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Consideration Of RFID Systems In The Factory Planning Process

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Abstract

RFID technology enables products and load units to be identified in the absence of a direct line of sight. In recent years, it has grown into one of the principal tools of identification used in industrial environments. For it to function properly, efficiently and reliably in such locations, factory planners require comprehensive integration of an RFID system. Although planning methods and tools for integrating RFID into existing production and logistical environments are available, it takes a great deal of time and expense to implement the procedures successfully. This is because logistics and production systems and processes need to be adapted to incorporate an RFID process, which discourages many companies from installing it in their production. Furthermore, to avoid identification problems in production and material flow processes, factory planners need substantial knowledge of the parameters that influence RFID.

This paper presents a generic planning method which considers the conceptual design and implementation of RFID systems in an industrial environment from the beginning of the factory planning process. The aim of the method is to give factory planners and RFID experts a guideline on how to plan and implement RFID, by taking an interdisciplinary approach. After first reviewing current RFID planning methods, the paper presents a new six-phase planning method the aim of which is to enable experts in the industry to plan their production, logistics and RFID systems simultaneously, with due regard for the individual requirements of each system.

Keywords

RFID Systems; RFID Planning; Factory Planning; Planning Processes

1. Introduction

RFID is a driving technology that enables processing companies to identify tagged products in the absence of a line of sight and to seamlessly track the goods at a production site. RFID tags are applied to goods and read by a dedicated RFID reader. The advantage of RFID technology is that it enables production and logistics to be controlled effectively and gives management an overview of material flows. Although RFID has further advantages, implementing this technology in a processing site is a challenging task. RFID has many restrictions, which managers and production site planners need to be aware of [1]. For example, metallic objects can interfere with or even block the electromagnetic waves of the RFID systems, which can lead to a breakdown in communication [2]. Other problems in the RFID system during the production process include RFID tags that cannot be read or electromagnetic waves from different RFID readers that interfere with each other.

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When such problems occur, factory managers have to make adjustments not only to the RFID technology itself but also to the production site and its logistics. This can seriously disrupt the production process, which in turn leads to a loss in profits. To prevent such problems, factory planners have to consider RFID when designing a new factory, redesigning an existing one, or implementing RFID for the first time at an existing site. To achieve this, RFID must be an integral component of the factory planning process. This concerns not only the planners and their methods, but also extends to their tools and way of thinking. An RFID system simulation may be an appropriate tool for such a purpose.

Many tools are already available that simulate RFID and the propagation of electromagnetic waves. Furthermore, manufacturers of RFID technology already possess detailed knowledge of the limitations and requirements of their products. Manufacturers use a variety of computer-aided models (CAX), which RFID experts can employ for their tools. These tools already exist and set the stage for planners of logistics, production and RFID systems to design factories in an integrative manner. However, it is necessary to address not only the questions of how and when different planners will work together but also how to implement the data flows of the different data formats between the planners and how the RFID simulation tools will be used to plan a factory. [3]

The authors of this paper present a method by which planners can design and lay out logistics, production and RFID systems for planning factories in an integrative manner.

2. Current approaches to planning RFID systems

Several RFID planning processes have been developed over the last few years, most of them concentrating on integrating the technology in logistical systems. The common ground of these processes is that they focus on integrating RFID into existing systems. Furthermore, the procedures in most of these models are generally the same:

1. Define the aims of using RFID;
2. Analyse the place of operation;
3. Derive the system requirements and boundary conditions;
4. Develop an application concept;
5. Implement the established concept.

Several good examples of these methods have been published [see 4-9].

Hellström proposes an RFID implementation process based on an IT implementation model [4]. The model is derived from data gathered from two use cases and divides the RFID implementation into seven stages: initiation, adoption, adaptation, acceptance, routinisation and infusion. The author points out that although all the stages can be performed simultaneously, if one step proves inconclusive regarding the benefits or implementation possibilities of RFID, it would be necessary to iterate previous steps. The activities of each implementation stage are outlined in the model. However, the model does not go into detail about how the activities should be conducted.

The method by *Donath*, as described in [5], introduces a process for implementing RFID in small and medium-sized enterprises (SMEs) and proposes an implementation in six phases rather than seven as in [4]. The author focuses on pointing out at which time of each phase different tests and analyses are performed to verify the concept for integrating RFID in existing logistical process. Among other things, the author proposes economic analyses, components, integration processes, systems and acceptance tests. The tests are categorised as laboratory (or synthetic) or on-site-tests. Again, the procedure is not further elaborated.

A similar method was developed by *Fruth* in [6], who also proposed an RFID implementation process for SMEs. Dividing the process into five phases (definition, concept, objective design, pilot, and implementation), the authors place the activities relating to implementation into one of three categories: performance processes, supporting processes or management processes. Each category of activity thus plays a different key role.

A different type of process model is presented by *Vogeler* in [7]. Based on case studies conducted in the textile industry, the author presents a model consisting of a series of flexible iterative steps, which are categorised into four activities: controlling, security, design and support. The steps are not necessarily followed in a linear fashion but can be repeated in one or more phases of the implementation process. A process intensity diagram shows where the planner of the RFID system should initiate each of the planning steps. The diagram also suggests milestones for each activity, but these may be moved depending on the project in which the model is used.

Fischer develops a modular concept for planning RFID-supported logistical processes in [8]. Instead of investigating the various planning phases, the author considers the different RFID modules. These are the RFID technology, the object of identification, and the identification process. In the first step, the requirements, boundary conditions, resources needed, and objects of interest are defined for each module. This is followed either by an evaluation of existing solutions for use in the current tasks or the development of new solutions.

A different approach to those given above is presented in [9] by *Steinhaus*. Instead of defining specific tasks in a specific order, the author presents questions intended to help SMEs implement RFID in their businesses. The questions are grouped into preparation, organisation, technology and process management. They are published in a guideline, which also gives examples of how RFID can be implemented in specific logistical processes.

3. Integrated RFID planning method

3.1 Method development

As stated in the previous section, current RFID planning methods focus on the implementation of RFID systems in an existing production or logistical environment. However, no link exists between the factory activities and the work of RFID planners. This section presents an integrated planning process, in which the two interacting aspects of RFID and factory planning are considered simultaneously from the beginning of the factory project. The aim of the method is to provide planners with a holistic and interdisciplinary guide, which they can use in a generic factory planning project. The method was mainly devised and evaluated for green field planning.

The method is based on the processes described in the Munich Model of Methods by *Braun & Lindemann* [10]. First, the existing methods, which were introduced in Section 2, were analysed. It was determined that since the respective planning procedures and phases in RFID are similar to those in the factory environment, they can be superimposed. The method developed is founded on the planning processes in [5,8,6]. However, as can be seen from Figure 1, the phases of the different processes do not coincide entirely.

For this reason, the RFID planning processes were broken down and the individual steps reallocated into the factory planning processes from [11], which is a more detailed extension of the standardised factory planning process of [12]. Further steps were added to meet the requirements of an integrated planning process. These steps mainly concerned the estimation of signal coverage using computational electromagnetics (CEM) software as an additional planning tool. The method and its phases are presented schematically in Figure 1. The different colours inside the phases correspond to the qualitative integration of the RFID planning steps of the respective authors into the factory planning process in [11]. Dark red indicates the additional planning steps devised for this new method, which include the use of CEM.

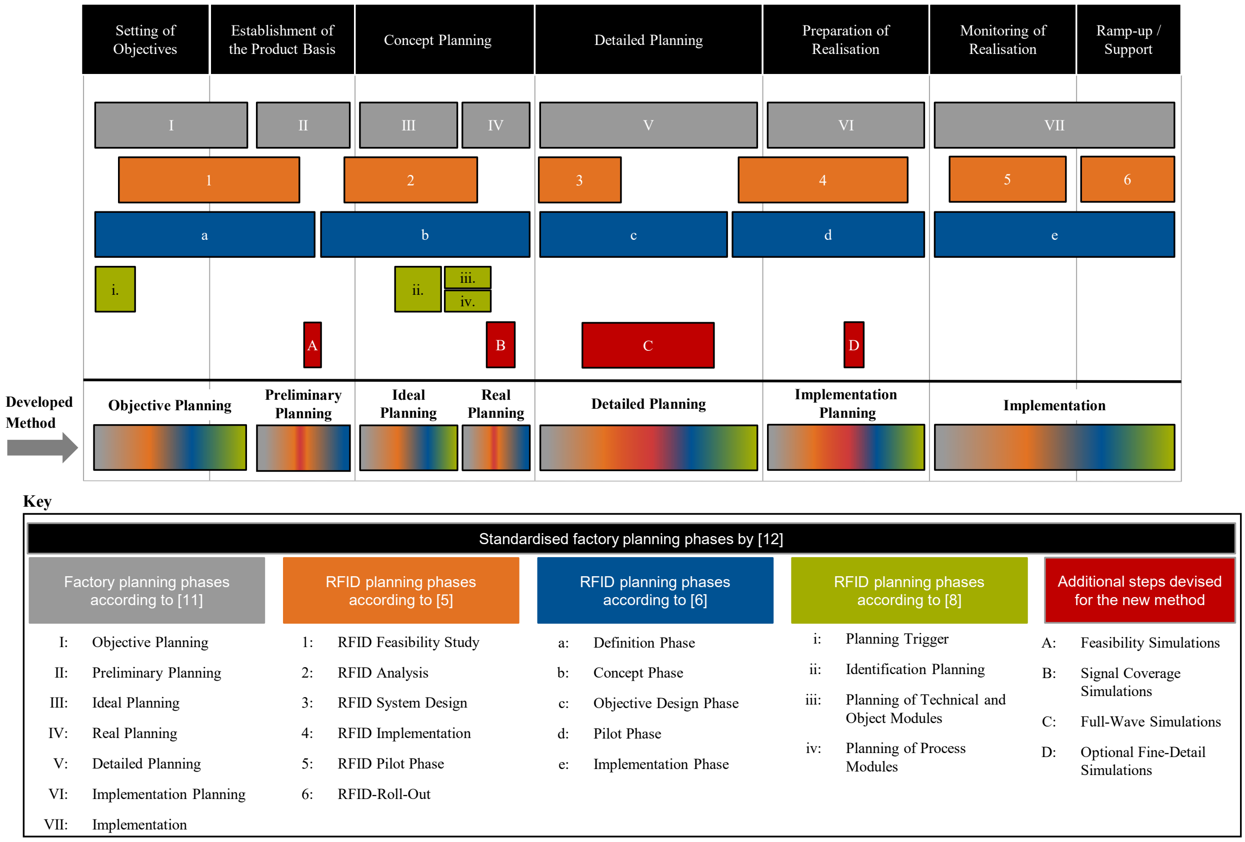


Figure 1: Qualitative comparison of the planning phases in [5], [6], [8], [11] and the method with the additional planning steps described section 3.2 in reference to the phases of the standardised factory planning process of [12].

The following section presents an overview of these steps in the different phases of the integrated planning process.

3.2 Planning phases of the integrated RFID and factory planning process

3.2.1 Objective planning

The integrated RFID and factory planning process commences with an objective planning phase, in which the objectives of the factory building project are set and the basis of the planning process established. The steps included in the general factory planning process phase determine the envisaged product range, set key dates, work packages and planning milestones, and compile an initial financial framework for the project as a whole. Also included in the first steps of the objective planning phase is the establishment of the data sets required for the subsequent planning process. The data can be obtained by revising past planning projects and product information, researching the latest government regulations, and gathering information on the state of the art in production as well as in logistics technology and processes.

The integration of RFID planning in this phase extends the general factory planning phase by ensuring that RFID is considered in the first few steps of the project. This includes analysing the use of RFID in past projects or researching the state of the art of different RFID systems for similar processes. Additionally, factory planners need to identify initial potential areas of deployment for RFID systems in the planned factory environment.

At the end of this phase, planners should have a portfolio of information gathered during the phase, as well as a complete project plan containing work packages and schedules for the project as a whole.

3.2.2 Preliminary planning

Planners use the data gathered in the objective planning phase to build an initial theoretical concept of the production and logistical systems and processes in the preliminary planning phase. The concepts in this phase do not include a factory layout but concentrate on the procedure and sequences of different processes in the production and logistical environment, and assemble them into flow charts, functional diagrams, etc.

The requirements of the RFID systems to be used in the production and material flow processes can then be derived from the resulting production program and production & material flow chart. This involves a requirements analysis, which includes analysing possible tag positions on the product, as well as tag types, reading distances, reading rates, and material influences. The requirements analysis should not only focus on the current production plans but also on planned future production projects and possible uses of RFID in the company, thus taking into account the adaptability of the factory. It is crucial that RFID system planners work closely with the planners of the logistics and production systems. Whenever there are any changes in the concept of any subsequent systems, these can affect the requirements which the RFID systems have to fulfil.

Once the preliminary requirements are available to the RFID planners, the next step requires them to set up initial concepts for the application of RFID tags and to perform the initial tests required for a feasibility study of these concepts. These can include synthetic laboratory tests (such as described in [13] and [14]) for example or simulations (e.g. as presented in [15]) to show how RFID tags can be applied to assembly components of product or loading units and how different setups (e.g. tag position, tag type, antenna type, etc) can affect system efficiency. The aim of these tests is to validate the application concepts developed and to determine the range in which RFID can be used in the various production and logistic processes.

Once initial production, material flow and RFID concepts are available, a rough hardware and software demand and cost assessment is conducted and compared to the financial framework setup from the objective planning phase. If these coincide, the management can accept the concepts, and the manufacturing and material flow processes can be adopted. In the next step, the factory planners can continue planning the ideal factory layout.

3.2.3 Ideal planning

The ideal layout planning phase is the first part of the factory planning process and culminates in the presentation of an initial layout design at the end of the phase. Schematics for the workflow in the factory can be derived from the production program and the manufacturing and logistical process concepts. By analysing these, planners can build up different scaled 2D floor plans, which include dimensions of factorial subsystems (such as the areas of different manufacturing and assembly zones) and the visualisation of the material flow between these areas.

At the same time, RFID experts can use the workflow schematics to specify the processes in which identification operations are to be used. It is important that there is an exchange of information between factory and RFID planners at this stage of the project, as further layout designs need to be adapted to the RFID concepts (such as space, cable planning, information flow planning, etc.) and vice versa. Planners should always bear in mind that the factory concept can be revised more easily at early stages. The cost and effort of changes rises in later stages.

Further analysis regarding the arrangement and implementation of RFID in factory processes requires more specific configuration of the various factory subsystems. This is why no additional RFID steps have been added to this phase of the integrated planning process. However, further steps will be conducted in the next phase, in which the real layout is planned.

3.2.4 Real planning

The aim of the real-layout planning phase is to concretise the ideal layout plan from the previous phase in an area-specific presentation of the factory area, or real layout. In this depiction of the factory, the areas for the machine groups, workstations, material flow paths etc. are arranged inside the areal-scaled layout plans of the ideal layout.

Up until this phase, planners had been devising RFID application concepts in the factory operations using workflow schematics created by factory planners in the initial phases of the planning process. In the next step, the planners will be designing the first factory plans with different real layout variants. This allows RFID experts to concretise the arrangements of the RFID systems inside the factory and identify specific boundary conditions which planners need to bear in mind when generating their RFID implementation concepts. Concretising the arrangement of RFID systems means specifying the number of identification points (points in a production or logistics process where an RFID tag may be read) and arranging them throughout the factory layout. In addition, a detailed installation approach for the RFID antennas has to be created, based on the experimental results of the RFID feasibility study in the preliminary planning phase (i.e. positioning the tag on the product or loading unit). It is also necessary at this point to consider how and how often identifiable products will pass by the identification point, as well as how and where RFID tags will be placed on these components. This also necessitates further simulation studies (e.g. using ray-tracing simulations as in Figure 2 and described by *Bosselmann* in [16]) to verify the layout of the RFID concept and the signal coverage within the vicinity of the antenna. Criteria for verification include the locations of critical wave dead spots and overreach. Dead spots, where tags cannot be read, have to be ruled out to ensure high system reliability, while overreach results in tags being identified outside the designated reading area.

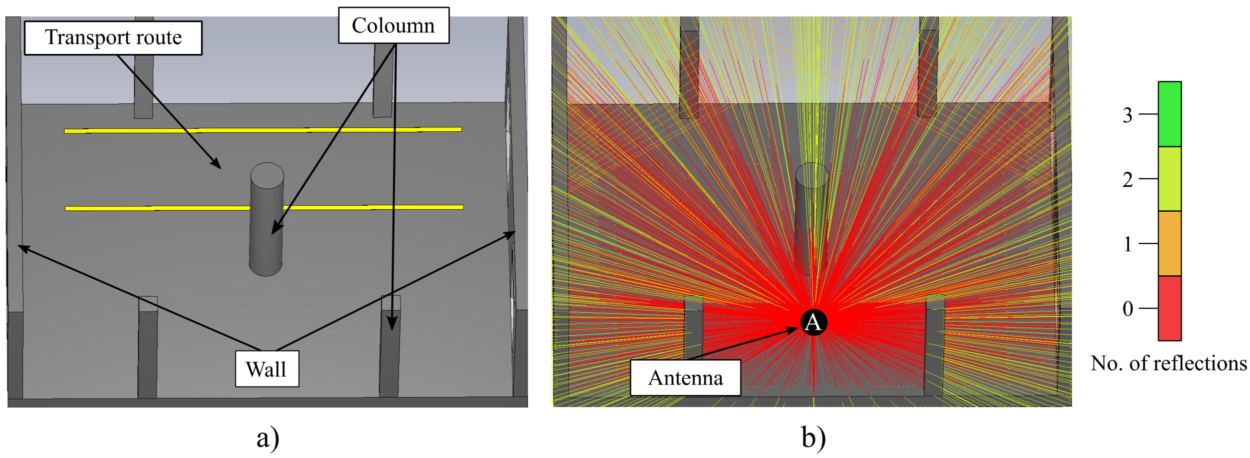


Figure 2: An example 3D model of an empty factory hall (a) and the same hall with an RFID antenna (b). Figure (b) also shows an analysis of indoor wave propagation utilizing ray-tracing simulations. (A) indicates the RFID reader antenna. The rays represent an approximation of the field distribution of the magnetic waves inside the hall.

These studies require 3D models of the factory environment, in which computer models of the RFID systems can be integrated. Also, these models should ideally be used to arrange the factory systems in the real layout. To shorten simulation times, it is advisable to divide the factory model into several smaller sections. Only those sections relevant to the RFID process are then analysed in the simulation studies. It should be noted that analysis of different sections can lead to different results if sections are combined or the area of a section increases. Again, factory and RFID system planners have to work together, and, where necessary, implement changes into their concepts to ensure that both systems work optimally.

While analysing the arrangement of the RFID systems, planners also need to draft the information flow system between the RFID and the other factory entities, in a parallel process.

Once different arrangement concepts for the factory and RFID systems have been completed and combined into a number of real layouts, they have to be assessed and the preferred alternative chosen. Relevant criteria to be considered for assessment are functionality, costs, profitability and goals set at the start of the factory planning process.

3.2.5 Detailed planning

The final step is the detailed planning phase, and it is here that the layout of the factory is detailed in full. By the end of this phase, planners will have developed a layout plan that can be used to build the factory in the subsequent implementation phase. The plan includes dimensionally accurate factory areas, the positions of workspaces, machines, equipment, and material handling and storage systems. It also includes installation details for IT and communications equipment.

The most detailed plan of the factory systems is used to finalise the RFID implementation concept and conclude the arrangement of the systems, the choice of hardware and software, and the planning and execution of the final feasibility study.

The feasibility study normally consists of hardware and process tests conducted in a realistic environment. We have extended the study by incorporating wave simulations in the test procedure, a process not included in previous methods. These simulations can be performed in parallel with the real-world tests. Both types of experiment need to be prepared simultaneously so that they can analyse the same settings. The objectives of the experiments are derived from the project goals and RFID requirements, and the setup is determined from the arrangement of the factory and RFID systems. The quantity and duration of the experiments to be conducted are determined by building experimental plans using design of experiments (DoE) processes, as described in [17,18].

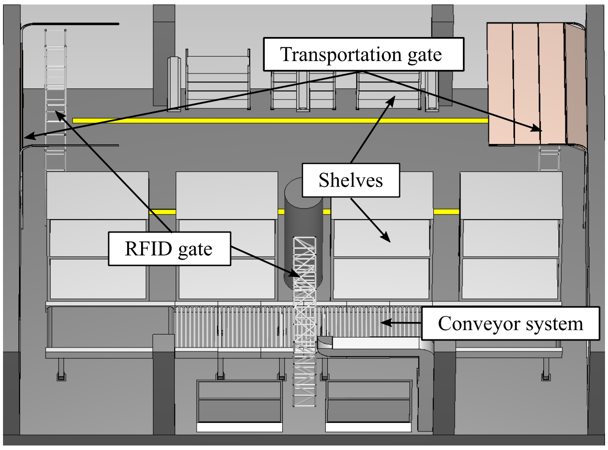
To use simulation as an analysis tool, further steps are required to ensure that the simulation is as realistic as necessary. Full-wave simulations are recommended for this purpose, example results of which are shown in Figure 3. These are more accurate than ray-tracing simulations in predicting the field distribution and power of electromagnetic waves, but they require a greater computational effort. It must first be ensured that the correct material parameters have been assigned to the objects in the simulation model and that the correct boundary conditions for the model are set. Furthermore, a simulation method for depicting wave propagation has to be chosen and the 3D model adjusted accordingly. Among other things, this means simplifying 3D models of machines to shorten the simulation times.

Once both test types have been completed, the results are compared and rated in relation to the project's goals and RFID system requirements. The concepts may also have to be adapted as necessary. If all requirements are fulfilled and the concepts for the RFID and factory systems coincide, a final evaluation (functionality, cost efficiency, etc.) of the factory and its concept as a whole is conducted before management approval of the plan is given in the final two phases.

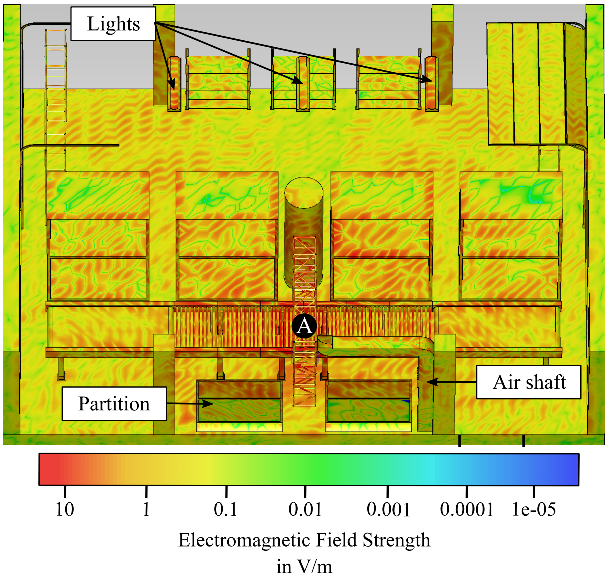
3.2.6 Implementation planning and implementation

The last two phases of the factory planning process are concerned with the planning and execution of the factory implementation. This includes the call for tender for the different systems and the planning of system assembly and installation (including RFID) as well as human resources.

Once the exact models of the machine and RFID systems are available, last-minute wave propagation simulations can be conducted if deemed necessary by the planners. These simulations are as accurate as possible, since all boundary conditions, material parameters and machine dimensions used in the factory are fully defined by this stage. The planner can use these to make last minute fine adjustments to tag or antenna positions at the various identification points, and, if required, increase the tag read rate and probability, and in turn, the efficiency of the RFID system as a whole.



a)



b)

Figure 3: The factory hall from Figure 2 with logistical systems (a) and the same hall with an RFID antenna, whose wave propagation is analysed by electromagnetic full-wave simulation methods (b). The latter shows the electromagnetic field distribution emitted by the antenna (A) in V/m throughout the hall.

Once a time schedule has been set for the building and installation project, the construction of the factory can begin. After completion of the factory, the project conclusion process begins, which includes calculating the total costs of the project and completing the project documentation. Pilot production, which takes place simultaneously, entails final process and system testing and also includes any last-minute changes.

Once the pilot production has been completed and the results accepted by the management, serial production can commence, signalling the conclusion of the integrated factory planning process.

4. Summary

This paper has shown that although planning processes already exist for integrating RFID into logistics and production systems, these models only consider the integration of RFID systems in existing factory systems. As this can lead to difficulties with refurbishment processes or even to production stops, the use of RFID needs to be considered from the very start of the factory planning process. The integrated planning process presented in this paper proposes steps to achieve this by combining the existing RFID planning processes with classic factory planning methods and extending these steps where necessary.

After briefly describing the development of the method, the authors elaborate the RFID planning steps that extend the factory planning process. The six stages of the factory planning process considered are the objective planning, preliminary planning, ideal planning, real planning, detailed planning and implementation planning phases and the implementation phase. The presented planning model shows that RFID can be considered in every phase of the factory planning process, and that, like the factory environment, the level of detail of the RFID system concept grows over the course of the planning process. Furthermore, additional analysis tools for evaluating the RFID system concepts are included in the various planning phases. Ray-tracing and full-wave propagation simulations are examples of such tools. The model also demonstrates that simultaneous, interdisciplinary planning of the factory including RFID is necessary, as the different systems (i.e. their dimensions and arrangements) affect each other. As it is far more expensive in terms of resources to make changes at a later phase of a planning project, it is crucial that work is conducted in an interdisciplinary manner from the very start of the project.

The method presented demonstrates that every phase of the factory planning process contains steps in which RFID systems can be considered. These have an impact on the different production and logistic systems and their processes, and conversely, the layout and processes of the system also have an impact on the composition of the RFID systems as well as on the process in which RFID is to be integrated. This is one reason why RFID should be taken into consideration right from the beginning of a factory planning project. Furthermore, retrospective integration of RFID into existing systems is more costly in terms of resources and replanning activities.

The next step is to verify and evaluate the functionality of the method introduced in this paper. Moreover, further work is needed to detail the interchange of data produced by the production, logistics and RFID planners and how each planning department can use the data of the other departments.

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Biography

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Miroslav Lach is a research assistant at the Associate Professorship of Microwave Engineering at the Technical University of Munich (TUM) since October 2019. He received his M.Sc. degree from the Department of Electrical and Computer Engineering at the TUM in 2019. His field of research is the analysis and simulation of UHF-RFID systems and their reciprocal effects on the operational environment.

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