Building **R**adio frequency **ID**entification for the **G**lobal **E**nvironment

Definition of RFID Decision Support System for Manufacturing Applications

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BRIDGE (**B**uilding **R**adio frequency **ID**entification for the **G**lobal **E**nvironment) is a 13 million Euro RFID project running over 3 years and partly funded (€7,5 million) by the European Union. The objective of the BRIDGE project is to research, develop and implement tools to enable the deployment of EPCglobal applications in Europe. Thirty interdisciplinary partners from 12 countries (Europe and Asia) are working together on : Hardware development, Serial Look-up Service, Serial-Level Supply Chain Control, Security; Anti-counterfeiting, Drug Pedigree, Supply Chain Management, Manufacturing Process, Reusable Asset Management, Products in Service, Item Level Tagging for non-food items as well as Dissemination tools, Education material and Policy recommendations.

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This document:

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Disclaimer:

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GLOSSARY

DSS	Decision Support System
TPS	Toyota Production System
IBC	Intermediate Bulk Container
DDD	Data Dependency Diagram
PRA	Production Responsiveness Audit
FMCG	Fast Moving Consumer Goods
JIT	just-in-time
UCD	Use Case Diagram
PPM	Physical Process Mapping
DataVis	Data Visibility
RFID	Radio Frequency IDentification
WIP	Work-in-progress

1. Introduction

The BRIDGE project manufacturing work package aims to develop tools and methodologies helping manufacturing organisations give effective decisions upon RFID implementation. As we have found out, implementing RFID within the four walls of a manufacturing plant requires extensive analysis and experimentation. A commonly cited risk of RFID implementation is inadequate assessment of existing business processes and the impact of RFID on them. Resulting from this observation we have developed problem analysis (D8.1 Problem Analysis) requirements analysis (D8.2 Requirements Analysis), business case (D8.3 Business Case) and pilot preparation (D8.4 Prototype Development) examples for the manufacturing industry as an exemplary systematic approach to understanding how and where RFID can be used, how priority areas can be detected, a business case can be developed, how requirements relating to hardware, software, human factors can be drawn, and planned for. In this document we discuss additional decision aid mechanisms for RFID implementation in manufacturing and present the drafting of a decision aiding mechanism: model based decision support, in other words discrete event simulation.

In this report we:

- Review current trends in decision making and simulating RFID implementations,
- Make the case for simulation as a decision support mechanism in RFID implementation,
- Propose an approach for using simulation as a decision support mechanism,
- Outline the case study we will use as a proof of concept.

This document is structured as follows:

Section 2 reviews currently existing decision support mechanisms for RFID implementation,
Section 3 zooms in to simulation based approaches in decision support,
Section 4 summarises the approach to be used when using simulation to investigate RFID implementation,
Section 5 presents the case study to be used in the decision support,
Section 6 provides the conclusions.

2. Review of decision support systems for RFID in Manufacturing

The literature of RFID in manufacturing covers topics such as benefits, business value, investment, integration, spending, implementation, and human factors impact. Moreover, pilot studies have been developed and successful isolated case-studies have been recorded in the literature. These studies are generally specific to a company or process, which managers find difficult to map to their problem. There has also been some investigation into the benefit analysis of RFID deployment including reduction in labour costs, inventory costs, and other benefits based on ROI (Lee 2004). These on the other hand tend to be very complex mathematical models which managers do not favour or use in decision making. In addition, many qualitative studies in white papers and reports based their analysis qualitatively on business cases for RFID applications (Lee 2004). These kinds of reports may be written by RFID hardware companies or system integrators which managers may find to generic and read with caution as the benefits reported may well be over-estimated. Key literature and applications of RFID in manufacturing have been investigated in the previous deliverables of the BRIDGE WP8 and hence are not repeated here.

As part of 8.6 Process Mapping we have also pointed out the difficulty in quantifying RFID benefits in manufacturing using existing literature, and expressed the need for more structural but less arithmetic methods that can be put to use by the industry. We have drafted a process mapping methodology in D8.6 to identify what manufacturing wastage can be reduced by implementing an RFID system so that a leaner process can emerge. The manufacturing wastage concerned was that of Ohno’s 7 wastes in Toyota Production. The methodology was comprised of identifying where RFID can bring value through automated data collection, conformance to data dependencies and improvements in visibility. PPM and UML Use case diagrams showed overall process information and target motion and transport wastage. DDD diagram showed wastage that may occur due to disrespecting data dependencies. DataVis diagrams showed how visibility improvements can help make better inventory decisions. Finally use of a production responsiveness audit was proposed to identify current disturbances in operation, capabilities and utilisation of those capabilities where RFID technologies are considered to improve existing capabilities or their utilisation. The toolkit was validated using industrial case studies throughout the document.

The next natural step of progression from such an analysis is a proof of concept using real manufacturing process data in order to decide on implementation and help justify the business case. We believe model-driven decision support i.e. simulation based analysis could be the answer to the current lack of satisfactory decision support. A simulation-driven approach as RFID decision support provides several advantages over traditional mathematical modelling and qualitative models, in that the use of such a technique could provide:

- Statistically sound analysis of RFID scenarios
- A simple experimentation platform where users can try out different scenarios as simulation modelling captures the dynamics of a process, breakdowns system complexity, and answers several 'what-if' questions.
- Elimination of complex calculations or qualitative benefit analysis whose bias is often questionable

For those aforementioned reasons, this stage of WP8 research will focus on taking a simulation approach to decision support specifically to investigate inefficiencies without RFID and show the benefits of RFID in reducing the seven wastes.

Although the literature has many isolated cases for specific applications of RFID in manufacturing, formal process modelling and simulation strategies have not been investigated to support to decision making for RFID in manufacturing.

In terms of generic RFID implementation, some leading firms such as Rockwell Automation advocate the use of simulation tools for experimentation with RFID strategy (Rockwell Automation 2004). (Lee et al 2004) simulated in supply chain, demonstrating that benefits of RFID in the supply chain are well beyond the automation oriented advantages such as labour savings.

More recently however, (Lu and Cheng 2005) simulated the use of RFID in gear manufacturing to evaluate benefits in terms of cost distribution and time utilisation, where the study illustrated an 8.63% improvement by implementing RFID technology in the system. The improvement resulted due to model parameters indicating that quality problems can be caught earlier, reducing work-in-process material.

Despite a few research papers dealing with simulation modelling of RFID in supply chain, with Lu and Cheng's example being the only paper in the area of simulation based analysis of RFID implementation in manufacturing, a research gap is clearly identified.

The questions then emerge whether it is possible to simulate RFID's impact in manufacturing processes, what steps should be followed and what window of analysis could be used to do so.

Simulation studies in manufacturing tend to frame their analysis in terms of costing, time, errors and scraps. Following our methodology proposed in D8.6, we propose to identify what wastage can be reduced using RFID through simulation, thus granularising the relatively broad frame of analysis that currently holds. This will provide a basic but effective template for manufacturing and ground the benefits of RFID in lean manufacturing. The wastes mentioned are:

1. Overproduction, which discourages a smooth flow and leads to excessive lead and storage times.
2. Waiting, which occurs when time is being used ineffectively.
3. Transport, a non-value adding operation which involves goods being moved around.
4. Inappropriate processing, which occurs when systems or procedures more complex than necessary are used, leading to excessive transport and poor quality.
5. Unnecessary inventory is unused capital, leading to storage costs, or possible quality deterioration of goods if the time of storage is critical to its health.
6. Unnecessary motion refers to the ergonomics of production when workers need to move in unnatural positions repetitively, possibly leading to tired workers and compromises on quality.
7. Defects are costs directly attributed to wastage of produced material that could potentially bring revenue.

Table 1 shows how currently barcode-controlled or manual information based production operations can contribute to wastage and what units in a simulation study can be used to show the waste. Using a simulation approach a process can be modelled, relative probabilities of failure of a production or information gathering step due to wrong or missed barcode scans can be configured, and the resulting analysis can be compared with a RFID scenario. It should be noted that the process model should be accurate, probabilities of scan errors should be gathered from real data, and a sensitivity analysis should be conducted in order to derive meaningful results.

Table 1 Contribution to waste in a non-RFID environment

Waste type	How is the waste created in a non-RFID environment?	Units of measure
Overproduction	Scanning the wrong barcode/recording information incorrectly can cause an overproduction as there will be a discrepancy between physical flow and information flow leading to inaccurate stock level	Number of product units
Waiting	Barcode and manual recording scenarios result in more time spent to record data, and correcting errors	Time
Transport	Wrong scanning association resulted in products being brought to the wrong location.	Time
Inappropriate processing	Traceability lost, product wrongly processed leading to waste of time.	Time
Unnecessary inventory	WIP will reduce as the result of a leaner operation.	Number of product units
Unnecessary motion	Operators use manual scan or information recording operations, which can be eliminated by RFID.	Time
Defects	Traceability lost, product wrongly processed leading to waste of material. Quality inspection was not associated with batch/item, and product has to be scrapped.	Number of scrapped/defected product units

Using this frame, a simulation analysis may investigate the following objectives:

1. Highlight the inefficiencies of a barcode or manual data collection system and show that it has a negative impact on waste reduction in an ‘AS-IS’ model
2. Show the benefits of RFID as an alternative in assessing its ability to reduce waste. A ‘TO-BE’ model entitled ‘RFID scenario’ will be designed for that purpose

3. Model-driven decision support: the simulation approach

Simulation modelling is an effective tool, widely used, entailing dynamic visibility for process reengineering and continuous improvement (Amini et al 2006). As a straightforward definition of simulation, it is the imitation of a process or system over time (Banks et al 1996) thus a dynamic model. The simulation model allows capturing the behaviour of the process through time (Banks et al 1996). Although analytical models such as operations research and heuristics can answer certain 'what-if' questions of a system, they have major complications when it comes to real complex processes (Venkateswaran et al , Law et al 1991). Computer-based simulation can evaluate a model numerically by gathering estimated data for certain characteristics of the process. It has also been noted in literature through many surveys that simulation modelling is widely used and a preferred tool in management science and operations research (Amini et al 2007). Simulation is widely used in lean manufacturing in validating lean designs such as reduction in lead-time and non-value-added activities i.e. wastes (Avni 1999). Business process re-engineering (BPR) has found its way in using simulation modelling to facilitate the change process, compare alternative scenarios, quantify improvements, and justify change (Avni 1999). All these points add to the justification of simulation to investigate how and to what extent a leaner process can be achieved through RFID implementation.

Simulation modelling has several advantages and disadvantages. Among the advantages is that it allows management of change and risk reduction as well as capturing system dynamics, improving communication, and answers for several 'what-if' questions (Venkateswaran et al) (Avni 1999). In a discrete simulation system, state variables vary at discrete points in time. Discrete-event simulation, which we will as the frame for our development, is widely used in business process modelling (Hlupie et al 2004)

Disadvantages of simulation has been found in literature such as difficulty in interpreting results, special training needed for modelling, and the time and cost of simulation (Venkateswaran et al). However, in our case time spent on the simulation and post-analysis is expected to be little, compared to justifying RFID by building a complex mathematical model. Furthermore, process modelling is an activity that anyway has to take place, when considering an implementation which can be re-used in simulation.

4. Approach

The simulation based analysis shall consist of the following stages:

<u>Step 1:</u> Process understanding and RFID opportunity analysis

1.1 Process modelling: a thorough understanding of the candidate manufacturing processes for RFID implementation should be obtained using process mapping tools, such as the analysis carried out in D8.1 Problem analysis with Value stream mapping.

1.2 Process analysis for RFID opportunity: This stage should consist of analysing the manufacturing process from an RFID opportunity perspective using tools described in D8.6 Process Mapping Methodology. This analysis will set the understanding for the wastes to be targeted for evaluation using simulation. The toolset described in D8.6 for this purpose is summarised in Table 2 below.

Table 2 Process mapping tools vs Identification of waste (D8.6 Process Mapping Methodology)

Mapping tool	Waste	Identification of waste
PPM	Unnecessary motion Transport	Identifies manual data collection points, geographical distribution of data locations leading to unnecessary movement of operators and products
UCD		Shows the use cases, that the current system knows how to perform, and actors taking part in system functionality. Can be used to differentiate what parts of the process are done by error prone actors, what parameters are modified by the information system.
DDD	Waiting Defects Overproduction Unnecessary inventory Inappropriate processing	**Identifies process decision points to conclude on the importance of data capture, and what processes are affected from what errors** **Identifies what level of concurrency is involved in the operations and if process speed will improve if data dependency conformance is automated**
DataVis	Overproduction Unnecessary inventory	**Identifies how visibility levels and parameters affect batch sizes, and work in progress and finished inventory.**
PRA	**All**	**Examines the impact of disturbances in a manufacturing process, helps understand current capabilities and utilisation of those capabilities to address disturbances. In doing so, examines whether RFID technologies can help improve existing capabilities or their utilisation.**

Step 2: Modelling the as-is process on the simulation tool

After an understanding of the steps involved in the manufacturing process and the waste that can be targeted with RFID is obtained, the next step is the modelling of the process in the simulation tool. Depending on the software tool used, different visualisation options will occur however the essentials of the process steps, i.e. timing, probabilities of pursuing various steps in the process and inputs and outputs to the process will be modelled regardless of the tool used. When setting the model the modeller shall consider various questions such as:

- Does the process step lie on critical path?
- Is it a data collection process step?
- Is there possibility for error using the current data collection method?
- Where is this data used?
- How does the type of error affect the completeness, accuracy and timeliness of the process data?
- What will the impact of the error/s be on inventory, product itself, transportation of the product, time it takes to complete the process?
- If error is noticed and corrected, what steps should be followed, what resources will be used to correct the error and how much time will it take? Error corrections are then modelled as additional process steps.
- How does any error impact the critical path?
- Is it vital for the subsequent process steps that data at this process is collected?

Step 3: Modelling the to-be process on the simulation tool

The next step is to model the changed process after RFID implementation. Different RFID scenarios can be implemented, for example a handheld scanner scenario and static, mounted reader scenario will give different results. Similarly, different numbers of read points may give different outcomes. Here, the as-is model is worked-on, if currently barcode scanning is used, the probability of scanning error, is reduced, the time for information collection is reduced, some process steps such as manual data recording might be eliminated etc.

Table 3 shows the types of process steps that can lead to waste in a non-RFID environment and how it can be measured in the simulation model. These steps should be identified in Step 1, modelled, and their probability of occurrence configured in Step 2. In Step 3, the steps should be reconsidered:

- Will the process step occur or be eliminated in the type of RFID to-be process being modelled?
- If the process step will remain, will the probability of its occurrence change? If yes, by how much?
- Will the step be replaced by other steps? For example a handheld RFID scanning operation may be replaced with manual data recording. This will lead to the replacement of the process step but a change in the time taken to complete the step and probability of an error. Consequently the steps that are taken to correct the error might be different and need re-modelling.

Table 3 Process steps creating waste vs Simulation model output

Waste type	Process creating waste	Output
Overproduction	Wrong data creates wrong demand level	Check inventory level in as-is and to-be processes and compare with demand level
Waiting	Error correction process step is taken	Time spent on error correction process step in as-is and to-be
Transport	Error results in products in the wrong location.	Once noticed, the time product spent between previous correct location and current wrong location is taken
Inappropriate processing	Product wrongly processed	Time taken to wrongly process product
Unnecessary inventory	Wrong data creates wrong demand level. Increased time in waiting may increase number products waiting to be processed.	Check WIP level in as-is and to-be processes and compare with inventory demand level
Unnecessary motion	Manual scan or information recording process steps	Time spent on manual data collection processes
Defects	Product wrongly processed	Number of scrapped/defected product units

Step 4: Sensitivity analysis

Sensitivity analysis (SA) is the study of how the variation (uncertainty) in the output of a model can be apportioned to different sources of variation in the input of a model (Cacuci 2005). The probability of errors in the as-is process due to wrong/lack of data collection is the benchmark for evaluating improvement in RFID scenario in terms of reduction of seven wastes. After the as-is and to-be models are created and ran, a sensitivity analysis needs to be conducted to investigate the effect on waste reduction by varying the probability of errors over a specific range on the new process model, so as to prevent any misinformed bias and analyse whether RFID can have a significant improvement over the as-is process. Hence, a number of differently configured to-be models need to be created for each of the to-be scenarios, to gather at what point the to-be model starts providing a better process than the as-is, and if that point is a realistic expectation.

5. Case study

In the first instance, the Intermediate Bulk Container Management (IBC) case-study will be investigated. The process is heavily analysed in the previous deliverables in terms of the steps involved and variations that an RFID-enabled to-be process will bring. The process id based on a FMCG (Fast Moving Consumer Goods) company, i.e. our application partner Nestle UK, following a push production system and managing inventory using an MRP II system.

On the other hand, it is dutifully noted that the seven wastes defined in Toyota Production System (TPS) might not be of equal importance to all manufacturing industries. In FMCG industries, specifically in company case-study, cost of opportunity loss is of much greater importance than cost of holding inventory. According to Nestle UK, waste of inappropriate processing, defect, and transport are critical and lead to opportunity loss. We will however, investigate all waste that is created as part of the simulation model.

A secondary case study will follow which will look into another type of manufacturing system such as a just-in-time (JIT) or pull system, to investigate the affect of RFID implementation.

It is expected to use the Arena simulation software, by Rockwell Automation, as this is readily available to the academic partners of WP8, and its use is well-grounded in various manufacturing process modelling applications.

6. Conclusion

There is a lack of flexible, easy to use and tailored decision support mechanisms for helping decision makers in implementing RFID in manufacturing processes. Currently managers have to choose between often overtly optimistic and biased whitepapers from RFID hardware sales or system integration companies, or use complex mathematical models proposed by Operations Management literature to estimate the value they can gain from RFID.

Simulation based i.e. model-driven decision support can be the answer to the current lack of decision support, allowing statistically sound, fast experimentations with different scenarios where the decision maker can modify the process simulation model tailored to the specific process under investigation.

In this report we reviewed the current lack of decision support mechanisms, made the case for simulation based analysis and proposed an approach which can be used for simulation based decision making. Our approach is once more based on using the seven wastes in the TPS as a template for identifying value in RFID. This approach includes understanding the as-is process through process mapping, identifying opportunities for reducing waste through RFID through the process mapping tools proposed in D8.6, modelling the as-is process in a simulation software, identifying and modelling a number of to-be process scenarios each representing different RFID implementation variations by re-configuring probabilities and times associated with each process step and replacing steps in the as-is model, and investigating the affect on each waste category through discrete event simulation. A sensitivity analysis is also proposed to determine at what point the RFID scenario results in a leaner process than the as-is.

We will investigate the results of this approach in our next deliverable, D8.8 Development of the decision support tool, through two case studies, one of which will include the Nestle UK IBC management process.

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