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SYSTEMS ENGINEERING IN SMEs – A CASE OF RFID SOLUTIONS PROVIDER

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Abstract:
Systems engineering (SE) is a well-known approach used for management of the development process of big and complex technical systems / products (usually) by large companies. There are a few initiatives of SE application for different industries as well as new SE standard development for small and medium enterprises (SMEs). Radio Frequency Identification (RFID) systems are a good example of systems development of which could be approached using systems engineering. In this paper, a case of an SME – a solution provider and system integrator of RFID systems is discussed, to discover how it is dealing with SE problems and issues. The paper also presents potential benefits arising from the utilization of SE in this type of projects realized by the SME in question.

Keywords: Radio Frequency Identification (RFID), Systems Engineering (SE), Small & Medium Enterprise (SME)

1. INTRODUCTION

From the practical point of view, SE is an interdisciplinary approach and a means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, and then proceeding with design synthesis and system validation while considering the complete problem: operations, cost and schedule, performance, training and support, test, manufacturing and disposal. SE considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs (Haskins et al., 2011). The SE is mainly applied for the development and implementation complex technical systems, often by a large company/-ies or consortium.

Radio Frequency Identification (RFID) is and automated identification technology receiving increasing interest among manufacturing and logistics companies. It has two key benefits: it enables monitoring data flow simultaneously with the flow of goods. It eliminates communication delays and errors due to improper identification. For this study, each time radio frequencies (RF) are used to identify and/or locate a tagged object, they are classified as RFID technology. Therefore, in this paper RFID technology is every technology based on radio frequencies (no matter the standards) that enable the process of identification and/or location. There are many areas of RFID application, e.g. warehouse inventory tracking and management, manufacturing logistics, control of material flows, management of picking, receiving and shipping, process monitoring, tracking of work in progress (WIP), quality control, tool management, external supply chain management, life cycle management and return logistics (Liukkonnen, 2015). Detailed description of the physics involved and RFID applications has been the subject of many publications (Dobkin, 2012; Finkenzeller, 2010).

RFID is a type of information and communication technology (ICT), and uses a similar implementation framework. Therefore, it is important to focus on hardware and software issues, and their integration with other ICT (e.g., enterprise resources planning), physical

systems (e.g., dock doors), or cyber-physical systems. RFID systems are complex in their nature as they require integration and cooperation with other systems presents in the company e.g. transportation systems and equipment, existing infrastructure in a facility, among others. RFID is data source for information systems (as ERP or WMS).

2. METHODOLOGY

The present research was focused on answering three questions (see Fig. 1):

- Q1. How do companies deal with RFID systems design, implementations, maintenance?
- Q2. How (if) are SMEs using systems engineering?
- Q3. What elements of systems engineering are used by the analysed company?
- Q4. What elements of systems engineering are not used, but would be applicable to the analysed company?

The defined questions aim to find how (if) systems engineering is applied by SMEs based on the on example of the analysed organization.

First, state of the art was researched in relation to RFID implementation frameworks and systems engineering for SMEs to answer Q1 and Q2. Second, a case study was performed (see Table 1) to answer Q3 and Q4 using unstructured interviews with and analysis of documentation.

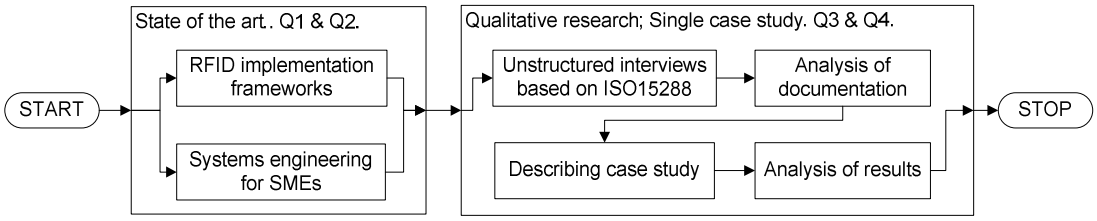

Fig. 1. Research procedure

Table 1
Boundaries of case study

Time	Interviews and documentation analysis from 2016-2018
Place	Limited to implementations in Poland
Definition and context	Related to the RFID definition presented in the "RFID technology" section
	- SME based in Poland - SME designing, developing, implementing and maintaining RFID systems for their customers (small, medium and large companies) - Interviews not limited to the customer type including e.g. rail logistics, warehouse management, leisure, fresh goods logistics - Documentation: internal communication platform of the analysed RFID provider, documentation delivered to their customer - Interviewees: R&D Manager, Chief of Software Eng., Project Manager

3. RESULTS

3.1. RFID implementation frameworks – state of the art

The literature on RFID implementation frameworks primarily addresses how to manage implementation projects. Ngai et al. (2010) and Ting et al. (2013) proposed seven and six stage frameworks for RFID implementation processes. Those frameworks are similar and presented in Table 2.

Table 2
RFID implementation frameworks

Ngai et al. (2010)	Ting et al. (2013)
1. Project feasibility and scoping	1. Project scoping
2. Project team formation	
3. 'As-is' assessment	2. Analysis of the existing system
4. Process redesign – 'to-be' processes	3. System design
5. Hardware adaption to the environment	4. Prototype testing
6. System implementation	5. Implementation
7. Continuous improvement	6. Continuous improvement

Source: based on (Ngai et al., 2010; Ting et al., 2013).

These two frameworks are generic and in fact applicable to any ICT implementation. In both processes, strategic assessments of RFID should be done before the implementation in manufacturing companies (Gladysz, 2015). Ngai et al. (2010) highlighted project management by the 'Project team formation' stage. Other stages in the frameworks can be treated as equivalent (see Table 2). Key success factors for RFID implementation projects do not differ significantly from other projects and include: (1) vendor selection; (2) organizational motivation; (3) cost/benefits evaluation; (4) top management support; (5) user involvement; (6) extent of progress supervision; (7) staff competence and training; and (8) policy, structure and operation process compatibility (Ngai et al., 2012).
There are also many papers focused on details of design of hardware or software itself, or details of deployment (e.g. tags' placement) without taking into account the bigger picture of the whole system (Cheung et al., 2014).
The SE approach allows to look at the designed system as a whole as well as provides detailed tools for:

- Identification and management of the requirements of the designed system throughout the design process, from defining to system verification;
- Definition and management of the architecture and functionality of the designed system;
- Analysis of all key aspects of the designed system;
- Definition interfaces between individual system components and interfaces between the RFID system and the object supported by the RFID system.

In particular the SE approach is used in the design process of critical RFID systems, e.g. for safety, defense industries. It provides rigorous approach to the design process.

3.2. Systems engineering for SMEs – state of the art

SE is an interdisciplinary process to ensure that all important requirements are satisfied in a high quality, cost efficient on time manner throughout a system's entire life cycle. This process usually focuses on the following seven tasks (Bahill and Gissing, 1998): 1/ state the problem, 2/ investigate alternatives, 3/ model the system, 4/ integrate, 5/ launch the system, 6/ assess performance, 7/ re-evaluate. It should be stressed that the SE process is not sequential. The tasks are performed in a parallel and iterative manner.
The process of a system requirements decomposition and analysis and further system element integration is usually performed under the V-model (see Fig. 2).

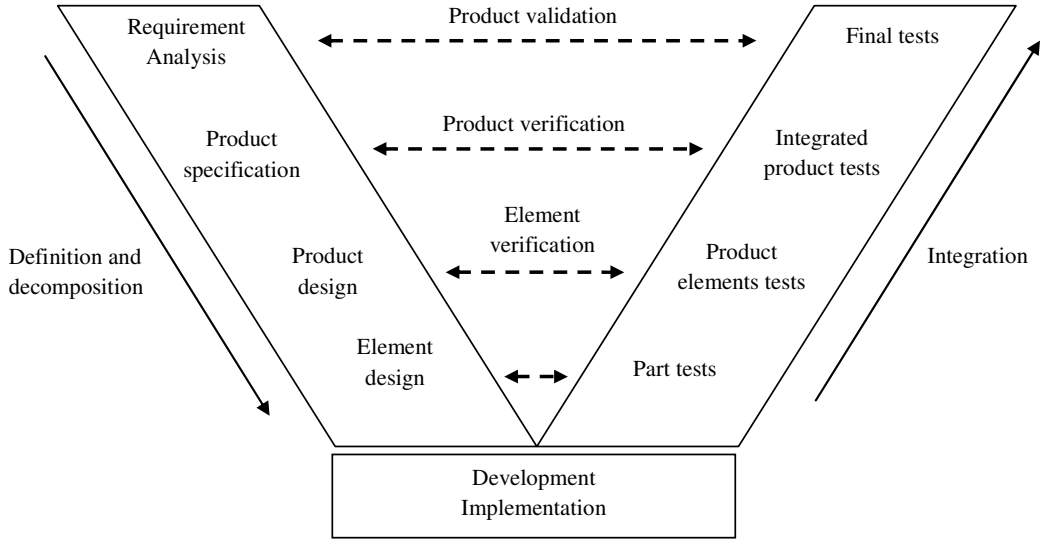

Fig. 2. V-model

Source: based on (Forsberg et al., 2005).

The basic standard of SE application is ISO 15288:2015, which assumes different types of processes supporting the realization of engineering projects:

- Agreement processes;
- Organizational project-enabling processes;
- Technical management processes;
- Technical processes.

SE is mainly used by big organizations. However, SMEs must use SE due to their involvement, usually as subcontractors, in the development and implementation process of big complex technical products / systems. There are relatively few publications in the SE literature devoted to the use of selected SE elements by SMEs. These are SMEs that use SE in requirements management in the IT industry (Kamsties et al., 1998; Besrour et al., 2016) or operating in industries where SE is a standard, e.g. defense (Tran et al., 2008; O'Connell et al., 2013; Aljeeran et al., 2016). Wiesner et al. (2017) discussed the issue of requirements engineering in industrial SMEs, to identify how practices from domains like mechanical engineering, software or service engineering can be adapted for the requirements engineering for complex product-service systems. To adapt SE for small organizations INCOSE (International Council on Systems Engineering) established the Working Group (WG) with the aim to develop a SE standard dedicated to very small entities (VSE), up to 25 people. ISO Working Group (ISO/IEC JTC1/SC7 WG 24) created set of ISO29110 SE standards for VSE (O'Connor and Laporte, 2017; Laporte and O-Connor, 2016). In the process of development of the new standard there has been involved representatives for several countries. The standard defines four organization generic profiles: (0) entry, (1) basic, (2) Intermediate, and (3) advanced in the SE application. Standard specifies also deployment packages tailored for VSE conditions, i.e. 1/ systems requirements engineering, 2/ system architecture, 3/ interface management, 4/ system integration, 5/ verification and validation, 6/ configuration management, 7/ project management, 8/ system deployment, and 9/ self-assessment.

A number of examples of ISO29110 standard implementation are available in the literature (Laporte et al., 2018). The most important benefits obtained by companies are: rework reduction especially in software development, increasing the percentage of projects realized with assumed schedule and on time, reducing the risk of project failure. It should be stressed that ISO29110 can be successfully used by large organizations in small projects (Laporte and Chevalier, 2015).

3.3. Systems engineering in SME providing RFID systems

The research focused on analysis of a small company dealing with the design and integration of RFID systems. The company is a leader on the Polish market in supplying RFID systems dedicated to manufacturing processes, logistic chains, and business facilities. The company employs ca. 30 qualified engineers. It has know-how in the design and integration of RFID systems. Table 3 presents the characteristics of projects realized by the company.

Table 3
Characteristics of analyzed projects

Characteristic	Small projects	Medium projects	Large projects
Duration	< 6 weeks	6 – 25 weeks	> 25 weeks
Team	< 3 engineers	3 – 6 engineers	> 6 engineers
Budget	< 5000 EUR	5000 – 20000 EUR	> 20000 EUR
Type	Dedicated / Standard	Dedicated / Standard	Dedicated
Requirements	< 70	70 – 150	> 150 (max. 500)
% by number of projects	80%	15%	5%

RFID systems implemented by the company typically consist of:

- Devices (e.g. tags, portals) provided by specialized external supplier companies and integrated/installed by the analysed company;
- Software engineered by own Software Engineering Department.

The discussion during the interview covered the scope of implementation of technical and technical management processes in the company (according ISO15288:2015) for the design and implementation of the RFID system. Usually the persons responsible for R&D, hardware (technical elements of the system), software, and service (for selected systems) are involved in system engineering. The role of systems engineer in projects realized by the company usually is taken by the Chief of Software Engineering or Chief of R&D Department. Due to the fact that it is a small company, in every project several project functions are combined by the same people. Fig. 3 shows the general diagram of the project implementation.

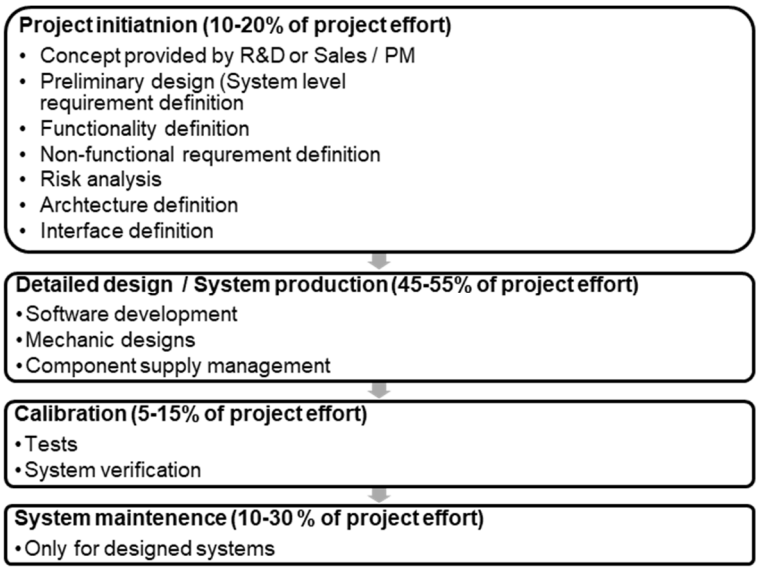

Fig. 3. Process of the RFID system design

It should be noted that the actual process of systems development is not iterative. Usually during the calibration of the system elements requiring changes in the software are identified,

and less often (which is more expensive and time-consuming) changes in mechanical components or the use of other components (e.g. readers).

4. CONCUSIONS

The analysed enterprise uses elements of SE, although it should be noted that this term is not used in the company. Elements of SE are used for project performance, e.g. utilized requirements management, architecture and functionality definition, especially during software development activities.

The company, what is typical for many small enterprises, is not really focused on building internal procedures. For this reason, the management of the company is interested in all solutions allowing for:

- Increasing customer satisfaction (meeting system requirements);
- Reducing the costs of development and implementation of the RFID systems;
- Improving of the project timing;
- Risk reduction.

However, with the growth of the company and concurrently with it the formal requirements on the part of customers (large companies), the company started work on internal procedures for project realization. The ISO29110 standard could be more supportive in order to develop such internal procedures than other standards, e.g. ISO15288:2015. The company sees a special added value in the development procedures for the verification before the installation of the system (at the customer) as well as the management of technical knowledge (best technical solutions from realized projects).

From the company's point of view, the implementation of each project should be considered in two dimensions:

- Business, i.e. how internal procedures will support business goals of the company (e.g. obtaining assumed margin on project performed);
- Technical, i.e. how internal procedure will support the work of engineering teams in solving technical problems.

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