visualization method.

At the moment no process visualization method exists which allows a complete process for an Auto-ID process recording taking into account material- and information flow, assistive equipment, resources as well as IT-Interfaces. Normally existing methods are focusing on a later process modeling 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 [2].

The following subchapters of this paper will describe at first the process how a new process visualization method was developed shortly and define where in the existing landscape of methods for process visualization it should be situated. Afterwards details how the method is structured and should be used will be given [3].

This paper is answering the open questions of technical kind such as chosen hardware and comparability of different applications with the help of two case studies: One case study for a small batch application and one case study for a mass production. The developed process visualization method will be applied on both case studies and the results will be compared afterwards.

The technology RFID offers many possibilities but for a certain application the question will always be “Is the achieved result worth the invest?”. Techniques to answers to this question are to found afterwards in the chapter “reasonable degree of visibility”. The developed techniques will also be applied and compared on both case studies.

III. GLAUTO Process Chain Paradigm

This chapter describes the first developed technique, which is a specialized process visualization method that is called

"Glauto".

A. Generalities

A new method for process visualization will be developed which is called "Glauto Process Chain Paradigm". It will feature an integral process recording with respect to material- and information flow, assistive equipment, resources as well as IT-Interfaces, which make it more, specialized for Auto-ID processes. It will also feature logical and conditional correlations because information deficits are a problem for planning and controlling of processes [4]. Glauto 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 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 [3].

Glauto will be developed as a standardized method. It will mainly be based on the visualization 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 "Gleser "and the "Auto" without ID to describe its aim to be specialized for Auto-ID applications [5].

Fig. 1 shows a diagram with three aspects namely "Logistics & Production", "Business Process Management" and "IT Soft- & Hardware". To be found in the diagram are commonly used process modelling and / or process analysing tools. The goal for Glauto 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 [3].

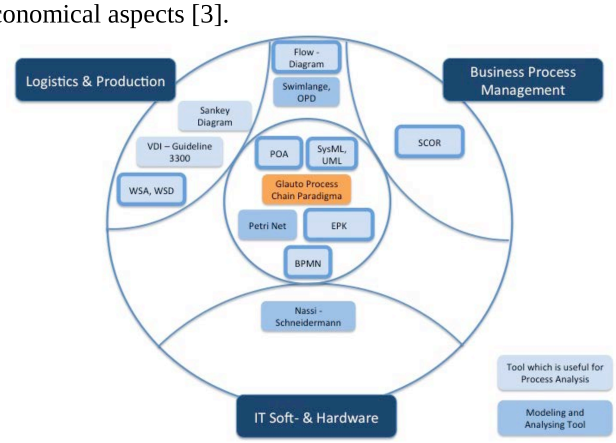

Fig. 1 Classification of Methods for Process Visualization (based on [2])

B. Definitions of Glauto Content and Process Key Figures

Next is to be found the definition of the processes used in the Glauto process chain paradigm

• Main Process

A main process is a sequence of interdependent and linked procedures, which, at every stage, consume one or more resources (employee time, energy, machines, money) to convert inputs (data, material, parts, etc.) into outputs. These outputs then serve as inputs for the next stage until a known goal or end result is reached [6]. A main process can consist of n sub processes and m operation block diagrams, with n < m [5].

• Sub Process

A sub process is a set of activities that have a logical sequence that meet a clear purpose. A sub process is a process in itself, whose functionality is part of a larger process [7][5].

• Operation Block Diagram

An operation block diagram is the smallest unit, belonging to a sub process and a main process in the Glauto process chain paradigm. It is characterized by its process type and contains a symbol for the type of operation [5].

Next is to be found a sample for process visualization with Glauto. 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. 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. Potential for improvement can be visualized by using a blizzard and next to it the improvement in textual description [5].

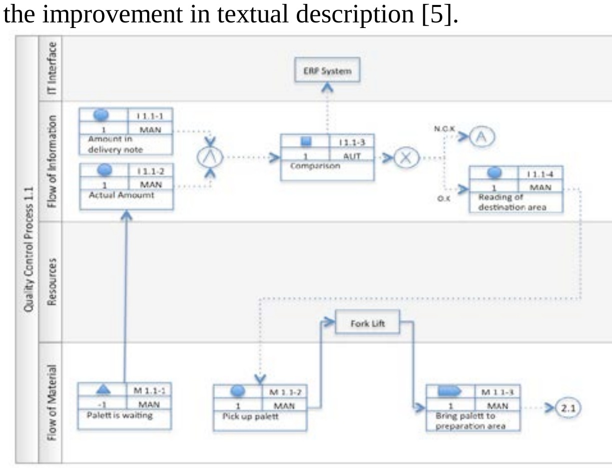

Fig. 2 Sample for a Glauto process chain plan with manual checking of goods at arrival (based on [2])

Next are to be found the definitions for the process key figures which can be used to qualify and compares Auto-ID application.

• Quality of material flow

The quality of the material flow for a sub process consisting of n block diagrams can be understood as below.

Glauto quality for material flow for a sub process is defined

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

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

where

$M_{x,y}$ sub material flow process,

$GQM_{x,}$ Glauto quality for material flow and sub process $M_{x,y}$,
$Y_{x,y-j}$ value of the block diagram,
j counter variable,
n number of counted block diagrams,
x counter variable,
y counter variable.
[5]

• Quality of information flow

The quality of the material flow for a sub process consisting of n block diagrams can be understood as below.

Glauto quality for information flow for a sub process is defined

$$GQI_{x.y} = \left[\sum_{j=1}^{n} Y_{x,y-j}\right] \Big/ n \; ; x, y = const \quad (2)$$

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

where

$GQI_{x,y}$ sub material flow process,

• Glauto quality

The term Glauto quality GQ should be understood as a combination of GQM and GQI. The weighting of GQM and GQI is equal.

$$GQ = [GQM + GQI]/2 \quad (3)$$

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

where

GQ Glauto quality,
GQM Glauto quality for material flow,
GQI Glauto quality for information flow.
[5]

• Degree of Automation

First of all values for the operation block diagram need to be defined. We already defined values for the operation block diagram itself (see chapter III B) but further more a definition of the variable Z (middle right of operation block diagram – Fig. 4.) has to be made in order to generate a number for automation degree.

Automated operation: Z = 1, manual operation: Z = 0.

The general form of degree of automation DoA is defined

$$DoA = \sum_{j=1}^{n} Z_j \; /n \; [\%] \quad (4)$$

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

where

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

IV. Case Studies

In this chapter two case studies are to be found which will be described in the following in detail.

A. Auto-ID in Small Batch Production: Case Study Manufacturing of Special Tools for the Metal Cutting Industry

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 an RFID systems should add benefit and minimize as well as prevent errors. Fig 3 shows the primary goals for this case study [8].

Fig. 3 Primary goals for an Auto-ID introduction for the small batch production [8]

Next is to be found the hierarchic process level model for this case study (Fig. 4). The considered part for this case study is production. It is the first step of the Glauto process chain paradigm. In order to keep the focus on the technical aspects this rough overview about the process itself is only included in this paper. [6]

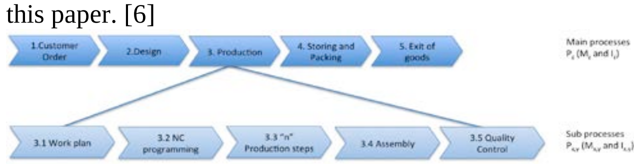

Fig. 4 Hierarchic process level model for the small batch production [8]

In the following details for the designed system is to be found. The first approach is the use of an RFID System, the second approach a Barcode System.

RFID System

In the following details for the first case study with the help of the RFID is to be found

Selection Frequency Range

Based on the standardization and that connected low costs for hardware the frequency range of 13.56 MHz is chosen. The influence of the contact with metal is just negative when direct contact occurs. But it can also be used for increase of the reading distance by a smart reflection.

Selection Transponder

Based on low acquisition costs and the possibility to print the box numbers directly would it be adequate to use “smart labels” on trial. When the robustness is not enough it could be switched on plastic coated transponder in keychain design. Therefore no exchange of the hardware is necessary. But robustness is certainly a factor, which can make RFID more favourable than a Barcode. RFID-Transponders can resist water, dirt, direct sunlight, salty air and aggressive environment influences. Barcodes often cannot resist these influences.

Selection Reader and Antenna

Solid installed readers with a flat table aerial on which the box is placed should be used here. As a supplement to the solid installed readers also mobile readers can be introduced or can be added later on. This would be good to display the delivery date, the production order number or something like that. For this hardware some additional programming needs to be done and the IT structure has to be converted to it because mobile readers are provided with data via WLAN.

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

Table 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

Calculation of Glauto Process Key Figures

Barcode System

In the following sub chapter a Barcode-Solution for a small batch production is to be found. A Barcode-Solution offers nearly the same advantages at lower acquisition costs. When comparing it to the RFID-Solution there are only slightly differences for this application. For this example the new idea is to identify the small load carriers not the working processes as it has done right now, which can be other realized with RFID transponders or with barcodes on the small load carriers.

Selection Reader

A CCD-Reader is a good compromise between costs and benefit. This reader allows a reading distance from zero to 40 cm, which is more than enough for this small batch production. First of all there are low quantities of goods and there is in nearly all cases the possibility to reach close to the goods for scanning them.

Selection Coding Technology

For this application it is not so important which barcode gets chosen because the information should be stored on the server. The barcode or RFID-Transponder is just the „key“ to the information. A typical industry barcode like Code 39 or Code 128 could be chosen but the slightly cheaper alternative might be EAN code. After the production the goods “leave” the industry sector and “enter” the trade/ logistics business. This is also an argument for the EAN code, it is wider spread to other branches than industry.

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

Table 2 Conception summary

Code Structure	1D	2D	3D	4D
Standard	EAN 128	QR Code (matrix code)	Additional colour (no standards)	Additional time and colour (no standards)
Reader	Handheld	Gate	Tunnel	Table integrated

Next are to be found data and key figures for the main processes, two and three and four, which consists of five sub processes as well as four main processes. The other processes (see Fig. 4) are not within the scope for this case study because of being out sourced or are not executed in the German subsidiary. Key figures are presented at main process level (no sub process key figures) due to readability and space restrictions.

Quality of material flow

2. Design (main process)

$$GQM_2 = \left[\sum_{j=1}^{1} Y_{2-j}\right] / 1 = 1 \quad (5)$$

3. Production (main process)

$$GQM_3 = \left[\sum_{y=1}^{5} GQI_{3,y}\right] / 5 = 1{,}28 \quad (6)$$

4. Storing and packing (main process)

$$GQM_4 = \left[\sum_{y=1}^{2} GQI_{4,y}\right] / 2 = 2 \quad (7)$$

Complete process

$$GQM_{tot} = \left[\sum_{z=1}^{3} GQI_z\right] / 3 = 1{,}43 \quad (8)$$

Quality of Information Flow

2. Design (main process)

$$GQI_2 = \left[\sum_{j=1}^{7} Y_{2-j}\right] / 7 = 1{,}14 \quad (9)$$

3. Production (main process)

$$GQI_3 = \left[\sum_{y=1}^{5} GQI_{3,y}\right] \Big/ 5 = 0{,}99 \quad (10)$$

4. Storing and packing (main process)

$$GQI_4 = \left[\sum_{y=1}^{5} GQI_{4,y}\right] \Big/ 5 = 1 \quad (11)$$

Complete process

$$GQI_{tot} = \left[\sum_{z=1}^{3} GQI_z\right] \Big/ 3 = 1{,}04 \quad (12)$$

Glauto Quality

$$GQ_{tot} = [GQM_{tot} + GQI_{tot}]/2 = 1{,}235 \quad (13)$$

Degree of Automation

2. Design (main process)

$$DoA_2 = \left[\sum_{j=1}^{8} Z_{2-j}\right] \Big/ 8 = 0\% \quad (14)$$

3. Production (main process)

$$DoA_3 = \left[\sum_{y=1}^{5} DoA_{3,y}\right] \Big/ 5 = 3{,}1\% \quad (15)$$

4. Storing and packing (main process)

$$DoA_4 = \left[\sum_{y=1}^{7} DoA_{4,y}\right] \Big/ 7 = 0\% \quad (16)$$

Complete process

$$DoA_{tot} = \left[\sum_{z=1}^{3} DoA_z\right] \Big/ 3 = 1\% \quad (17)$$

The Interpretation of the key figures is to be found in chapter 4.3.

B. Auto-ID in Bulk Applications: Case Study European Logistics Centre for Textile Production

The considered company is a Swiss company, which produces outdoor- and mountain clothing and -equipment. The company is specialized 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. Cardboard boxes and cases are stored in it for commissioning. When they are needed they are automatically delivered 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 [6].

Fig. 5 Primary goals for an Auto-ID introduction for the bulk application [8]

Next is to be found the hierarchic process level model for this case study (Fig. 6). The considered part for this case study is storing and packing. It is the first step of the Glauto process chain paradigm. In order to keep the focus on the technical aspects this rough overview about the process itself is only included in this paper [8].

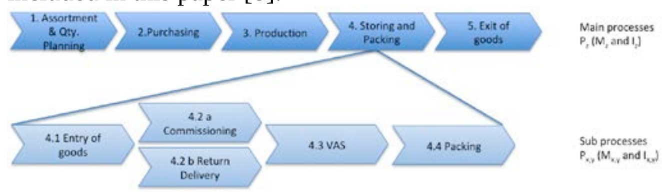

Fig. 6 Hierarchic process level model for the bulk application [8]

In the following details for the designed system is to be found.

Selection Frequency Range

Based on the standardization of the ultra high frequency range in 2014 for logistics and additionally the desired long reading distances and the desired reading speed the frequency range of 868 MHz is chosen. The transponders can be read in distances up to several meters with the backscatter technology, which is needed for this application.

Selection Transponder

Based on low acquisition costs and the possibility to print labels directly would it be adequate to use "smart labels" in the read only variant. With the backscatter technology also bulk reading and anti collision is possible, which means up to 500 transponders can be read in a few seconds. In this application approx. 3 millions transponders are needed each year, if tagging is done on article level. Thus the transponders have to be as cheap as possible to gain economical usage. With smart labels the price is in 2016 approx. 0,1 €/ pc. for the needed quantity of transponders. They can be easily printed additionally with a barcode and can replace the barcode that is used now.

Selection Reader and Antenna

For the European logistic centre three different types of reader will be used as there are:

1. Tunnel reader at the conveyer belts at 4.1 entry of goods and 4.2 a commissioning, which automatically checks the packed goods.

2. For the reworking places at 4.1. entry of goods and 4.2 solid installed readers with a flat table aerial on which the box is placed should be used. The antennas can be mounted under the table.

3. Optional handheld readers can be used for 4.2 b return of delivery and 4.3 VAS (Value added services) because pallets have to be read. The advantage is that there is no need for manual counting and booking of goods.

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

Table 3 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

Calculation of Glauto Process Key Figures

Next are to be found data and key figures for the main process four which consists of five sub processes. The other processes (see Fig. 7) are not within the scope for this case study because of being out sourced or are not executed in the European logistics centre. Thus key figures for the complete process cannot be presented here. Key figures are presented at main process level (no sub process key figures) due to readability and space restrictions.

Quality of material flow

4. Storing and packing (main process)

$$GQM_4 = \left[\sum_{y=1}^{5} GQI_{4,y}\right] \Big/ 5 = 0{,}94 \quad (18)$$

Quality of Information Flow

4. Storing and packing (main process)

$$GQI_4 = \left[\sum_{y=1}^{5} GQI_{4,y}\right] \Big/ 5 = 1{,}2 \quad (19)$$

Glauto Quality

$$GQ_4 = [GQM_4 + GQI_4]/2 = 1{,}07 \quad (20)$$

Degree of Automation

4. Storing and packing (main process)

$$DoA_4 = \left[\sum_{y=1}^{5} DoA_{4,y}\right] \Big/ 5 = 21{,}22\% \quad (21)$$

The Interpretation of the key figures is to be found in chapter 4.3.

V. Auto-ID in Small Batch Production and in Bulk Application: Comparison

Submission of a manuscript is not required for participation

ish is a valid reason for rejection. **Authors of rejected papers may revise and resubmit them to the NAUN as regular papers, whereupon they will be reviewed by two new referees**.

VI. Publication Principles

Both case studies are designed to reach different goals (see Fig. 3 and Fig. 5). 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). Also for the first case study many improvements are possible due to a low degree of automation (see Fig. 9). In contrast to that the second case study has a very high degree of automation wherever it is economically efficient, especially in the sub process commissioning (see Fig. 11). In addition to that the Glauto quality of information flow for the main process 4 storing and packing is also higher (16,67 %) which also indicates automatic processes (see Fig. 8 and Fig. 10).

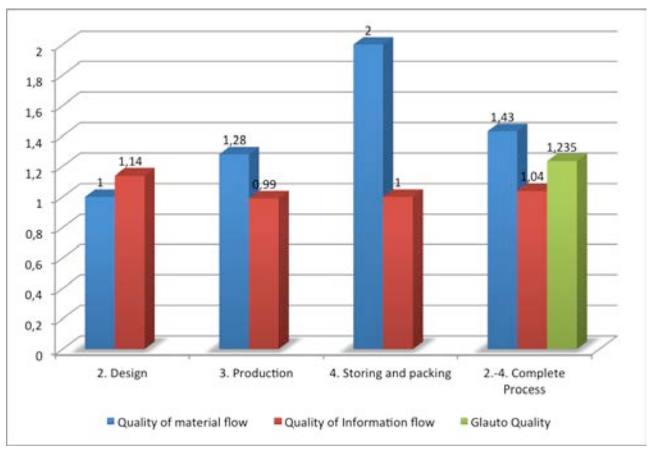

Fig. 8 Several process key figures for the first case study: small batch production

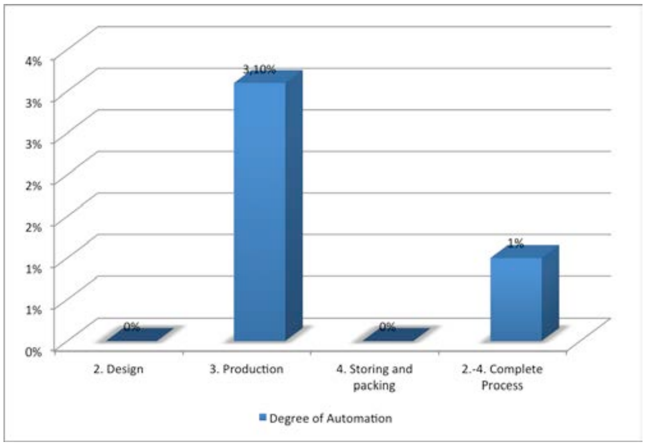

Fig. 9 Degree of automation key figure for the first case study: small batch production

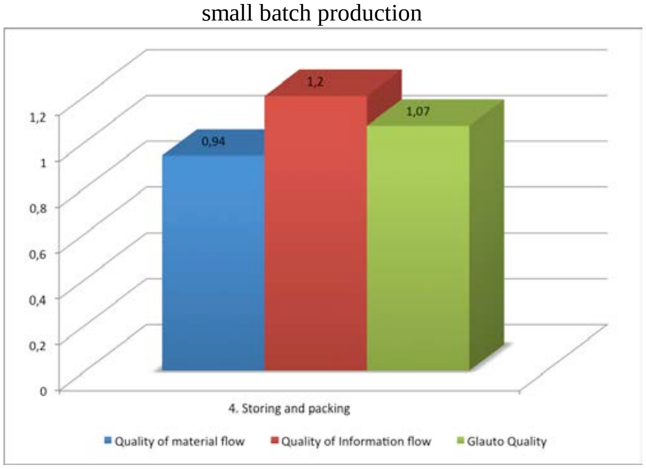

Fig. 10 Several process key figures for the second case study: bulk application

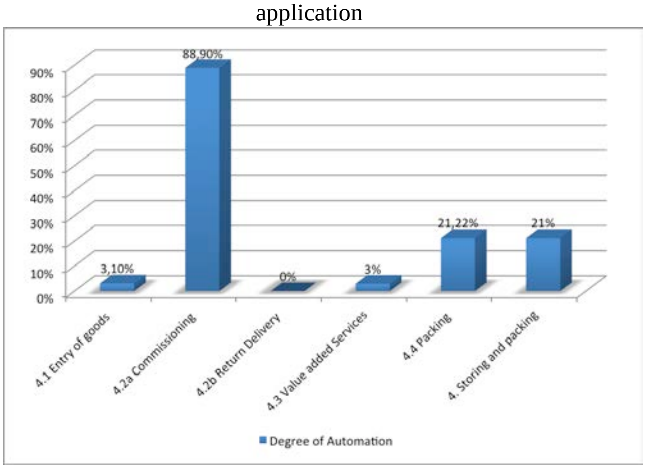

Fig. 11 Degree of automation key figure for the second case study: bulk application

VII. The Reasonable Degree of Visibility

This chapter is dealing with the reasonable degree of visibility for RFID applications. 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 (Fig. 15). 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 analyzed for defining the reasonable degree of visibility for each case study.

A. Generalities and Definitions

In this subchapter the most important generalities and definitions are to be found.

• Transparency

Transparency differs from visibility. The difference is that transparency also considers social aspects e.g. formal understanding and visibility mainly focuses on informational aspects. [9,10]

• Visibility

In logistics literature visibility mainly is defined in two different views:

1. Visibility as information sharing [11,12,13]
2. Visibility as supply chain inventory visibility [14] [15,16,17,18]

The first definition focuses on exchange of information between supplier, producers, distributers and stores. The exchanged information is mainly about warehouse stocks and demands forecast. The goal is to reduce warehouse stocks by equalizing the demand fluctuations.

The second definition focuses more on Auto-ID projects. The goal is to achieve data about the actual position of goods – not only in warehouses etc., also on transportation processes for improving logistic processes [9].

This leads to a view of visibility, which is defined by the following aspects:

- Data granularity
- Semantic integration in logistic processes
- Views of visibility data
- Real-time capability
- Data quality [9]

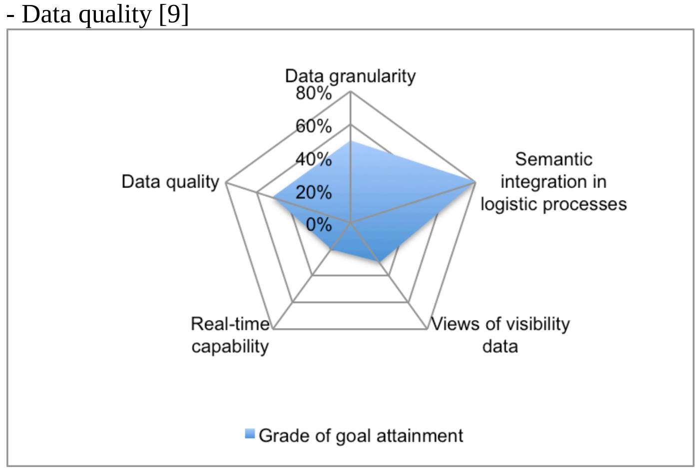

Fig. 12 Example for the grade of goal attainment for visibility

o Data granularity

The data granularity offers many facts about the performance capability of an Auto-ID system. Referring to Fleisch/ Christ/ Dierkes it is described with four dimensions: temporal/ local granularity, load carrier granularity, object coverage, data richness [13,19].

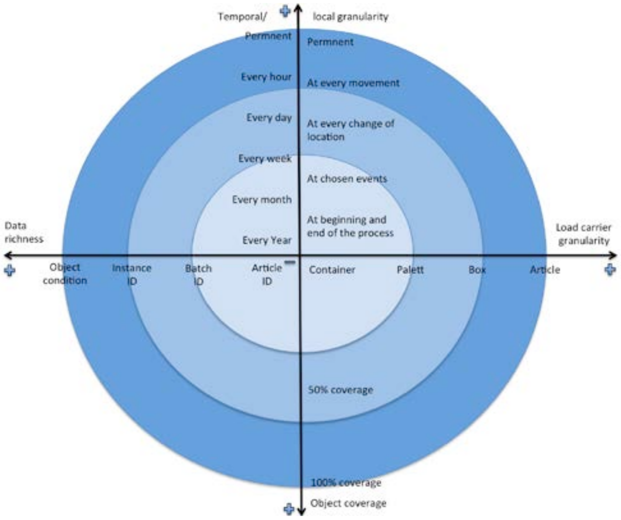

Fig. 13 Visibility shown via data granularity [19]

Data have to be connected with logistic units, orders, deliveries, customers, suppliers or organisation units [15].

o Views of visibility data

Two different views on visibility are possible.

o Point-in-time view: It is possible to view in an IT system where something is actually is situated.

o Cross-time view: It is possible to view when something will arrive somewhere.

o Real-time capability

Visibility data should be accessible as fast as possible from any location. As it not possible for every case e.g. active transponders send their data in defined intervals this is also a criteria to consider for a visibility definition [9].

o Data quality

According to Wang/ Strong four characteristics for data quality are discussed for a definition.

o Intrinsic data quality: Quality of data as well as impartial and reputation quality are considered.

o Context relevant data quality: The presented data should be relevant and complete.

o Representation of the data: Every user should have the same understanding of the data or data have to be precise enough e.g. with correct unit to make them understandable.

o Quality of the access: Every user should have access to the system, as well as fast and easy access [20].

The described aspects are summarized in Fig. 14.

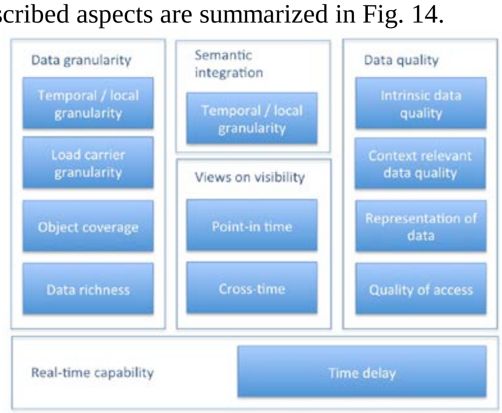

Fig. 14 Aspects of visibility [9]

• The reasonable degree of visibility

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 [9].

B. Mathematical Approach

This chapter is dealing with the mathematical approach to calculate the reasonable degree of visibility. Fig. 15 shows graphically the situation to be analyzed. 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.

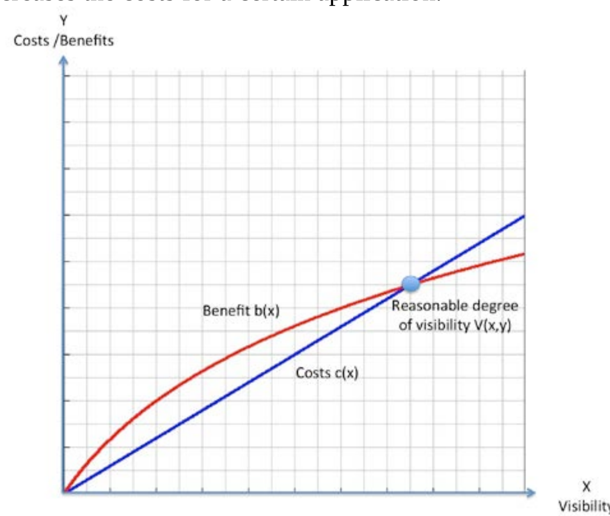

Fig. 15 Qualitative visualisation of the reasonable degree of visibility

Setting of the Algorithm: Objective Functions

This subchapter defines the chosen objective functions in detail.

Function for costs c(x) is defined

$$c(x) \in \mathbb{Q}_{>0} \, ; f, v \in \mathbb{Q}_{>0} \qquad (22)$$

where

c(x) function for costs,

f factor for fix costs respectively acquisition costs,

v factor for variable costs respectively yearly costs.

with

$$f = \begin{cases} 3 \; for \; aquisation \; costs > 300\,000 \\ 2 \; for \; 100\,000 > aquisation \; costs \leq 300\,000 \\ 1 \; for \; aquisation \; costs \leq 100\,000 \end{cases} \qquad (23)$$

and

$$v = \begin{cases} 1{,}5 \text{ for yearly costs} > 2 \times \text{aquisation costs} \\ 1 \text{ for } 1/5 \times \text{aquisation costs} > \text{ yearly costs} \leq 2 \times \text{aquisation costs} \\ 0{,}5 \text{ for yearly costs} \leq 1/5 \times \text{aquisation costs} \end{cases} \quad (24)$$

Function for benefit b(x) is defined

$$b(x) \in \mathbb{Q}_{>0} \,;\, q, s \in \mathbb{Q}_{>0} \quad (25)$$

where

$b(x)$ function for benefit,
q factor for maximum benefit,
s factor for yearly benefit.

with

$$s = \begin{cases} 1{,}2 \text{ for yearly benefit} > 2 \times \text{yearly costs} \\ 1{,}5 \text{ for } 1/5 \times \text{yearly costs} > \text{ yearly benefit} \leq 2 \times \text{yearly costs} \\ 1{,}8 \text{ for yearly benefit} \leq 1/5 \times \text{yearly costs} \end{cases} \quad (26)$$

and

$$q = \begin{cases} 4 \text{ for yearly benefit} > 300\,000 \\ 3 \text{ for } 100\,000 > \text{yearly benefit} \leq 300\,000 \\ 2 \text{ for yearly benefit} \leq 100\,000 \end{cases} \quad (27)$$

Calculation of the point of Intersection via equalizing the equation delivers

$$c(x) = b(x) \quad (28)$$

$$v \times x + f = log_s(x+1) + q \quad (29)$$

$$\Rightarrow v(x) = log_s(x+1) + q - v \times x - f \quad (30)$$

The equation can only be solved numerically. The Newton method will be used for calculating the values for each of the case studies, which is defined

$$x_{n+1} = x_n - \frac{v(x_n)}{v'(x_n)} \quad (31)$$

where

$v(x_n)$ combined function consisting of c(x) and b(x),
$v'(x_n)$ derived combined function,
x_{n+1} root of the tangent.

The goal is the calculate the reasonable degree of visibility, which is defined as below

$$v(x) = c(x) - b(x) \quad (32)$$

$$V(x,y) = \text{reasonable degree of visibility}$$

where

$v(x)$ function for reasonable degree of visibility,
$V(x,y)$ reasonable degree of visibility.

C. *Application of the reasonable Degree of Visibility for the Small Batch Production*

In the following the defined objective function are applied on the two case studies. For each case study are to found the objective function as well the graphical visualization in the following.

RFID System

Inserting values in formula (23) delivers

$$c_{SBP\ RFID}(x) = 1{,}5 \times x + 2 \quad (33)$$

Inserting values in formula (24) delivers

$$b_{SBP\ RFID}(x) = log_{1,2}(x+1) + 2 \quad (34)$$

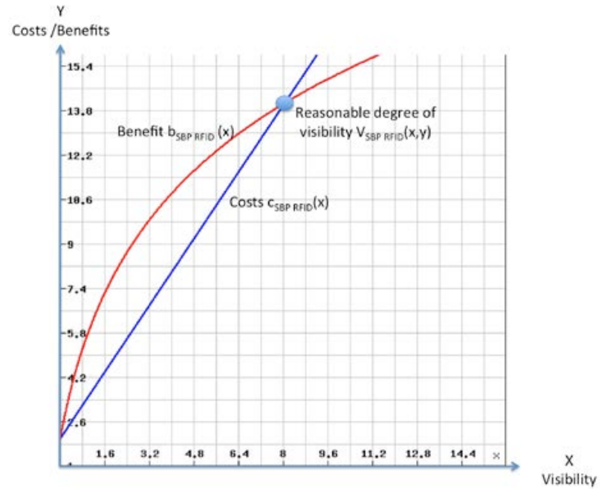

Fig. 16 The reasonable degree of visibility for an RFID System for the SBP

Calculation of the point of Intersection via the Newton method delivers the value for the degree of visibility.

$$V_{SBP\ RFID}(x/y) = 8{,}05/14{,}1 \quad (35)$$

Barcode System

Inserting values in formula (23) delivers

$$c_{SBP\ BAR}(x) = 1{,}5 \times x + 1 \quad (36)$$

Inserting values in formula (24) delivers

$$b_{SBP\ BAR}(x) = log_{1,2}(x+1) + 2 \quad (37)$$

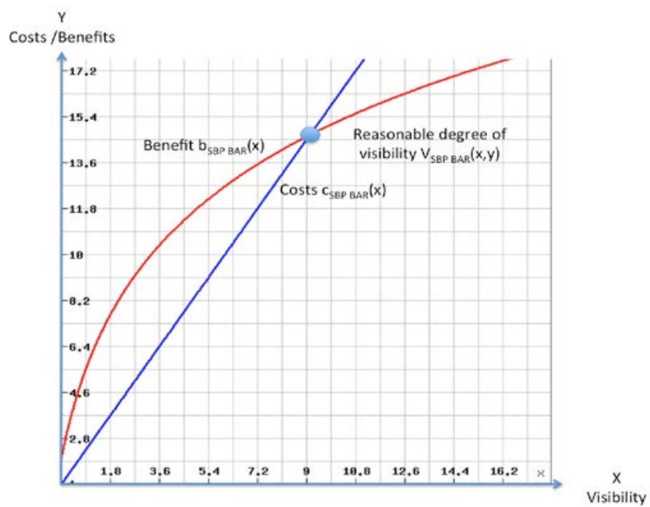

Fig. 16 The reasonable degree of visibility for an Barcode System for the SBP

Calculation of the point of Intersection via the Newton method delivers the value for the degree of visibility.

$$V_{SBP\ BAR}(x/y) = 9{,}1/14{,}7 \quad (38)$$

D. *Application of the reasonable Degree of Visibility for the Bulk Application*

Inserting values in formula (23) delivers

$$c_{BA}(x) = 1 \times x + 2 \quad (39)$$

Inserting values in formula (24) delivers

$$b_{BA}(x) = log_{1,5}(x+1)+3 \tag{40}$$

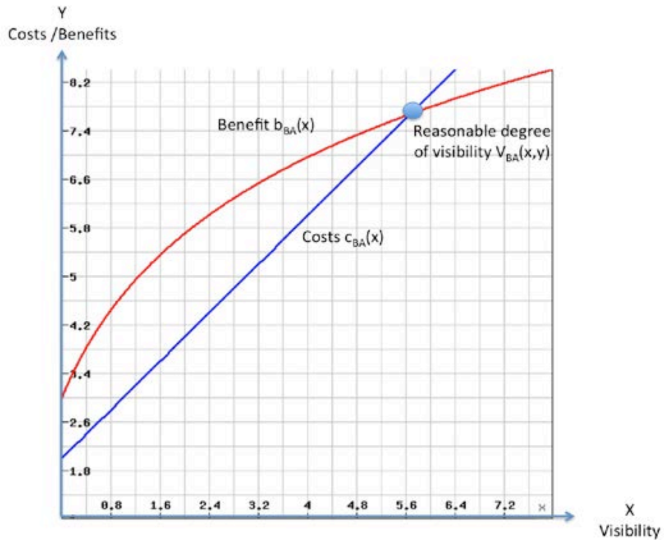

Fig. 16 The reasonable degree of visibility for an RFID-System for the BA

Calculation of the point of Intersection via the Newton method delivers the value for the degree of visibility.

$$V_{BA}(x,y) = 5{,}7/7{,}7 \tag{41}$$

E. Comparison of the reasonable Degree of Visibility

This chapter deals with the comparison of values, which are calculated for the two case studies.

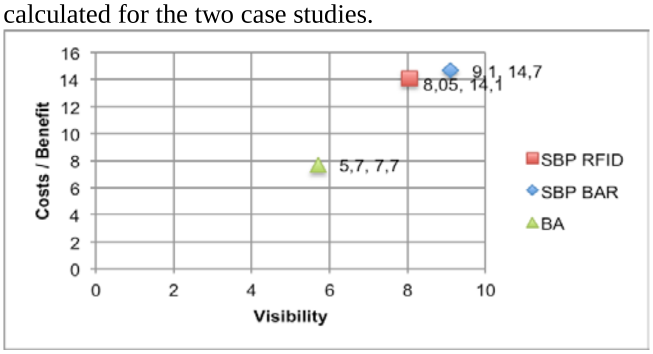

Fig. 17 Graphical comparison of the reasonable degree of visibility

Yearly costs are always to be seen in relation to acquisition costs (compare formulas (24) and (26)). 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.

VIII. 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 influences 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 specialized process visualization method for Auto-ID projects is now possible to quantify and compare different projects with each other. Another big advantage with the Glauto process chain paradigm is the structured way or workflow of noting down each sub process (see Fig. 2). 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 recognize 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.

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 help of the Glauto process chain paradigm and the reasonable degree of visibility. There can be no general statement if it leads always to a sustainable development but Auto-ID projects can help to achieve sustainable development.

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