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Challenges in Integrating Product-IT into Enterprise Architecture – a case study

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Abstract

Digital Innovation (DI), Internet of Things (IoT) and Cyber-physical Systems (CPS) offer new opportunities for enterprises but also cause new challenges for Enterprise Architecture Management (EAM). Based on an industrial case from power garden products illustrating potentials and challenges of DI and IoT, this paper investigates the integration of product-IT into enterprise architecture (EA). Product-IT includes the embedded IT-systems in physical products and services / components for operations, maintenance or evaluation purposes. The paper investigates problems in product-IT and enterprise-IT integration and challenges for the field of EAM. The case study shows that industry implemented pragmatic solutions for dealing with P-IT integration into EA, but there is a clearly expressed demand for improvements and a need for refined EAM standards in this context.

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Keywords: Product-IT, Enterprise-IT; Enterprise Architecture Management; Integration

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1. Introduction

Today's dynamic business environment with its rapidly advancing IT capability through evolving phenomena like digital innovation (DI), internet of things (IoT), cyber physical systems (CPS) presents enterprises with both new opportunities and new challenges. This together with Industry 4.0 opens up for new ways for enterprises to organize themselves in terms of business models, practices, and processes, how they communicate with their customers, deliver services, perform product development etc. However, while it is evident that suitable IT solutions are required in order to achieve organizational goals, the effective support of business operations with appropriate IT is complicated due to the dynamic nature of business and IT [1].

The various aspects of an enterprise include organizational structure, business processes, information systems, and infrastructure, which together form an Enterprise Architecture (EA). When it comes to models representing these areas, the quality and completeness of information often decreases when going from top to bottom [2]. The top layers of architecture models contain more complete and up-to-date information. For lower levels information such as concrete IT services and applications is often difficult to collect and keep up-to-date. This is what we refer to as ***enterprise-IT*** (E-IT). In addition, more and more data on lower levels originates from usage of CPS and IoT. Within CPS and IoT, data is produced by numerous communicating entities. These entities are usually IT-components built into the products, which will be further addressed as ***product-IT*** (P-IT). In particular, enterprises in manufacturing industry, and in sectors where a lot of value creation is represented by IT-components built into the products find a lot of new opportunities created by seamless and real-time integration of physical systems and IT. Use of real-time data for enterprise architecture analytics has been a challenge due to shortcomings of information technology possibilities (limits in volume, variety and speed of data collection), and by the fact that P-IT has mostly been considered separately from EA. Advancement in the area of Big Data helped to overcome the first challenge [2], whereas overcoming the second challenge still requires finding a way to deal with E-IT and P-IT in an integrated manner. Even though the areas of EA, EAM, and variants of P-IT attracted a lot of research during the last 10 years not much work has been done on their integration, i.e. positioning P-IT into EAM consideration. Therefore, our main research question is: *How can product-IT and enterprise-IT be integrated in the context of enterprise architecture management?*

In the context of our ongoing research work, this paper presents first observations and findings. The main objectives of the paper are (1) to position the area of P-IT in the field of EAM, and (2) to identify challenges from real-world cases regarding integration of P-IT into EA. The rest of the paper is structured in the following way: Section 2 presents related work and Section 3 the research method. In Section 4 an industrial case study provides empirical evidence of the current challenge. In Section 5 we discuss the case study from the perspective of our research questions and digital business models. The paper ends with conclusions and future research in Section 6.

2. Related research

The background for our work primarily relates from EAM which is summarized in section 2.1. Furthermore, we discuss related work on P-IT integration in enterprise architectures, including challenges that IoT poses for EAM, in section 2.2.

2.1. Enterprise architecture management (EAM)

In general, an EA captures and structures all relevant components for describing an enterprise, including the processes used for development of the EA as such [3]. Research activities in EAM are manifold. Literature analysis [4] shows that elements of EAM [5], process and principles [6], and implementation drivers and strategies [7] are among the frequently researched subjects. Furthermore there is work on architecture analysis [8], decision making based on architectures [9] and IT governance [10]. However, there is no specific focus on the integration of P-IT and EAM. Of specific relevance for P-IT integration are EAM frameworks identifying recurring structures in EA. In this context, TOGAF [11] is considered by many researchers as industry standard and defines three different architectural levels which are visible in many other frameworks: *The Business Architecture* defines the business strategy, governance, organization and key business processes. *The Information Architecture* often is divided into two sub-layers: Data

Architecture and Application Architecture. The Data Architecture describes the structure of an organization's logical and physical data assets and data management resources. The Application Architecture provides a blueprint for the individual application systems to be deployed, for their interactions and their relationships to the core business processes of an organization. *The Technology Architecture* describes the physical realization of an architectural solution. The logical software and hardware capabilities, which are required to support the deployment of business, data, and application services, are also defined in this dimension [11].

2.2. Internet of things in EAM

EAM is a management practice that establishes, maintains and uses a coherent set of guidelines, architecture principles and governance styles to achieve enterprise's vision and strategy [3]. Facing opportunities and challenges derived from the IoT revolution, business leaders need new ways to conduct effective strategic decision towards IoT business [12]. With the huge diversity of IoT technologies and products enterprises have to leverage and extend previous EA efforts to enable business value by integrating the IoT into their business environment [13]. The impact of digitalization wave on enterprise systems in modern manufacturing, which claims that IoT infrastructure can support information systems of next-generation manufacturing enterprises effectively [14]. Data acquisition systems are suitable to be applied in collecting and sharing data among manufacturing resources. However, they argue that the application of IoT in enterprise systems are at its infant stage, more research is required in modularized and semantic integration, standardization, and the development of enabling technologies for safe, reliable, and effective communication and decision-making. On the way towards IoT-inclusive EAM integrating the growing IoT architectural descriptions into a consistent enterprise architecture as a significant challenge [13,15]. There is an approach for the IoT application development, which includes a role-specific development methodology, and a development framework for the IoT [15]. Another architecture evolution approach relies on the idea of integrating small EA descriptions (for each relevant IoT object) into a coherent EA description [16]. EA-IoT-Mini-Descriptions include partial EA-IoT-Data, partial EA-IoT-Models, and partial EA-IoT-Metamodels that are associated with main IoT objects defined by the approach.

Considering the potential gains that IoT has to offer, has presented a new business model that can be more suitable for organizing business in an IoT age [17]. This and other new business models emerging in the IoT age will have impact on EAM practice. There is, however, lack of research regarding EAM and IoT. Furthermore, our observation is that there is neither a common understanding of the scope and content of the main activities in EA management and IoT or P-IT integration, nor has a commonly accepted reference method been developed [18]. EAM currently concentrates on E-IT side including number of its layers, whereas P-IT, i.e. what is built into the products or supporting industrial automation, is mostly outside of EAM consideration.

3. Research method

According to our findings existing literature does not investigate integration of P-IT into EA. Thus, we decided to investigate an industrial case in this subject area in order to better understand the challenges, hinders and potential integration paths. From a method perspective, the work followed the case study research approach [19]. Qualitative case study is an approach to research that facilitates exploration of a phenomenon within its context using a variety of data sources. This ensures that the subject under consideration is not explored from only one perspective, but rather from a variety of perspectives which allows for multiple facets of the phenomenon to be revealed and understood. Yin differentiates various kinds of case studies [19]: explanatory, exploratory and descriptive. The case study can be classified as exploratory, i.e. we explore the phenomenon of P-IT in its natural organizational context. As focus of the case study, we decided to address the P-IT/EA integration from an architectural and a management perspective. The architectural perspective addresses commonalities in structure and components of P-IT and enterprise architecture. The management perspective concerns procedures for architecture development, implementation and maintenance. More concrete, the case study explores the following questions addressing the perspectives:

Does the architecture of product-IT in the case study show similar levels as known from traditional EA?

If it is possible to either discover such levels or to assign existing components to these levels, an integration could be discussed using established EA layer thinking. If not, more substantial changes to enterprise architectures would be required to facilitate an integration.

Are there existing or potential commonalities between product-IT architectures and EA?

Existing commonalities could be existing services developed for both parts or processes running "across" both architectures. Potential commonalities are functionally similar or equivalent services or structures.

What are the central roles in product-IT management and are these roles comparable to the roles in EAM?

P-IT management is in this context supposed to include product management, architecture definition and integration into the overall architecture.

What are the cooperation processes between EA and product-IT architecture management?

If cooperation is established and common practice, how do the processes look like and do they cover all architecture levels?

In the case study, we so far analyzed documents of the case study company, performed interviews, and modeling activities in order to describe the current AS-IS situation and to identify in what directions to proceed. The interviews performed as part of the case study were semi-structured interviews. Semi-structured interviews have in-depth character and allow capturing the respondents' perspective on a situation or event under study [20]. Semi-structured interviews imply using a predefined list of questions, but allow the interviewer to follow up on leads provided by participants for each question (ibid). The interviews were carried out at Husqvarna Group AB, one of the respondents is a director of architecture and digital solutions at Husqvarna, whereas the other respondents were project managers, product owner, enterprise architects, and squad leaders. Interviews included a number of questions that aimed to explore the challenges that the respondents have faced and observed in relation to EAM practice and digitalization demands/opportunities, as for instance, increasing number of P-IT entities that companies need to deal with, the significant influence these P-IT entities have on the amount of data produced, ability to manage and analyze the produced data, and the ability to manage it in an integrated way with an E-IT.

The modeling activities have during this phase mainly been according to a Role-based integration approach where we together with the different roles at Husqvarna have created descriptions (interaction models) of how these roles (project managers, product owner, enterprise architects, technical architects, and squad leaders) interact with each other, what the interactions objects are, and the interaction logic. This way of working with models have elucidated a number of challenges in their work with taking a substantial step into the digitalization age. An example of such an interaction model can be seen in the figure below.

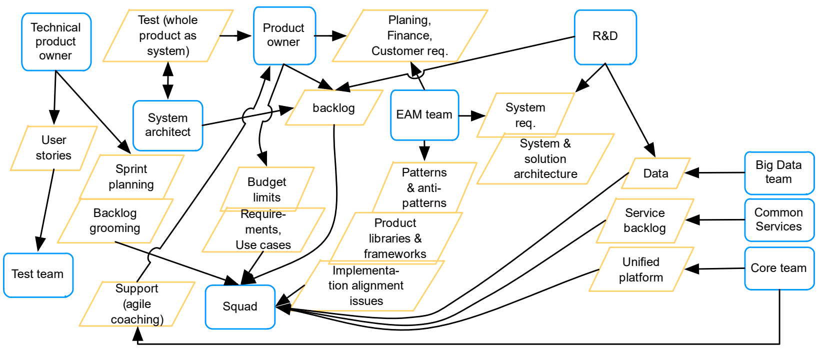

Figure 1: Overall interaction model

4. Industrial case study

The industrial enterprises considered in the case study is Husqvarna Group AB. Husqvarna is a world-leading producer of outdoor power products including chainsaws, trimmers, robotic lawn mowers, garden tractors, watering systems, cutting equipment, and diamond tools for the construction and stone industries. Husqvarna is multinational and offers products and services for both the private and industrial market. Husqvarna is right now in a transformation process where they see it as a necessity to embrace the digitalization trends that's been presented above in order to stay competitive and to deliver improved value to their stakeholders.

Many of the Husqvarna products for professional customers do not only have built-in electronics or embedded systems but also networking and communication capabilities. The built-in IT is in many cases used for controlling the different mechatronic components of the product and for collecting data when the product is in use, either performance parameters or used product features, or the environment of the product. The networking features are used for communicating usage statistics, license information or location information (if anti-theft features are activated) to either the product owner or the back-office of the manufacturer. Other functions are software upgrades and functionality add-ons implemented by configuration changes (e.g. for optimizing energy consumption).

Figure 2 illustrates a typical scenario from a customer perspective. Different Husqvarna products are installed for supporting maintenance of the garden, all of them equipped with wireless communication. Among them is a fleet of robotic mowers (1) and a lawn watering system (5). The robotic mowers and the watering system communicate with each other to synchronize mowing and watering, but they also provide operations data to the base station (2) and receive software updates or schedules from it. The base station is connected to the cloud by using the customer's Internet access. In the cloud, Husqvarna backend and customer services are available (3). Thus, the owner of the garden has access to services for operating, supervising and planning garden maintenance using mobile devices (4).

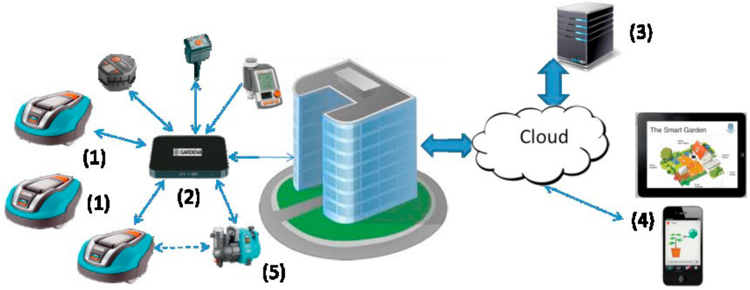

Figure 2: Scenario illustration

Since many of the products offer similar functionality regarding networking and communication, Husqvarna designed and implemented reusable services and components for either the product or the back-office infrastructure which comprise an IT and service architecture for the P-IT. In this context, it has to be discussed, what the difference between a license management services - to take one example - for product licenses (in P-IT) and software licenses (in E-IT) is. Can both service types be based on the same technical infrastructure and use the same encryption and logging services (to take just two examples)? If so, why not define common EA elements on application architecture level for P-IT and E-IT? A core challenge for Husqvarna to handle the integration of P-IT and E-IT is to handle the bimodal dimensions of the IT lifecycle. The E-IT dimension (Mode1), designed for stability, efficiency, and low cost, which is closely related to traditional EAM. P-IT on the other hand (Mode 2) is constituted by development projects that help to innovate or differentiate the business. This requires a high degree of business involvement, fast turnaround, and frequent update, the so-called rapid path to transform business ideas into applications. To handle this Husqvarna is implementing DevOps Teams designed for agility, rapid development and short time to market. Today Husqvarna experience a clear tension between Mode 1 and Mode 2 and they give testimony of a number of more specific challenges in relation to the bimodal dimensions of IT, such as governance and responsibilities between research and development and IT, how to increase speed and suitable methods to support agile teams, how to balance governance and support between P-IT and E-IT, lack of frameworks to describe IT technology stacks for IoT and digitization, how to handle legacy- systems during the transformation into the digitalization age.

5. Discussion

5.1. Elaboration on research questions

Does the architecture of product-IT in the case study show similar levels as known from traditional EA? The TOGAF levels previously introduced will in this section be considered as "traditional" EA levels. On the technology architecture level, we found different hardware/software architectures which define platforms and reuse concepts for electrical/electronic control units in the products, sensors and actuators connecting to them and communication or networking components. Furthermore, the communication networks connecting the products to the backend network or the Internet could also be considered as part of the technology architecture. However, this part is provided by standard mobile or fixed line infrastructures.

On the data architecture level, we found different data structures present in usage scenarios of P-IT, but not all of them are fully stored in the product. The most prominent data structures are configuration and license information for the actual product in use, usage data collected during operations (operation time, operator id, temperature, power consumption and other usage information of the device) and data structures for representing evaluation results of the operations data (indicator development statistics, triggered alarms and notifications, rules, etc.). Parts of the data are captured in the physical product or base stations made for forwarding the data. Other parts are stored in the cloud. Future scenarios also include streaming of real-time data via the base station to the cloud.

The application architecture showed a separation between external services made for the use by customers, the back-end services for the physical products and the services built-into the physical products. While external services are quite unified across the different product categories (ownership and warranty registration, archive for manuals and technical documentation, statistics and alerts), the back-end and built-in services are dependent on product categories. An example is to lock/unlock the physical product using an app on the smartphone or smartwatch. This requires a corresponding backend and built-in services which is not appropriate for all kinds of products.

The business architecture basically exists of the customer value and the use cases that have been designed and implemented to deliver the customer solutions. These values and use cases have been documented and are maintained, but in the conventional meaning of the business architecture they do not cover the functions and processes of Husqvarna Group by of their customers.

Table 1: Summarizes the results from discussion of the first research questions.

Architecture Layer	Content
Business architecture	Not explicitly defined as architecture; made up by customer value and supporting IT solutions
Application architecture	External customer services, backend services, services built into the physical products
Data architecture	Operations data, evaluation and statistics, configuration data
Technology architecture	Embedded systems architecture, communication components, infrastructure components

Are there existing or potential commonalities between product-IT architectures and EA? On the technology architecture level, most parts of the product's technology, i.e. the hardware/software architecture and communication interface, seem not to be relevant for an EA integration. However, when it comes to the communication infrastructure it can be expected that we will move from point-to-point to mobile edge computing (MEC) which would affect even the enterprise architecture. MEC basically adds additional functionalities to 4G mobile networks which basically deploys computing services at the access nodes.

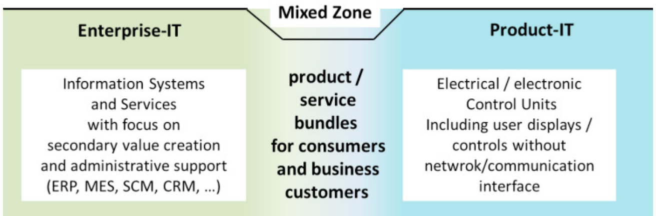

Figure 3: Summary of results for research question 2

What are the central roles in product-IT management and are these roles comparable to the roles in EAM? The roles identified in the analysis are product owner, enterprise architect, system architect and service delivery manager. The product owner is responsible for managing the feature of a product for the different target groups, the version and roadmap planning for implementing the features and the operation planning. The service delivery manager takes care of operations, maintenance and transition between service versions. Enterprise architect and system architect design the overall system, one with the focus on backend and enterprise integration, the other with focus on IT components in the product. The enterprise architect has as a part of his role to coordinate the enterprise architecture integration. Although this pragmatic arrangement works well, it is considered by the use case partner as not pro-active enough, i.e. a general road mapping for joint E-IT and P-IT development is missing.

What are the cooperation processes between EA and product-IT architecture management? The cooperation processes in the case study data so far do not give a complete picture. We found processes directed to those embedded systems in the product including electrical and mechatronic parts which only communicate with other internal components in the product by internal bus systems or other mechanisms. Parts of this process are outsourced. These "P-IT only" processes are in the case study not considered as interesting for the overall EA, maybe with the exception of the architecture for the control units.

Furthermore, we found processes for components in the physical product connected via radio networks, e.g. for communication to the base station or other devises. Here, the process of developing new P-IT components, versions or features is well-defined at the use case partner. This process also includes steps aiming at the coordination of the development of services on an enterprise level with the responsible enterprise architect involved. Many of these processes are following the "DevOps" procedure model which includes the development of components and services and operations tasks. As there are services which have the potential to be shared with administrative parts of the EA, they can be considered as part of the "mixed zone" in the figure above. On the side of the traditional enterprise architecture for administrative functions and the secondary value creation we have not yet investigated the processes.

5.2. Relation to digital business models

A conjecture evolving during the case study is that there might be a close relationship of P-IT/E-IT integration and digitization of business models. The origin of this was the observation that statements about "contributions of the P-IT to digitization needs" or "new digital business models connected to P-IT and E-IT" integration was elucidated quite often in interviews with enterprise architects. One explanation might be a change in the corporate strategy towards more digitization which was announced during our case study. In order to further investigate the above conjecture, we used a structural approach for analyzing digitization paths [21]. This approach considers two dimensions of potential digitization, the digitization of the product offered by a company and the digitization of the operational procedures for offering these products. In both dimensions, three steps are distinguished. In the product dimension, the steps are to *enhance* (add complementary services to a product), *extend* (new product features by using digital components) or *redefine* products (newly designed products replacing the earlier generations). In the procedure dimension, the steps are *create* (new IT-based operating capabilities), *leverage* (the new capabilities for more efficient procedures) and *integrate* (more efficient and traditional procedures).

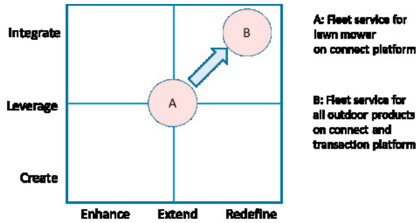

Figure 4: Transformation of business model in the case study

Using this approach, we first positioned examples for products and procedures currently established in the case study, i.e. in a situation without P-IT and E-IT integration. Afterwards, we developed a projection towards the desired future products and procedures related to the selected examples, see Figure 4 below. In the current situation (A), fleet services (one example) are offered for robot mowers on the "auto-mover connect" platform. This product and procedure bundle already includes extended features of the product as compared to the initial robot mower product and procedure which leverage the more digitized operations mode for new services. In the desired future situation, seamless integration between fleet services and other services for power garden products would be available which also allow for customer transactions (e.g. buying additional services and changing status information) on the enterprise's back-office infrastructure. For this projection from (A) to (B) we investigated whether or not P-IT and E-IT integration would be supportive. Neither P-IT nor E-IT in isolation would be sufficient for supporting the future situation, as P-IT alone does not allow for transaction processing and E-IT alone does not allow integration between those services of power garden products dependent on the technical infrastructure on site of the installation. Although the above discussion might be considered as anecdotal, it anyhow indicates the need of further investigation regarding the relationship between P-IT/E-IT and digitization. Our assumption is that the transformation from (A) to (B) has to be considered as closely related to the integration of P-IT and E-IT. To verify this assumption has to be part of future work.

6. Conclusions and future work

Based on an industrial case from outdoor power products, this paper discussed the issue of integrating P-IT into EA. The literature study performed as part of this work indicates that this subject is widely unexplored in academic literature but very important for industry. The Husqvarna case shows that industry implemented pragmatic solutions for dealing with P-IT integration into EA. Although these solutions work in an acceptable way there is a clearly expressed demand for improvements and the statement that many of the EAM standards do not work in this context.

Furthermore, our investigation showed that traditional enterprise architecture layers are suitable for structuring P-IT but not optimal for this purpose. More refinement layers are required, e.g. by identifying a "mixed zone" between P-IT and E-IT which is structured differently. The borderline between E-IT and "mixed zone" disappears more and more by integration of mixed zone and E-IT services. In P-IT some architectural parts remain non-connected which essentially are the isolated control systems for the outdoor power products with their machine-focused use interfaces. The mixed zone can roughly be divided into layers according to the enterprise architecture but should considered from a more fine-grain structure.

The main limitation of this work obviously is that it is based on just one industrial case. We performed an exploratory case study meant to contribute to a better understanding of the problem. From this perspective, this limitation is not severe at this early stage of the work. More case studies are of course required to get a more complete picture. Future work will include continued data collection in the Husqvarna case study. Interviews with more persons involved in the garden power products and on the E-IT side are planned. Furthermore, we will start a second case study in cooperation with the second industrial partner in the research project, Skye Consulting, which will be directed towards turbine manufacturing of one of the world leading companies in this field. On the theoretical side, future work will include an extended literature research also including AISeL and IFAC online library.

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