Analysis of Profitability by Implementing RFID-Technology in 3PL Warehouse Business

Dipl. Kffr. Andrea Mayer (andrea.mayer@global-logistics-competence.partners)
University of Applied Sciences Kempten, Germany

Summary

Research question: Facing the dynamic field of warehouse logistics and the rising customer process demands combined with cost pressure then a constant change management and continuous, customer-oriented improvement process must take place in 3PL warehouse business. Hence technological change, especially in regards of automatic object localisation and product tracking along the supply chain, gains in importance. That raises the question if a change from barcode technology to radio frequency identification generates profitability in 3PL warehouse business.

Methods: Based on the principles of continuous process improvement, change management, process modelling, process time measurement, logistics-oriented value stream mapping and process calculation the profitability of RFID technological is evaluated. The analysis evaluates different scenarios, ranging from full pallet to item RFID-tagging by producer or by 3PL.

Results: The RFID-profitability-analysis shows positive financial savings for well-selected, dominant full pallet handling operations, especially when all involved business partners along the supply chain cooperate. This cooperation must be based on a fair cost-benefit sharing model, which requires negotiation skills, as well as change management skills to make partners participants and supporters of the change.

Structure of the article: 1. Introduction; 2. Status Quo of RFID Technology Research and Development; 3. Results of RFID Studies and Implementations on the Market; 4. Elements of a Cost-Benefit Analysis; 5. Hypothesis; 6. Empirical Analysis; 7. Conclusion; 8. About the author; 9. References

1. Introduction

"The only thing certain in life is change." (Plenert 2012, pg. 15)

Also in contract logistics business a constant change in process requirements and market demands exists.

A major driver of this growing process complexity is the highly competitive market in which 3PL´s customers play and which, hence, influence customer´s wishes.

So the 3PLs have to go through a change to meet the global challenges in future. In order to be prepared for the future the 3PL´s view must be turned onto the establishment of continuous improvement processes, which means to establish transparent, optimal workflows, a healthy, stable, well-trained resource-base, a reliable, satisfied customer-base and business profitability.

But such a paradigm shift requires the ability to be creative and open for innovative thoughts and ideas.

The latest developments in technology foster a more optimised and leaner logistics process realisation, either with state-of-the-art camera systems, modern automation technique, like conveyor systems and automated guided vehicles or sophisticated auto-identification technology, like RFID.

Due to the advancements in the field of auto-identification technology the time has now come to evaluate if state-of-the-art technology, like RFID, creates optimisation and saving potentials in warehouse businesses.

RFID not only changes the warehouse processes and personnel costs, but has also impact on stock accuracy, avoidance of out of stock situations at point of sale and an avoidance of "backorder" (Ustundag, Kilinc 2013, pg. 73). Considering these areas then benefits as well as occurring investments for "hardware (…) software (…) service" (Ustundag, Kilinc 2013, pg. 72) and "reoccurring costs, namely cost of tags and maintenance" (Ustundag, Kilinc 2013, pg. 73) need to be portioned among all members, e.g. manufacturer, distributor, retailer.

The establishment of such cost benefit sharing (CBS) models is difficult and requires negotiation efforts. It requires transparency on all stages in order to offer "a win-win situation" (Uckelmann 2012, pg. 94). But, as Uckelmann (2012, pg. 94) stated, "this level of transparency is quite often not wanted by companies" (Uckelmann 2012, pg. 94). A network-wide optimization based on RFID is realizable but "the effort involved to install and maintain such a system may even exceed the advantages" (Uckelmann 2012, pg. 94).

It is the target of this study to evaluate from a process-related point of view and from a financial perspective the benefits of a change from barcode technology to RFID for all business partners involved in warehouse operations.

2. Status Quo of RFID Technology Research and Development

Like barcode technology RFID has its origins in the military explorations regarding Auto Identification run in the 1930s and 1940s (Mayer 2013, pg. 5). Until now RFID has developed to a consumer-focused, transparency-providing technology, able to store huge product-relevant data, which will be transferred to readers via ultra-high-frequency, electro-magnetic-waves even without an existing line-of-sight (Mayer 2013, pg. 5 and pg. 6).

The main advantages in RFID are the omission of a direct "line-of-sight (…) [as well as] a longer read range" (Mayer 2013, pg. 12). The tag robustness against external influences and the possibility of a re-usage of a tag, depending on the tag classification, are other arguments for RFID (Mayer 2013, pg. 12). The transparency aspect, especially regarding inventory control, provides further advantages regarding correctness and accuracy (Mayer 2013, pg. 12). Furthermore RFID offers the possibility to store a large amount of product-specific data on a tag, which also fosters transparency and consumer-orientation (Mayer 2013, pg. 11).

All standardization could not prevent criticism, which arose regarding the read quality of the RFID-tags, especially when being used on products like metal or liquids, regarding the data security by reading data without line-of-sight (Mayer 2013, pg. 13) and regarding the related tag-costs (Mayer 2013, pg. 12).

The formerly seen advantage in a wider read range, based on UHF-waves, and the omission of a direct line-of-sight, while reading the transponder, turned to difficult obstacles to overcome. The read quality of bulk reading, where more than one tagged product on, e.g., a pallet needs to be read simultaneously remains error-prone.

Data security aspects and privacy issues play another important role in criticising RFID.

Other pitfalls of RFID are the related implementation costs (Mayer 2013, pg. 12) and the lack in distributing the costs among the involved business partners, e.g. along the supply chain (Uckelmann 2012, pg. 2). Furthermore RFID-tags, based on EPC, contain a broader bandwidth of product-related information, which is also currently difficult to be translated to UPC (Mayer 2013, pg. 12).

Communication norms of RFID equipment, used for instance along the supply chain by different partners, are not yet defined and can also create data transmission errors due to not matching equipment, like antennas, readers and tags (Mayer 2013, pg. 13).

In order to provide answers for these difficulties research has been progressed. Middleware has been developed to transform RFID-specific EPC data to currently used WMS system standards (Mayer 2013, pg. 19). Tag programming specifications have been researched to guarantee data security.
Progress has also been made in the read quality of RFID tags, which currently reaches up to 98% (Roberti 2009, pg. 1) and 99,8% (Pique 2012, pg. 1).

3. Results of RFID Studies and Implementations on the Market

The area of RFID applications changed during the last approx. 8 years, from a formerly planned use for single item tracking, for instance on the basis of yoghurt pot tracking, RFID now turned to an adequate solution for asset tracking in closed loop systems, premium-product tracking, temperature control, e.g. for products in the cold chain, object localisation (real time location systems, RTLS), e.g. for fork lifts or trucks, work place safety, maintenance control, automation technique control, like for instance sorter machines in the apparel industry. An overview of all fields of application with RFID in use is shown in the following illustration (Illustration 1).

Illustration 1: Summary of main RFID applications

All applications have one in common, namely the tagging of a special single object, either a premium product, a machine, a bin, a vehicle or even in regards of work place safety, a person.

For a profitable RFID implementation the field of application must be well selected, because as Hess, Medical Director of the Asklepios Future Hospital Program, once said, the view must be turned onto what is financially profitable than on what is "technically feasible" (Compamed 2013).

Although RFID is still not a widespread, all comprising, all market players and processes including identification technology, the described fields of applications are successful, profitable and hence promising for a further progress.

Research centres also intensified their studies on RFID. The German “RFID Anwenderzentrum München [, abbreviated] RFID-AZM” (AZM 2013), FIR e. V. of RWTH Aachen, or Fraunhofer-Gesellschaft, just to name a few, operate various different RFID-based research projects.

Fraunhofer IML studies, called “smaRTI, DyCoNet, IOT-A, (…) and LokLog” (Fraunhofer IML 2013d) focus primarily on RFID in asset tracking, air-freight container localisation, definition of the internet-of-things architecture and object localisation.
RWTH Aachen runs the RFID pilot project “Smart.NRW” (Lutz 2013a) with European EPC Competence Centre GmbH, and industry players like Mars, Metro and Mondi (Lutz 2013b). Target of this study is to create a transparent supply chain, to guarantee highest product quality in regards of product-specific best-before-dates (Lutz 2013c) and to enhance “product availability” (Lutz 2013c, own translation).
RFID-AZM operates, among other RFID-driven studies, in the field of an “Augmented Reality (AR)” (Günthner, Wölfle 2011, pg. 14), like “wearable computing” (Günthner, Wölfle 2011, pg. 40), and in the field of “Ubiquitous Computing” (Günthner, Wölfle 2011, pg. 41).

4. Elements of a Cost-Benefit Analysis

Calculatory Analysis

The cost-benefit analysis contains a calculatory and a process-related evaluation.

Quantifying the financial benefit of an RFID implementation and calculating the expected return-on-investment (ROI) often reveals difficulties in evaluating the several different effects on productivity, transparency and strategic benefit (Ivantysynova et al. 2009, pg. 3).

Literature differentiates between “tangible and intangible costs and benefits” (Ivantysynova et al. 2009, pg. 5), whereas tangible refers to monetary “quantifiable costs and benefits” (Ivantysynova et al. 2009, pg. 6), like fixed and variable costs and benefits (Ivantysynova et al. 2009, pg. 6), intangible represents “non-quantifiable costs and benefits” (Ivantysynova et al. 2009, pg. 8), like operational, strategic and risk related aspects (Ivantysynova et al. 2009, pg. 8, pg. 9 and pg. 10). Whereas fixed and variable costs are easily quantifiable, benefits are more difficult to be evaluated. Benefits due to RFID are for instance optimised processes, due to missing manual barcode scan processes. Further benefits are changes in the administrative process, where process time can be saved due to less errors and automated, systemic process solutions (Ivantysynova et al. 2009, pg. 8).

A standard approach in calculating the profitability of RFID in 3PL warehouse business is a conventional return on investment calculation, with “net returns divided by total expenditure” (Baysan, Ustundag 2013, pg. 17).

Therefore the process time savings due to a change from barcode to RFID technology are examined and compared to the necessary investment of hardware and running costs like RFID tags. The conventional net present value method is used to assess the correct investments, depreciated over a fixed time period, which is assumed to be 10 years with an interest rate of 4.5%.

Process and Material Flow Analysis

Elaborating a customer-oriented improvement process requires the fit to the organisational system of the enterprise (Plenert 2012, pg. 7).

The underlying methodologies range from the Toyota´s Production System (TPS), to Six Sigma,, Lean Management and Total Quality Management (TQM), to name a few.

Representative for this ongoing, never-ending improvement process is Deming´s total quality management improvement process (Plenert 2012, pg. 41), also known as “Deming´s Quality Wheel” (Plenert 2012, pg. 62) of “PDCA (Plan-Do-Check-Act)” (Plenert 2012, pg. 62).

Based on the PDCA-approach various different techniques can be used to first plan the process, to implement and run the process, to verify the process and lastly to adapt the process to new circumstances (Plenert 2012, pg. 62).

One important element of the continuous improvement process is the creation of transparency by illustrating the process in so called Swimlane Diagrams.

Based on this method the as-is-process is described and forms the base for the definition of an optimised target-process, which can be continuously checked and adapted.

Process Workflow Analysis

Process workflows are illustrated as “Swimlane diagrams” (inHarmony 2012, pg. 4) on Microsoft Office VISIO base. Here all processes are clustered in areas of responsibility, so warehouse workers are directly assigned to process steps. Interfaces between different areas of responsibility are also described.

This offers the chance to install “decision points within a process” (inHarmony 2012, pg. 5) and to increase process and product quality.

Material Flow Analysis

The “material flows” (Schmidt 2008a, pg. 83) in regards to the yearly, monthly and daily volume flows, is also graphically definable.

The graphical illustration of these volume flows is also called “Sankey Diagram”, referring to its inventor “Riall Sankey” (Schmidt 2008a, pg. 82). They illustrate the volume flows of pallets for example, but can also be used to illustrate flows of energy or recycling material, of consumption material or production material (Schmidt 2008b, pg. 181).

Depending on the arrow width the volume of the material flow is indicated (Schmidt 2008b, pg. 174).
The advantage of Sankey Diagrams is the summary of all production or warehouse inflows and outflows of material on one page. Bottlenecks, especially at peak seasons, are determined visually, as well as not optimized material flows due to layout reasons or process errors.

Value Stream Mapping (VSM)
From a logistical point of view a traditional VSM shows limitations, because industrial value stream maps represent logistics processes only in two VSM-symbols, one are arrows, showing the movement of products and connecting two production areas and the other one are storage and buffer signs (Günthner et al. 2013, pg. 135).

In order to adapt the technique of value stream mapping onto the demands of logistics the TU Munich elaborated a logistics-oriented approach (Günthner et al. 2013, pg. 135). The main differences to traditional VSM are firstly, that transportation is defined in "process box[es]" (Nash, Poling 2008, pg. 10), providing deeper insight into the process parameters, like "distance (…) cycle time (…) frequency (…) carrier (…) capacity (…) resource" (Günthner et al. 2013, pg. 226, own translation). Also any product storing is represented in box-illustrations, showing the "stock (…) area required (…) stock turn rate (…)" (Günthner et al. 2013, pg. 227, own translation).
Any product, picking, packing are separately defined in process boxes, as well as the logistics administrative process (Günthner et al. 2013).

In all processes product quality needs to be maintained or increased, e.g. in value-adding processes, the quantity of the required article has to be correct, e.g. in pick and pack processes and furthermore the delivery time and the destination need to be met. In a logistics-focused value stream design the process-specific handling and transportation times, as well as a production-optimised order inflow are harmonized and aligned to the available resources and their productivity (Günthner et al. 2013).

The main influences on logistics processes are the customer-specific order requirements and order delivery times. They determine the process flow and the cycle time. The customer is hence the "pace maker" (Günthner et al. 2013, pg. 43, own translation) in the logistics system. The 3PL is able to react on these influences with optimized, intelligent process solutions, guaranteeing on customer´s side quality and value-creation but also profitability from an internal perspective.

5. Hypothesis

In order to stay competitive on the market 3PLs have to fulfil customer demands and have to deliver highest qualitative services and transparency combined with competitive prices.

The complexity in warehouse processes enhances the necessity to optimise its processes constantly in order to operate business profitably. One of the process areas, where optimisation potential is hidden, is the time-consuming manual barcode-label scan process. It is the target of this study to evaluate from a process-related point of view and from a financial perspective the benefits of a change from barcode technology to alternative technologies. The selected auto-identification technology is Radio Frequency Identification, RFID.

The hypothesis is that it is profitable to implement and to use RFID technology in 3PL warehouse businesses. The target it to prove that it is profitable to replace the currently installed barcode-label technology with an intelligent auto-identification system, RFID.

6. Empirical Analysis

Methodology
The profitability analysis is firstly based on process evaluations. The target is to show that there are significant process-time savings due to a change from barcode-driven processes to RFID-driven processes. The process analysis will be based on a process workflow, process time measurement and a material flow analysis. All elaborated process steps,

process volumes and process times will be summarized in a logistics-oriented value stream design.

The second step turns the view on financial aspects. A net present value calculation is used to evaluate the related investment, compared to monetary assessed process savings.

Field study

The empirical analysis has been conducted at three different warehouse operations, one dominant full pallet handling business, one with a majority of mixed pallet picking operations and one with a focus on internal transports due to a high amount of value-added-service activities at a specific packing area. The determined scenarios relevant for this process-specific evaluation are summarized in table 1.

	Full Pallet & Item Tagging by producer vs. 3PL (scenario 1 + 2)	Full Pallet Tagging by producer vs. 3PL (scenario 3 + 4)	Scenario 3 w/o Transition Zone Scan (scenario 5)	Scenario 5 w/o admin. Savings (scenario 6)
Administration	x	x	x	
Un- / Loading Loop	x	x	x	x
Put Away In/Out Loop	x	x	x	x
Store-In / Out Loop	x	x	x	x
Pick & Pack MP	x			
Pick & Pack Parcels	x			
VAS	x	x (full pallet transports)	x (full pallet transports)	x (full pallet transports)

Table 1: Scenario Definition

Empirical Process Analysis

The analysed warehouse processes are administration, inbound, put away, store in, store out processes, as well as warehouse-internal pallet movements, replenishment and loading processes, including all relevant customer-demands like picking and packing procedures as well as value-added-services.

In order to avoid empty runs so called loops are introduced in the process definition. One loop focuses on the loading and unloading of pallets at the ramps, another loop guarantees optimal put-away processes and store-out-processes. Especially the last-mentioned loop combines on the one hand electrical pallet truck processes, to bridge long distances between ramp and rack storage, and on the other hand reach truck processes at the rack storage, combining store-in and store-out runs. These optimised double cycle movements avoid empty runs and enhance warehouse productivity.

In some warehouses the described process requires transition points to transfer incoming and outgoing full pallets close to the ramps (inbound-, outbound zone), as well as close to the rack. Additional transition points are necessary for the value-added-service area, were replenishment pallets with packaging material or articles must be pushed in and ready display pallets or remaining pallets with residual packaging or articles must be pulled off to be stored back to the rack storage or loaded on trucks.

In this concept it is assumed that all pallet movements to and from transition points are supported by barcode-driven label scans.

Process Time Measurement

The outcome of the process time measurements is that barcode-label scan processes at pallets vary between 0.02 and 0.09 HMin./scan.

Orientation processes, which mean to demote and go up a fork lift, get and deposit handheld scanner, search barcode label, etc. vary between 0.07 and 0.18 HMin./action.

Rack location label scans, also representative for transition zone scans, are between 0.03 and 0.06 HMin./scan, depending on the worker´s qualification and barcode-label condition.

Table 2 provides a summary of measured barcode process times.

For calculation purposes the average value of the mentioned scan times are used, which is for scan processes including orientation time, approx. 0.19 HMin. / scan and for rack location and transition zone scans approx. 0.15 HMin. / scan.

Barcode-Process	Measured Process Time [HMin]
Inbound barcode-label scan with handheld scanner	0.02 – 0.09
Outbound barcode-label scan with handheld scanner	0.02 – 0.09
Rack location label scan with handheld scanner	0.03 – 0.06
Orientation time for each pallet scan process	0.07 – 0.18

Table 2: Summary of measured barcode-related process times

Logistics-oriented Value Stream Mapping (VSM)

The VSM is grouped in product families.

One product family represents inbound pallets from production site to the high rack storage. A different product family is formed for pallets from production sent to the floor storage. Other product families refer to pallets from external suppliers and pallet flows to high rack or floor storage.

Each process box represents a value-adding logistics process, like unloading, transport, scan, store in, etc.

The time where the pallet is not moved due to buffer times on inbound or outbound zones or due to the period of storage, is summed up and illustrated in the total idle-time of the value stream.

The time where the pallet is moved or processed is called process time or cycle time. This time per pallet from inbound to outbound is also summed up along the value stream.

Illustration 2 is the value stream for pallets moving from production site to high rack storage. Each process box describes the relevant process for that product, e.g. unload pallet, scan pallet, put away, store in, store out and load.

Summing up all process times of the defined process boxes then a total process time from inbound to outbound per pallet is received; see the coloured line below the process boxes in illustration 2.

Comparing a barcode-driven process, see measured process times in table 2, with an auto-identification based process in this value stream design then a process time reduction of 15 % per pallet is achievable (Illustration 2).

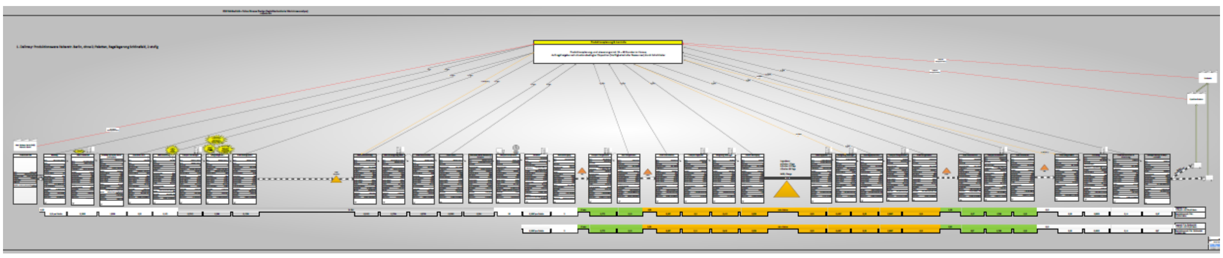

Illustration 2: Logistics-oriented Value Stream Map (product family 1)

Process Time Analysis

The process time calculation per branch serves now as basis for further calculations. As already described, the scenario definition determines which process step, and hence, which process time influences the scenario-specific calculation.

Scenario 2 and 4 examine which effects may arise on 3PL warehouse side, if the logistics service provider is obliged to tag both full pallets and items on the pallet, see scenario 2, or full pallets only, see scenario 4. The respective process time for such additional work is also included in the examination.
The additional work time is subtracted from the total process time saving generated by the change to RFID.
In order to evaluate process time savings on a conservative way additional process time for booking procedures are also calculated, in case the RFID-tag of a pallet or item are not read. These corrective actions are also regarded and their process time is also subtracted from the total process time saving. Depending on the analysed scenario a certain amount of corrective actions is assumed. Currently achievable read rates of 98% (Roberti 2009, pg. 1) define the necessary amount of corrective actions in this warehouse analysis. A failure read rate of 2% is included in the calculation of work time.
The multiplication of process time with process-related yearly volumes defines the total yearly process time saving per process step in seconds.
The sum of saved seconds is transformed then to minutes, to hours and lastly to work-days, with 8 work-hours per work-day.
A monetary evaluation of process time savings is based on personnel costs per hour, incl. equipment and consumption costs, of rounded 25 € per hour.

The result is that the highest process time savings are realisable on 3PL side in scenario 1, 3, 4, 5, 6 and especially in full pallet handling businesses. An exception is scenario 2, because pallets and items have to be tagged by the 3PL.
The process-related efforts are extremely high and require additional manpower, which make a change from barcode technology to auto-identification technology inefficient and uneconomic. All other scenarios, even the one where the 3PL tags all incoming full pallets on its own, generate process time savings.

Illustration 3 shows graphically the effects on personnel costs per year in percentage, realisable with an implementation of RFID technology. In this illustration 3 scenario 2 shows a plus of 298 % in personnel costs due to tagging efforts of pallets and items in the warehouse inbound (Illustration 3).

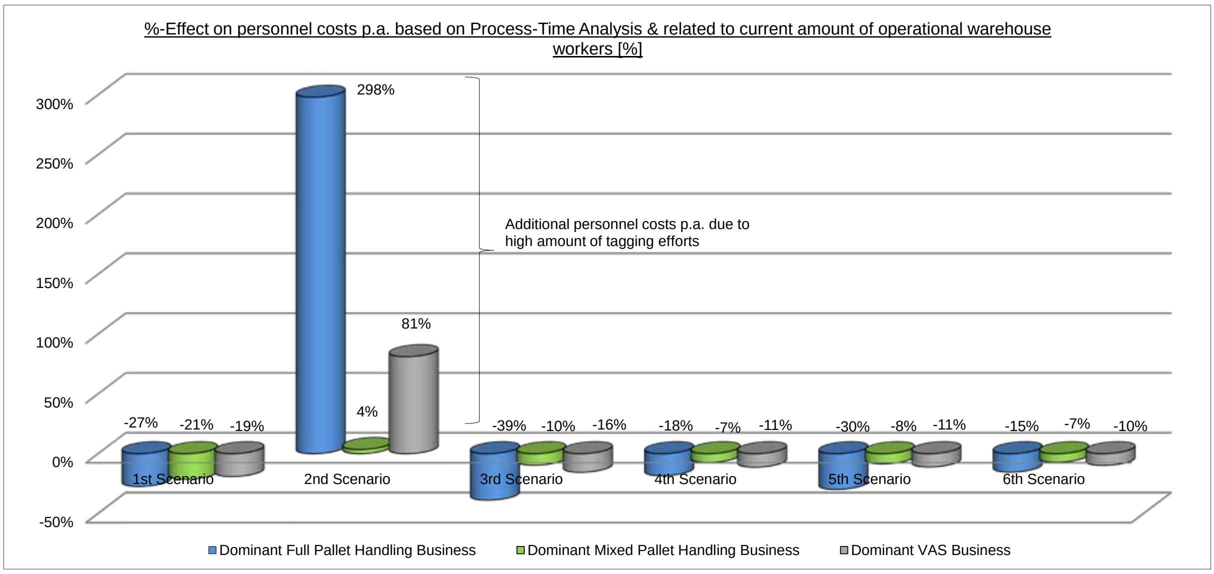

Illustration 3: Effects on personnel costs p.a. [%]

Scenario-specific RFID- Investment and Running Costs Calculation

The calculation is divided into two segments, on the one hand fixed costs and on the other hand variable, running costs. Whereas the fixed costs for hardware investment is a one-time payment, depreciated over 10 years linearly with an interest rate of 9 %, the running costs occur constantly and are in this analysis the RFID-tag costs per pallet or per item of 10 cent per transponder.

The hardware components included in this study are RFID portal readers, RFID reader & antennas at material handling equipment, handheld scanners, (passive tag) printers and for the picking process in particular RFID reader installations at the picking trolley.

Illustration 4 provides an overview of required RFID investment and costs per scenario.
The highest total costs for RFID hardware and running costs arise in scenario 2 because of the high amount of transponders needed for the item tagging process in the inbound (Illustration 4).

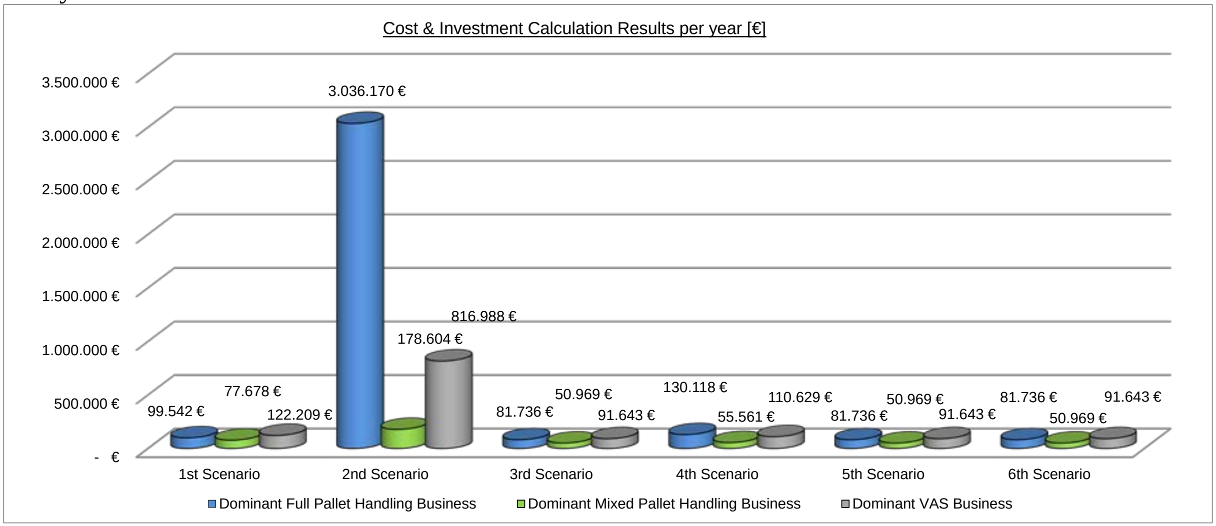

Illustration 4: Cost & Investment Calculation Results p.a. [€] for RFID Equipment depreciated and RFID-tags

Scenario-specific Calculation Results

The hypothesis that RFID generates profitability in 3PL warehouse business could be proven in all scenarios, except scenario 2.

Illustration 5 shows the effect of a change from barcode to RFID technology on the yearly warehouse budget. It is shown that except scenario 2 all others have a decrease in yearly warehouse budget costs (Illustration 5).

Implementing an RFID-driven business based on tagged items, leads to high financial losses in the analysed businesses. Hence RFID on item-level is not profitable.
Instead of using RFID-tags on single items all other scenarios showed monetary savings. Either attached by producer or warehouse provider the results for full pallet tracking based on RFID-technology are positive. Favourable for RFID, as auto-identification technology, are hence full pallet dominant businesses.
That result underlines the previously introduced main fields of application. RFID is primarily used in object localisation, premium product tracking, closed-loop asset tracking, just to name a few.

Important for a successful RFID implementation is a supply-chain wide, all partners including cost benefit sharing model.
The benefits could be spread and costs could be splitted. Nevertheless the willingness of participation must be lived by all business participants.

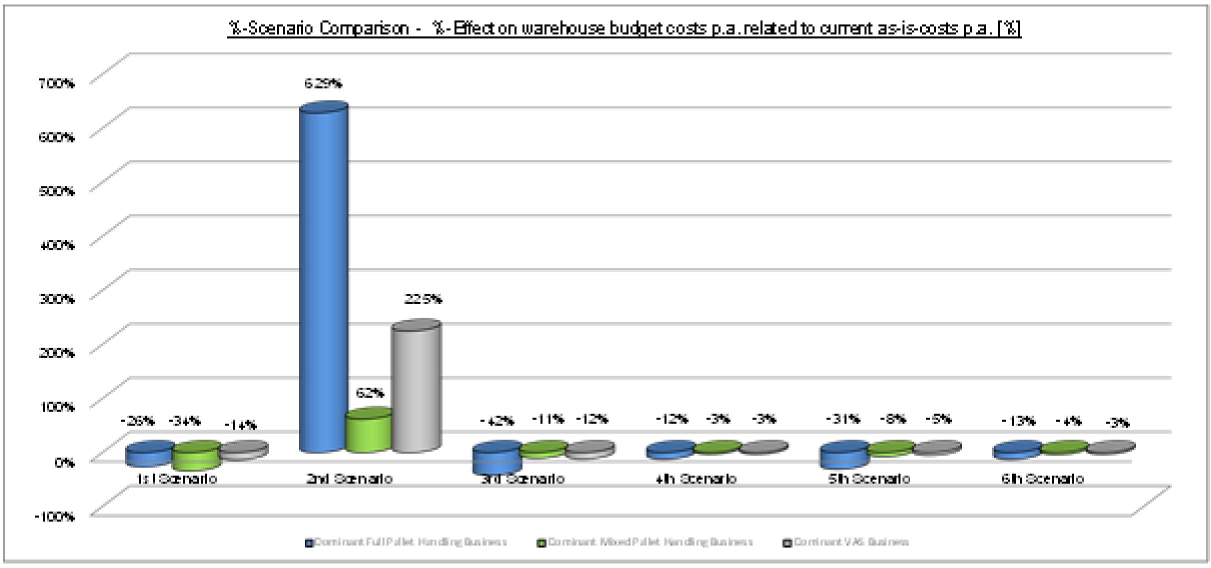

Illustration 5: %-Scenario Comparison - Effects on warehouse budget costs p.a. per scenario [%]

7. Conclusion

The analysis has been conducted on a detailed data base. The process workflow and material flow definition, combined with a detailed process time measurement, provided a solid base for a transparent cost-benefit analysis. The existing barcode-driven as-is processes have been analysed and measured in real time. So the benefits of an avoidance of manual barcode scan processes could be evaluated upon realistic data. The hypothesis has been, except for scenario 2, proven that RFID technology generates profitability in 3PL warehouse businesses.

Nevertheless it has to be emphasized that the analysis excluded explicitly all software-specific IT-programming efforts or middleware installations. Not considered are also one-time costs per RFID-installation, like engineering and installation costs, programming efforts, yearly maintenance costs and the elaboration and installation of an IT-emergency concept and back-up solution.

Furthermore the cost calculation is conservatively calculated. Only the higher cost estimations for RFID-tags and hardware have been selected. In a pilot study a proof-of-concept analysis must be calculated in order to specify the costs.

The scenario-calculations represent realistic situations, although no RFID-based failure-reducing effects in barcode-processes like partial withdrawals, clearance processes, and loading errors, return processes due to loading, picking errors, inventory adjustments, stock controls and systemic corrective actions have been evaluated. It is the responsibility of the warehouse manager to establish optimised processes with no errors, with or without RFID-technology in use, although RFID-technology is able to monitor and enhance the process quality, better than currently achieved by barcode-technology.

For a detailed analysis it was also important to distinguish among two different scenario-parameters, either tagging at producer´s site or at the 3PL warehouse. From a 3PL perspective it is essential to know the impacts, if a customer is not willing to participate in a change to RFID. The warehouse leader has to be able to decide upon valid, profoundly analysed data if a RFID-transponder-tagging process by warehouse workers is profitable.

In case the customer participates and RFID-technology is established along the supply chain then it will be necessary to negotiate a fair cost and benefit distribution among all parties.

So for this analysis the calculated financial saving for the 3PL in scenario 1 and scenario 3, where the producer is forced to attach RFID-transponders on pallets and/or items, will be reduced with a fair CBS model.

But on the contrary monetary savings on 3PL side will be increased in scenario 2 and scenario 4, where part of the RFID-transponder running costs will no longer be covered by the 3PL only, but will be also covered by other supply chain partners, like the producer.
In this context it has to be mentioned, that if the 3PL is able to install an automated RFID-label machine at the production line of the customer, as well as an RFID-reader gate, all financed by the 3PL, then the manual pallet labelling process in scenario 4 can be avoided. Although RFID-equipment, RFID-label-machine, RFID-transponders are still paid by the 3PL, the savings of scenario 3 keep on rising. The avoidance of manual RFID-pallet labelling processes leads to a time saving, which is monetarily a sum of 58.461 €, calculable on top of the scenario 4 result.

Furthermore it has to be emphasized that the analysis only focused on the warehouse business. The interface to the transportation has not been further investigated.

Nevertheless this study has proven that a change from standardised, trusted approaches to state-of-the-art technology and optimised process-solutions is overdue. The profitability increase is one result; the process- and quality-optimisation with an impact on an ergonomic workplace design is another point of view. Lastly the reputational effect, produced and reflected on the market, leaves an impact on customer satisfaction and customer acquisition.

The view on workforce is important, not just in terms of labour costs. According to Prof. Dr. ten Hompel (2013) it is for the future predicted that in seven years the labour market may suffer employee scarcity (ten Hompel 2013, pg. 7). The labour market will be understaffed with up to “2 Mio. workers” (ten Hompel 2013, pg. 7, own translation) and the problem will grow until 2050, where a lack of “5 Mio. workers” (ten Hompel 2013, pg. 7, own translation) is predicted.
A parallel development in the next years is the technological advancement. Until approx. 2023 the systemic “storage density” (ten Hompel 2013, pg. 11, own translation) may reach a ten times higher level than today (ten Hompel 2013, pg. 11). That data-increase enhances the complexity with which employees as well as currently used systems and databases have to cope with. With such a development new technology opens new fields of applications, like advanced RFID-transponders and readers, modern camera-systems able to read 2D-/3D-barcodes, automated guided vehicles, intelligent bins, etc. The objects will become as a consequence more intelligent, with the result that they coordinate themselves independently (Fraunhofer IML 2013i). The objects will interact with each other in the future (Fraunhofer IML 2013i). The skills and abilities of objects are going to rise, whereas the costs for the components are going to fall. A logistics service provider has to be aware of these developments. In order to keep track of the latest advancements it is obligatory for all 3PLs to analyse constantly new applications on the market, like realised with RFID.

In all these necessary evaluations it is important to evaluate what fields of applications are improvable with what technological innovation. The target must be to determine the cornerstones of transparent, glassy, optimised and profitable warehouses and distribution centres.

RFID-technology is one piece of the puzzle, fitting well for full-pallet-handling business. Nevertheless the search for an optimal fit of new technology keeps on going on.

8. About the Author

Andrea Mayer studied economics with a specification in logistics at the University of Augsburg. She worked for DB Schenker AG and DACHSER GmbH & Co. KG in the field of contract logistics optimisation, accompanied by a part-time MBA study in International Logistics Management at the University of Applied Sciences Kempten.

In 2014 she founded GLC Global Logistics Competence Ltd. with Rainer Woelk in order to support companies in developing their logistics competence and to optimise their logistics performance along their supply chain. The focus of GLC Global Logistics Competence Ltd. is hence on competence development, coaching and human-oriented change management in Logistics. A continuous improvement process, combined with process optimisation methods, requires sustainability in workers´ commitment and daily motivation producing best quality.

Their intensive connection to global research institutes completes their portfolio with a practical oriented Logistics 4.0 approach. Global Logistics Competence Ltd. provides the basis for future-oriented technological advancements in Logistics

9. References

Aberdeen Group (2013). Our research methodology. Retrieved from http://www.aberdeen.com/about-us/our-research-methodology.aspx

Aberdeen Group (2010). Retail shelf-level inventory tracking, traceability, and visibility: Perfecting customer-centric inventory management. Retrieved July 20, 2013, from http://www.aberdeen.com/Aberdeen-Library/6638/RP-retail-inventory-tracking-visibility.aspx

Amato-McCoy, & Deena M. (I 2012). *the state of loss prevention in retail.* Retrieved July 20, 2013, from http://www.aberdeen.com/Aberdeen-Library/7490/RA-retail-loss-prevention.aspx

Amato-McCoy, & Deena M. (II 2012). The RFID revolution. Retrieved July 20, 2013, from http://aberdeen.com/Aberdeen-Library/8235/AI-loss-prevention-retail.aspx

Anderseck, B., & Hille, A. (2013, March). smaRTI: Deploying the internet of things in retail supply chains. *Logistics Journal.* Retrieved July 20, 2013, from https://www.logistics-journal.de/not-reviewed/2013/03/3578/smarti_anderseck_hille_2013_03.pdf

AZM (2013). RFID-Anwenderzentrum München. Retrieved from http://www.rfid-azm.de/

Baysan, S., & Ustundag, A. (2013). The Cost-Benefit Models for RFID investments. In A. Ustundag, I. Fakultesi (Eds.) *The value of RFID* (p. 13 – 22), London: Springer-Verlag. doi: 10.1007/978-1-4471-4345-1

Benghozi, P.-J., Bureau, S., & Massit-Folléa, F. (2009, January 2). The internet of things - What challenges for Europe? *praTICs*, Ch. 1. Retrieved from http://books.openedition.org/editionsmsh/97

Bensel, P., Fürstenberg, F., Truschkin, E., & Vogeler, S. (2011). Management Summary zur Studie: RFID in der Logistik *ISI AutoID/RFID Special Edition, 1-2011*, München: isi Medien. Retrieved from http://www.isis-specials.de/profile_pdf/1t266_ed_rfid0111.pdf

Bensel, P., Fürstenberg, F., Straube, F., Truschkin, E., & Vogeler, S. (2009). *Exklusive Management Summary zur Studie: RFID in der Logistik – Empfehlungen für eine erfolgreiche Einführung* Retrieved from http://ko-rfid.hu-berlin.de /forschungsarbeit/publikationen/2009/

Best, T. (2010). *Work measurement in skilled labor environments*. Retrieved August 2, 2013, from http://www.iienet2.org/uploadedfiles/ SHS_Community/Resources/Work%20Measurement%20in%20Skilled%20Labor%20Environments.pdf

Brown, A. (1994). MTM core data validation. *Work Study*, *43*(5), 15 – 22, MCB University Press.

Choi, C.K., & Ip, W.H. (1999). A comparison of MTM and RTM. *Work Study*, *48* (2), 57 – 61, MCB University Press.

Compamed (2013). RFID: The technology is able to support many processes concerning patients. Retrieved July 11, 2013, from http://www.compamed-tradefair.com/cipp/md_compamed/custom/pub/content,oid,21163/lang,2/ticket,g_u_e_s_t/~/%22The_technology_is_able_to_support_many_processes_concerning_patients%22.html

Dachser (2013). Our mission. Retrieved from http://www.dachser.com/de/en/Mission_27.htm

Deeley, A. J. (1991). Implementation of MTM systems. *Work Study*, *40*(3), p. 12-13, MCB University Press.

Denker, J. P. (2012). Kein Wachstum ohne RFID Retrieved from http://www.rfid-im-blick.de/201209261849/kein-wachstum-ohne-rfid.html

DIN (2013). DIN 66001 - Informations-verarbeitung; Sinnbilder und ihre Anwendung. Retrieved July 28, 2013, from http://www.nia.din.de/cmd?artid=1080044&contextid=nia&bcrumblevel=1&subcommitteeid=54755362&level=tpl-art-detailansicht&committeeid=54738935&languageid=de

DSI (2013). DHL industry partner. Retrieved from http://dsi.dhl-innovation.com/en/partner/industry

DyCoNet (2013). About the project. Retrieved from http://www.dyconet.de/p/about-project.html

Edraw (2013). Standard flowchart symbols and their usage. Retrieved from http://www.edrawsoft.com/flowchart-symbols.php

Ehrhardt + Partner (2008a). Neuer RFID-Kommissionierwagen entwickelt. Retrieved August 8, 2013, from http://www.ehrhardt-partner.com/fileadmin/user_upload/E_P.com/PDF/Press-Releases/RFID-Multipicker_PR_GER.pdf

Ehrhardt + Partner (2008b). HCO_Kommwagen. Retrieved August 8, 2013, from http://www.ehrhardt-partner.com/fileadmin/user_upload/E_P.com/Bilder/Produktbilder/HCO_Kommwagen_10_frei.jpg

Ehrhardt + Partner (2013a). Praxisgerechte Hardware für die besonderen Anforderungen des Warehousebetriebs. Retrieved August 8, 2013, from http://www.ehrhardt-partner.com/fileadmin/user_upload/E_P.com/PDF/Press-Releases/CeBIT_News_GER_Endversion.pdf

Ehrhardt + Partner (2013b). VIR - Voice Integrates RFID. Retrieved August 8, 2013, from http://www.logismarket.de/in/ehrhardt-partner-neuentwicklung-von-ep-effizienzsteigerung-im-lager-mit-vir-voice-integrates-rfid-voice-integrates-rfid-von-ehrhardt-partner-773801-FGR.jpg

Ehrhardt + Partner (2013c). Pick-Manager – die Pick-by-Voice-Lösung für Ihr Lager. Retrieved from http://www.ehrhardt-partner.com/produkte-dienstleistungen/pickmanager-pick-by-voice/

Fischer, R., Salfer, M., & Wölfle, M. (2010). Strukturiertes Testen von RFID-Systemen. *Einblick in AutoID/RFID,2010*, p. 32-33. Retrieved from http://www.fml.mw.tum.de/fml/images/Publikationen/StrukturiertesTestenvonRFID-Systemen.pdf

Fraunhofer IFF (2013a). “RFID-Handschuh” für eine effiziente Güteridentifikation. Retrieved from http://www.iff.fraunhofer.de/content/dam/iff/de/dokumente/publikationen/rfid-handschuh-fuer-effiziente-gueteridentifikation-fraunhofer-iff.pdf

Fraunhofer IFF (2013b). RFID-Tunnelgates für eine sichere Pulkerfassung. Retrieved from http://www.iff.fraunhofer.de/de/geschaeftsbereiche/materialflusstechnik/rfid-tunnelgate-logistikdienstleister-fiege.html

Fraunhofer-Gesellschaft (2013a). We forge the future. Retrieved from http://www.fraunhofer.de/en/about-fraunhofer.html

Fraunhofer-Gesellschaft (2013b). Structure and organization of Fraunhofer-Gesellschaft. Retrieved from http://www.fraunhofer.de/en/about-fraunhofer/structure-organization.html

Fraunhofer IML (2013a). About our institute. Retrieved from http://www.iml.fraunhofer.de/en/institue_profile.html

Fraunhofer IML (2013b). Fields of activity. Retrieved from http://www.iml.fraunhofer.de/en/fields_of_activity.html

Fraunhofer IML (2013c). OpenID-center. Retrieved from http://www.iml.fraunhofer.de/en/researchhallslaboratories/openid-center.html

Fraunhofer IML (2013d). Research. Retrieved from http://www.iml.fraunhofer.de/en/fields_of_activity/packaging_and_trade_logistics/research.html

Fraunhofer IML (2013e). Rund um den Globus: Den Container stets im Blick. Retrieved from http://www.oid.fraunhofer.de/de/Forschungsprojekte/DyCoNet.html

Fraunhofer IML (2013f). Unser Projekt: LokLog - Lokalisierung in der Logistik. Retrieved from http://www.oid.fraunhofer.de/de/Forschungsprojekte/abgeschlossene_projekte/LokLog.html

Fraunhofer IML (2013g). Selbststeuernder Materialfluss mit smarten Ladungsträgern. Retrieved from http://www.oid.fraunhofer.de/de/Forschungsprojekte/smaRTI.html

Fraunhofer IML (2013h). Fehlertolerante RFID Pulklesung. Retrieved July 20, 2013, from http://www.iml.fraunhofer.de/de/themengebiete/maschinen_und_anlagen/Integration_von_Sensorsystemen_Maschinen_und_Anlagen/rfid_pulklesung1/_jcr_content/contentPar/linklist/linklistPar/download/file.res/Produktblatt_RFIDPULKLESUNG_20100519.pdf

Fraunhofer IML (2013i). Forschungsprojekt „Schwarmintelligenz für die Logistik“ ist ein „Ausgewählter Ort 2012“. Retrieved August 12, 2013, from http://www.iml.fraunhofer.de/de/presse_medien/pressemitteilungen/land-der-ideen-2012.html

GBU (2013). Process simulator. Retrieved from http://www.gbumbh.de/html/process_simulator.htm

Goebel, C., Tribowski, C., Günther, O., Tröger, R., & Nickerl, R. (2009). RFID in the supply chain: How to obtain a positive ROI - The Case of Gerry Weber. In *11th International Conference on Enterprise Information Systems (ICEIS 2009)*, Vol. Information Systems Analysis and Specification, (pp. 95-102). Milan, Italy. Retrieved from http://warhol.wiwi.hu-berlin.de/aigaion2/index.php/publications/show/223

Günthner, W.A., Durchholz, J., Klenk, E., & Boppert, J. (2013). *Schlanke Logistikprozesse –Handbuch für den Planer*. Berlin Heidelberg: Springer Verlag.

Günthner, W.A., & Rammelmeier, T. (2012). Vermeidung von Kommissionierfehlern mit Pick-by-Vision. Retrieved from http://www.fml.mw.tum.de/fml/images/Publikationen/Forschungsbericht_AiF_16398_N.pdf

Günthner, W. A., & Wölfle, M. (2011). Papierlose Produktion und Logistik. Forschungsbericht, Forschungsstelle Technische Universität München, *RFID im Blick, Sonderausgabe "RFID in der Region München"*. Retrieved from http://www.bvl.de/files/441/481/522/578/Forschungsbericht_Papierlose_Produktion_15666_N_digital.pdf

Hansen, W.-R., Gillert, F., Cox, K., & Schmid, V. (2008). *RFID for the optimization of business processes*. John Wiley & Sons.

Harrington, H.J. (1997). *Business process improvement workbook.* New York: McGraw-Hill.

Harrop, P., & Das, R. (2013). RFID forecasts, players and opportunities 2012-2022. Retrieved from http://www.idtechex.com/research/reports/rfid-forecasts-players-and-opportunities-2012-2022-000322.asp

IDTechEx (2013a). Overview. Retrieved from http://www.idtechex.com/contact/about-us.asp

IDTechEx (2013b). Positioning systems, RFID, NFC and WSN. Retrieved from http://www.idtechex.com/reports/topics/rfid-nfc-rtls-and-wireless-sensors-000009.asp

Iliev, S., Vinci, G., & Luy, J.-F. (2007). RFID system read range in automotive assembly lines. Retrieved July 8, 2013 from http://www.cst.com/Content/Documents/Events/UGM2007/07-Iliev.pdf

IOT-A (2013). Introduction. Retrieved from http://www.iot-a.eu/public

inHarmony (2012, March). The art of warehousing. *inHarmony*, the autumn edition. Retrieved from http://www.fbsaust.com.au/media/4471/march2012-ed2-autumn.pdf

Ivantysynova, L., Klafft, M., Ziekow, H., Günther, O. & Kara, S. (2009). RFID in manufacturing: the investment decision. *Pacific Asia Conference on Information System (PACIS), PACIS 2009 Proceedings, Association for Information Systems.* Retrieved from: http://www.icsi.berkeley.edu/pubs/other/RFID1.pdf

Klein, R., & Anand, S. (2011). The 2011 store-level RFID benchmark report: Operational intelligence and inventory visibility. Retrieved July 20, 2013, from http://www.aberdeen.com/aberdeen-library/6967/RA-optimized-inventory-visibility.aspx

Klenk, E., & Knössl, T. (2010). Logistikorientierte Wertstromanalyse – Identifikation von Wertschöpfung und Verschwendung in der Logistik. Retrieved from http://www.fml.mw.tum.de/fml/images/Publikationen/Klenk_Kn%C3%B6ssl_Adaptierte_Wertstromanalyse.pdf

Kuehne & Nagel (2004). Siemens Business Services and Kuehne + Nagel connect Europe and the US with RFID. Retrieved July 10, 2013, from http://www.kn-portal.com/nc/about_us/media_relations/news/show/?cHash=cfc53290292efee01861c5cb7b0a95f2&tx_knnews_pi1%5Buid%5D=548

Kuehne & Nagel (2008a). New Kuehne + Nagel logistics centre in Melbourne. Retrieved July 10, 2013, from http://www.kn-portal.com/nc/about_us/media_relations/news/show/?cHash=28d43c8675b60635c37299847defb44f&tx_knnews_pi1%5Buid%5D=710

Kuehne & Nagel (2008b). Contract logistics expansion in Malaysia. Retrieved July 10, 2013, from http://www.kn-portal.com/nc/about_us/media_relations/news/show/?cHash=4ad8c630d1f1f040a62b1432d14b12f2&tx_knnews_pi1%5Buid%5D=805

Kuehne & Nagel (2009a). Kuehne + Nagel wins "2009 RFID Italia Award". Retrieved July 10, 2013, from http://www.kn-portal.com/nc/about_us/media_relations/news/show/?cHash=a11b8e43a01914b9a926711a6e2d664e&tx_knnews_pi1%5Buid%5D=887

Kuehne & Nagel (2009b). Flowers from Mount Kenya. Retrieved July 10, 2013, from http://www.kn-portal.com/fileadmin/user_upload/documents/about_us/Media/KN_World_Mag/2009_2/KNWorld_2_09E.pdf#search=%22rfid%22

Kuehne & Nagel (2010). IVECO renews major contract for spare parts logistics throughout Europe. Retrieved July 10, 2013, from http://www.kn-portal.com/nc/about_us/media_relations/news/show/?cHash=ac19ddfc4fce4053c28a2d2cdb26b28c&tx_knnews_pi1%5Buid%5D=938

Kuehne & Nagel (2012). Cargo 2000 awards Platinum Status to Kuehne + Nagel. Retrieved July 10, 2013, from http://www.kn-portal.com/fileadmin/user_upload/documents/about_us/Media/KN_World_Mag/2012/KN_World_02-2012_uk.pdf#search=%22rfid%22

Kuehne & Nagel (2013). Retail. Retrieved from http://www.kn-portal.com/de/industry/retail/

Lebensmittelzeitung (2013). Top 20 Logistiker Europa 2011. Retrieved fom http://www.lebensmittelzeitung.net/business/daten-fakten/rankings/Top-20-Logistiker-Europa-2011_227.html#rankingTable

Lim, M.K., Bahr, W., & Leung, S.C.H. (2013). RFID in the warehouse: A literature analysis (1995 – 2010) of its applications, benefits, challenges and future trends. *International Journal of Production Economics*, Elsevier B.V., article in press.

Lin, C.-Y. (2009). An empirical study on organizational determinants of RFID adoption in the logistics industry. *Journal of*

Technology Management & Innovation, 4(1), p. 1-7.
Logident (2013a). RFID-Lösungen für die sichere Erkennung. Retrieved August 8, 2013, from http://logident.com/fileadmin/user_upload/regular_content/brands/logident/pdf//br_de_li_concept_gen_v100309_as_mp.pdf
Logident (2013b). Eingebaute Intelligenz – logident. Retrieved August 8, 2013, from http://logident.com/fileadmin/user_upload/list_content/tt_news_files/press/press_release/pdf/pr_de_li_eingebaute-intelligenz_log_v080402_mh_sd.pdf
Lutz, T. (2013a). Smart.NRW - Das Projekt. Retrieved from http://projekte.fir.de/smartnrw/
Lutz, T. (2013b). Smart.NRW - Das Konsortium. Retrieved from http://projekte.fir.de/smartnrw/das-konsortium
Lutz, T. (2013c). Smart.NRW – Der Feldversuch. Retrieved from http://projekte.fir.de/ smartnrw/der-feldversuch
Lutz, T. (2013d). Smart.NRW – Produktion RFID-getaggter Kartonagen. Retrieved from http://projekte.fir.de/smartnrw/das-projekt/ergebnisse/produktion-rfid-getaggter-kartonagen
Machiavelli, N. (2013). The prince – chapter VI - concerning new principalities which are acquired by one's own arms and ability. Retrieved from http://www.constitution.org/mac/prince06.htm
Materialfluss (2011). Zukunftsfähige Lösung aus einem Guss. Retrieved from http://www.materialfluss.de/forder-und-hebetechnik/zukunftsfahige-losung-aus-einem-guss/
Mayer, A. (2013, February 27). *Is RFID an option for Dachser´s warehouse services?* (Term Paper for the MBA 19-seminar Management of Logistics Networks). University of Applied Sciences Kempten, Prof. Dr. Martin Göbl.
Nash, M. A., & Poling, S. R. (2008). *Mapping the total value stream*. Taylor & Francis Group / CRC Press.
Otto, C. (2009). DB Schenker setzt RFID in der Museumslogistik ein. Retrieved July 27. 2013, from http://www.mm-logistik. vogel.de/management-it/articles/198631/
Pique, S. (2012). The truth about rfid read rates. Retrieved August 12, 2013, from http://www.rfidjournal.com/articles/view?9475/
Plenert, G. J. (2012). *Strategic continuous process improvement: Which quality tools to use, and when to use them*. New York: McGraw-Hill.
p.l.i. solutions GmbH (2013a). Kompetenz bieten – Erfolg garantieren. Retrieved from http://www.pli-solutions.de/unternehmen
p.l.i. solutions GmbH (2013b). Zeitwirtschaft effizient gestalten mit der PROCESS TM Software. Retrieved from http://www.pli-solutions.de/zeitwirtschaft
p.l.i. solutions GmbH (2013c): Software zur Durchführung von Multimomentaufnahmen. Retrieved from http://www.pli-solutions.de/multimomentstudie
RAN (2013). Hardware und Technik - Das Arbeitspaket 4. Retrieved July 27, 2013, from http://www.autoran.de/kommunikation/downloads.html
Ranasinghe, D.C., Sheng, Q. Z., & Zeadally, S. (2010). *Unique radio innovation for the 21st century*. Berlin Heidelberg: Springer-Verlag.
RFID Atlas (2013). Praxisbeispiele. Retrieved from http://www.rfidatlas.de/
RFID Journal (2008). Midsize companies start to move. Retrieved July 2, 2013, from https://www.rfidjournal.com/purchase-access?type=Article&id=4250&r=%2Farticles%2Fview%3F4250
Roberti, M. (2009). RFID read reliability is not an issue. Retrieved August 12, 2013, from http://www.rfidjournal.com/articles/view?5065
Schenker Deutschland AG (2013). On the cutting edge: new standards and solid foundations. Retrieved from http://www.logistics. dbschenker.de/log-de-en/start/itcompetency/innovativesolutions.html
Schmidt, M. (2008a). The sankey diagram in energy and material flow management – Part I. *Journal of Industrial Ecology*, *12*(1), p. 82- 94.
Schmidt, M. (2008b). The sankey diagram in energy and material flow management – Part II. *Journal of Industrial Ecology*, *12*(2), p. 173 – 185.
Schneider, M. (2013). Logistics for recycling management. Fraunhofer IML. Retrieved July 12, 2013, from http://www.iml.fraunhofer. de/content/dam/iml/en/documents/OE%20310/OE310_recycling_management_EN.pdf
Tarun, S. (2007). Erster Testeinsatz bei KUKA – Das intelligente mit RFID-Sensoren ausgestattete Flurförderzeug ist Realität. Retrieved from http://www.rfid-ready.de/200711202659/erster-testeinsatz-bei-kuka-das-intelligente-mit-rfid-sensoren-ausgestattete-flurfoerderzeug-ist-realitaet.html
Ten Hompel, M. (2013, June 11 & 12). Effiziente Logistik – Logistik auf dem Weg zur hybriden Dienstleistung. *Warehouse Management* [Presentation on symposium], Dortmund. Provided by Rainer Wölk, Group leader and referent (rainer.woelk@dachser. com). Retrieved from https://www.hanser-tagungen.de/web/index.asp?vid=201303071524582&task=001
Thonemann, U., Behrenbeck, K., Küpper, J., & Magnus, K.-H. (2005). *Supply chain*

excellence im Handel. (1st ed.). Wiesbaden: Gabler.

Uckelmann, D. (2012). *Quantifying the value of RFID and the EPCglobal architecture framework in logistics*. [Dissertation November 21, 2011] Berlin Heidelberg: Springer.

Ustundag, A., & Kilinc, M.S. (2013). RFID in supply chain: The tagging cost sharing approach. In A. Ustundag & I. Fakultesi *The Value of RFID* (pp. 69-77). London: Springer-Verlag. doi: 10.1007/978-1-4471-4345-1

Ustundag, A. & Fakultesi, I. (2013). *The value of RFID – Benefit vs. Costs*. London: Springer-Verlag. doi: 10.1007/978-1-4471-4345-1

Ustundag, A. & Ugurlu, S. (2013). Evaluating RFID investments: A real options approach. In A. Ustundag & I. Fakultesi *The value of RFID* (pp. 69-77). London: Springer-Verlag. doi: 10.1007/978-1-4471-4345-1

Werth, S. (2008). DB Schenker: Wechselbrücken mit RFID. Retrieved July 27, 2013, form http://www.transport-online.de/Transport-News/Fahrzeug-Technik/8638/DB-Schenker-Wechselbruecken-mit-RFID

Wessel, R. (2011). DB Schenker uses temperature-logging tags to monitor drug shipments. Retrieved July 27, 2013, from http://www.rfid journal.com/ articles/view?8629

Wölfle, M. (2011). Fehlervermeidung durch den Einsatz eines RFID-Handschuhs. Retrieved August 8, 2013, from http://www.fml.mw.tum.de/fml/images/liz/Download/Logistikseminar%202011/05_W%C3%B6lfle_Vortrag.pdf

Zebra (2013). RFID-Drucker / Kodierer. Retrieved from http://www.zebra.com/id/zebra /na/en/index/de/products/printers/rfid.html

Zehnpfennig, M. (2010). RFID bei Deutsche Post DHL. Retrieved July 10, 2013, from http://www.fom.de/download/290-FOM_Logfor_MZ_20100114_01.pdf