Fundamentals of the eMaintenance Concept

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ABSTRACT

Many intellectual, societal, business and technological forces are continuously pushing forward the frontiers of science. When being effectively combined, they may provide an umbrella for generating new fields and exploring new grounds. One such emerging field is *eMaintenance*. It is based on the fields from operation & maintenance engineering, software engineering, information systems, business management, and many other strongly varying fields related to the application domains of *eMaintenance*. As a novel field, *eMaintenance* addresses new needs and provides various benefits in form of increased availability, reduced lifecycle cost and increased customer-value. On the other hand, being in a continuous flux, it suffers from many infant illnesses in form of lack of or fuzzy definitions and theoretical foundations. This paper constitutes the first call to the *eMaintenance* community to gather their forces and commonly define the *eMaintenance* concept. As an initial step, it outlines its ten essential components. These are (1) *Definition*, (2) *Business*, (3) *Organization*, (4) *Product*, (5) *Service*, (6) *Methodology*, (7) *Technology*, (8) *Information*, (9) *Customer*, and (10) *Education and Training*. The paper also suggests a timeless definition of *eMaintenance*, it places *eMaintenance* in the context of other *eDomains*, and it elicits *eMaintenance* intellectual opportunities and challenges to be met by both the academia and industry when researching on or transitioning to the *eMaintenance* mode.

Keywords

Business, product, service, customer, information logistics, maintenance support, service-oriented approach, eTechnology.

1. INTRODUCTION

It is not always easy to predict and envision new emerging fields. Some of them may crop up suddenly out of the blue whereas others may follow a slow and steady growing pace. Irrespective of how they come to light, they all need to be based on solid theoretical foundations before they can manifest themselves as valuable and useful. One such a field is *eMaintenance*.

Recently, *eMaintenance* has reached a high degree of attention within the industry [3; 9; 17; 18; 22; 24; 25; 27]. It has emerged around year 2000 from the integration of other fields that together are now ripe to harvest. These fields are operation & maintenance engineering, software engineering, information systems, business management, and other fields related to the application domains of *eMaintenance*. Together, they enable a more proactive, effective, efficient, and thereby, more cost-sustainable maintenance of many complex industrial systems.

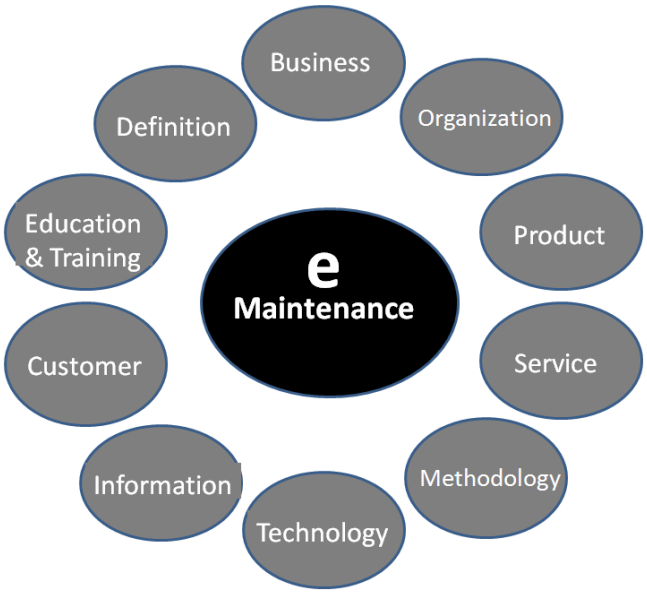

Figure 1. The essential components of the eMaintenance concept.

Because of its enormous breath and youth, *eMaintenance* is still considered to be an immature and challenging field. It suffers from many infant illnesses such as lack of common definitions and lack of sound and widely accepted underlying theories, vague usage scope, and lack of credible experimental base.

To stay vital and vibrant, *eMaintenance* needs to be well defined and established as a field. Its scope, benefits and drawbacks should be identified, understood, and clearly specified. Although it sounds simple, it is not so easy. Right now, there are many definitions and models of how to theorethicize about *eMaintenance*. They usually reflect the understanding of the field from one or a limited set of perspectives, mainly of the technical character. No one has, however, considered its broad multidisciplinary nature. To grow, or even to survive, the perspectives of other multidisciplinary "outside-the-discipline" voices must be opined and considered. It is only in this way experts in one field will obtain pertinent clarification of how the new field relates to other fields.

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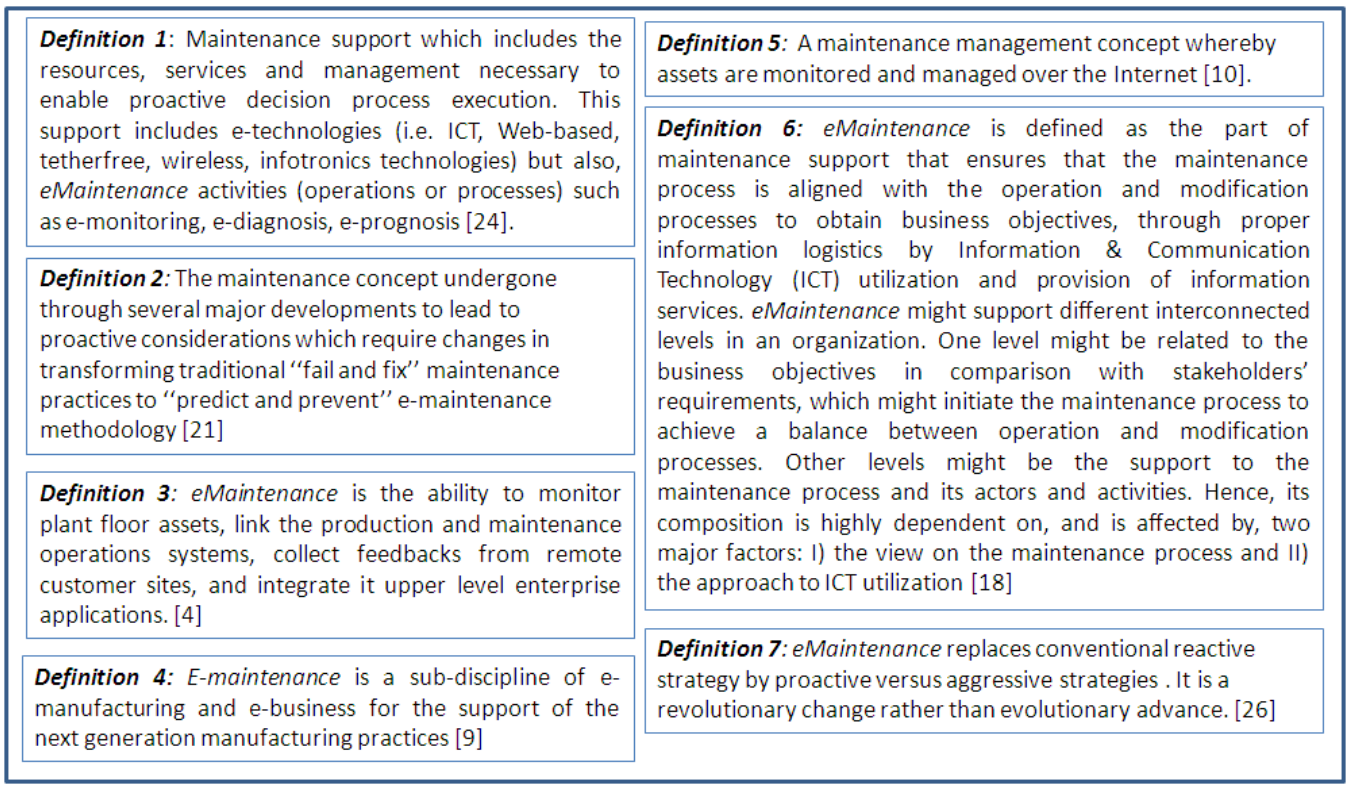

Figure 2. Definitions of *eMaintenance.*

To define a concept of an emerging unidisciplinary field is a challenging task. It is even more challenging to define a concept of an emerging multi-disciplinary field. This is because such a field is very broad, it lacks empirical basis to emulate standard theories, it lacks a common definition, it lacks a glossary necessary for articulating it, and its scope is many times too vague and ambiguous.

Being based on many strongly varying disciplines, it may be difficult for only one expert to define it. For this reason, this paper constitutes the first call to the *eMaintenance* community to gather their forces and commonly define the *eMaintenance* concept. As a first step towards that end, we outline the concept and put some initial body into it. As illustrated in Figure 1, we suggest the body be encompassed by ten essential components. These are (1) *Definition*, (2) *Business*, (3) *Organization*, (4) *Product*, (5) *Service*, (6) *Methodology*, (7) *Technology*, (8) *Information*, (9) *Customer*, and (10) *Education and Training*. In our opinion, these components are the most basic parts contributing to the characteristics of the *eMaintenance* domain. They also constitute a combination of various parts organized as a complex whole that must be considered by the industry when transferring to *eMaintenance* mode and by researchers when providing various research suggestions and solutions.

The paper also places *eMaintenance* in the context of other *eDomains*, it provides insight into the state of the *eMaintenance* art and it elicits the intellectual opportunities and challenges to be met by both the academia and industry. Finally, it reasons about the future of *eMaintenance* as an emerging field and identifies research questions that may serve as a roadmap and impetus for defining future research strategies.

The remainder of this paper is as follows. Section 2 describes the method taken in this study. Section 3 suggests the definition of *eMaintenance*. Section 4 lists the domains in which *eMaintenance* has been established. Sections 5-9 describe the remaining components in our *eMaintenance* concept. Section 5 describes how *eMaintenance* impacts organizational infrastructures. Section 6-9 describes the *eMaintenance* impact on product, services and information, technology, customer and education and training. Finally, Section 10 identifies challenges to be met when transferring to *eMaintenance*, and Section 11 makes conclusions and suggestions for future work.

2. Research Method

Our work consisted of five steps. These are (1) literature study, (2) identification of the initial *eMaintenance* components, (3) establishment of what has been done so far, (4) creation of the essential *eMaintenance* components, and finally, (5) mapping out of the field. Below, we briefly elaborate on those steps.

As a first step, we collected all the literature that was relevant for our study. Just because the field is fairly new, not much has been published about it. Hence, the task of collecting relevant publications was fairly manageable. At this step, we collected about 100 papers, from the sources such as IEEEXplore, Elsevier, Emerald, maintenance-related conferences, doctoral theses and similar sources.

After having read the collected literature, we identified the initial criteria that might provide a basis for defining the *eMaintenance* concept. Simultaneously, we read the articles in order to establish the status in the field. For each of the initially identified components, we created a separate file in which we recorded all the information about it. In practice, this procedure implied that

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we quoted the authors' text in these files. The reason why we did so was the fact that we wished to keep the original texts untouched. For clarification reasons, however, some texts were complemented with the description of the papers' contexts.

Creation of separate files containing all the descriptions about the initially defined *eMaintenance* essential constituents strongly contributed to the validity of our results. First, it assured that no important descriptions were omitted, Second, by having them collected in one file, we made sure that all the three authors had access to the same information. Third, the files have contributed to the increase of common understanding of the components. The update and study of the separate files has provided enough feedback for creating the *eMaintenance* components to be presented in this paper.

3. Definition of eMaintenance

Definitions are usually the most difficult to create. They should neither be too general nor too detailed. They should be clearly delimited to determining the essential nature of the field without providing too many technical details. In this way, they may stand the test of time and embrace changes made to their underlying constituents. In this section, we first present current *eMaintenance* definitions and express our opinion about them and then suggest a new *eMaintenance* definition.

3.1 Current eMaintenance Definitions

There are many definitions of *eMaintenance* today. To the knowledge of the authors of this paper, there are about ten different ones. Some of the most representative ones are listed in Figure 2.

All these definitions provide different views of *eMaintenance*. They either specify it as a sub-discipline of e-manufacturing and e-business (see Definition 1), they treat it as a concept or as a strategy (see Definition 7), or they provide details about their constituents concerning business and technological aspects (see *Definitions 2, 3, 4, 5 and 6*). Summing up, they are either too tightly bound to current terminologies used, they are too abstract in their delineation of the *eMaintenance* domain, or their scope is limited to only some technological parts or to some product lifecycle phases.

It is not easy to create a general definition of *eMaintenance* that stands the test of time. Too general definitions are often too abstract whereas too detailed ones may not always anticipate future changes to the domain under consideration. For this reason, we suggest that the field of *eMaintenance* should be defined on two abstraction levels. The first abstraction level communicates general principles and theories. It resists future changes to its underlying constituents and thereby it may be shared by many stakeholders involved in *eMaintenance*. The second abstraction level instantiates these principles and theories. It is specialized towards various contexts that are dependent on current advancements made within methodologies, technologies, business management and other areas. It provides an outlook to a context for the *eMaintenance* solutions. Understanding the context increases the ability to select appropriate methodologies and technologies when establishing *eMaintenance* solutions in an organization.

3.2 eMaintenance Definition

By looking at the word *eMaintenance*, we may clearly identify two parts "*e-part*" and "*Maintenance-part*". We use them as a basis for defining *eMaintenance*.

Let us start with the second part first, that is, the *Maintenance-*part. It is fairly easy to define. As defined by IEV [7], it is "*the combination of all technical and administrative actions, including supervision actions, intended to retain an item in, or restore it to, a state in which it can perform a required function*".

Regarding the first part, the *e-part*, it is more difficult to define, partly because there are about 170 definitions of the abbreviation e [1]. "e" may stand for experience, excitement, energy, employment, electronic, and other meanings. The astute reader, however, may quickly relate it to the context of this paper, which is *e – electronic*.

The prefix *e* has been recently coined in the English vocabulary. It has been stuck on the front of many different words representing various domains such as, for instance, *eHealth, eGovernment, ePrognosis, eBusiness,* and *eCommerce*. When being combined with them, it resonates a revolutionary movement towards making major changes in the domain whose name it prefixes. This movement should have an effect or impact beyond what is immediately apparent. In the context of *eMaintenance*, we understand it as a revolutionary movement towards making maintenance more effective.

As already mentioned in Section 3.1, our requirements are that the definition of *eMaintenance* on the *Abstraction Level 1* should stand the test of time and embrace changes made to its underlying constituents. It should be neither too general nor too detailed. However, it should clearly communicate what it stands for. For this reason, on the *Abstraction Level 1*, we define *eMaintenance* as:

> *eMaintenance is maintenance managed and performed via computing.*

The second abstraction level of *eMaintenance* definition is to provide its contextual definition reflecting current status of its underlying methodological, technological, business, product lifecycle scope, and other relevant aspects. Regarding the scope, it is commonly recognized that maintenance-related information can be utilized not only for the post-delivery utilization and support phase of a product's lifecycle, but also during other post-utilization phases such as retirement phases and predelivery phases such as conceptualization, design and production [12]. Hence, on the *Abstraction Level 2*, we define *eMaintenance* as:

> *eMaintenance is a multidisciplinary domain based on maintenance and information and communication technologies (ICT) ensuring that the eMaintenance services are aligned with the needs and business objectives of both customers and suppliers during the whole product lifecycle.*

4. eDomains

In this section, we describe *eDomains*, including *eMaintenance* domain. Section 4.1 *presents eMaintenance* and lists its inherent *eMaintenance* services. Section 4.2 presents other *eDomains* and explains their similarities and differences with respect to *eMaintenance*.

4.1 eMaintenance Domain

Despite its young age, *eMaintenance* proliferates within many industrial areas. The bottom part of Figure 3 lists a few of such areas. These range from various manufacturing industries, to aviation, railway industry, to shipping, and to nuclear power industry.

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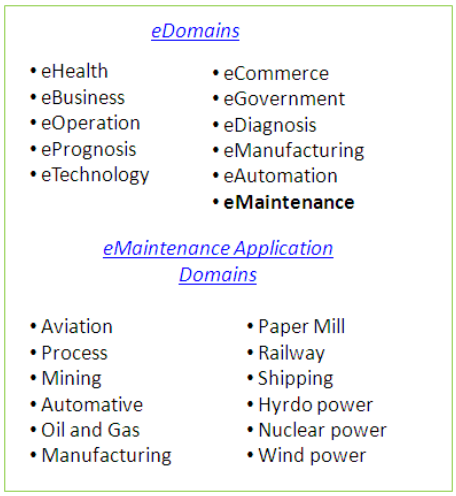

Figure 3. e and eMaintenance domains.

Figure 4. A subset of eMaintenance services.

The genesis of *eMaintenance* cannot be clearly identified. However, *eMaintenance* services aimed for use in diagnosis and prognosis have been in focus in the industry for many years. Especially, the industries having complex technical assets with a long hard life such as aviation, navy, manufacturing, mining and transport have shown great interest in this domain. Their incentive has been an enhanced automation of the maintenance process, and thereby more cost-effective maintenance. Hence, they consider *eMaintenance* as a business driver, rather than a cost driver. This has contributed to the evolution of *eMaintenance* towards the integration and harmonization of maintenance-related services.

The spread of *eMaintenance* within many different industries indicates that *eMaintenance* will stay with us for some time, if not for ever. Even if the industries practicing *eMaintenance* differ, they still use a common set of *eMaintenance* services. Figure 4 lists a subset of them. Due to space restrictions, we cannot describe them all but focus on only four of them. These are:

- *Diagnosis services* aimed at facilitating the understanding and identification of the nature of failure and root cause of it.
- *Prognosis services* aimed at facilitating the prediction process of failure outcome.
- *Logistics services* supporting the maintenance process by enablement of integrated logistics.
- *Documentation services* providing the maintenance actors with right information in right time, e.g. technical publication and work orders.

4.2 Related *eDomains*

eMaintenance has not risen from nowhere. It has been pioneered by other *eDomains*. The top part of Figure 3 lists their subset. Below, we briefly describe some of them. We then round up their description by listing similarities and differences.

- *eHealth* is as an emerging field intersecting business, medical informatics, and public health. It provides health services based on information delivered or enhanced through the internet and related technologies.
- *Electronic business* - the super-set of *eCommerce*, commonly referred to as *eBusiness* or *e-business* - is defined as the application of information and communication technologies (ICT) in support of the business activities.
- *Commerce* constitutes the exchange of products and services between businesses, groups and individuals and can be seen as one of the essential activities of any business. Electronic commerce focuses on the use of ICT to enable the external activities and relationships of the business to individuals, groups and other businesses. It is commonly known as (electronic marketing) *e-commerce* or *eCommerce*. It consists of the buying and selling of products or services over electronic systems such as the Internet and other computer networks.
- The area of *eOperations* encompasses the processes of how customer commitments get fulfilled through products and services within companies. This includes procuring products, arranging shipping and transport, and handling information needs and flows in relation to these operations [8].
- *ePrognostic* is the term referring to continuous prognostic to be supported by ICT-technologies, aimed at detecting a failure condition in development rather than reporting a failure which already affects the production. The aim is to reduce maintenance time, and increase operational time [5].
- *eGovernment* (short for electronic government) is a generic term for web-based services from agencies of local, state and federal governments. In *e-government*, the government uses information technology, and particularly, the Internet to support government operations, to engage citizens, and provide various governmental services.
- *eDiagnostic* referring to the establishment of an online-automated fault diagnostic scheme for shortening the time delay between breakdown and notification with the use of computer based communication technology [6].
- eManufacturing is a system methodology enabling the manufacturing operations to be successfully integrated with the functional objectives of an enterprise through the usage of Internet, tether-free (i.e. wireless, web, etc.) and predictive technologies [19].
- *eAutomation* defines a new generation of automation systems using the latest networking and agent technologies for information management, condition monitoring, and real-time control of a range of distributed industrial systems [23].

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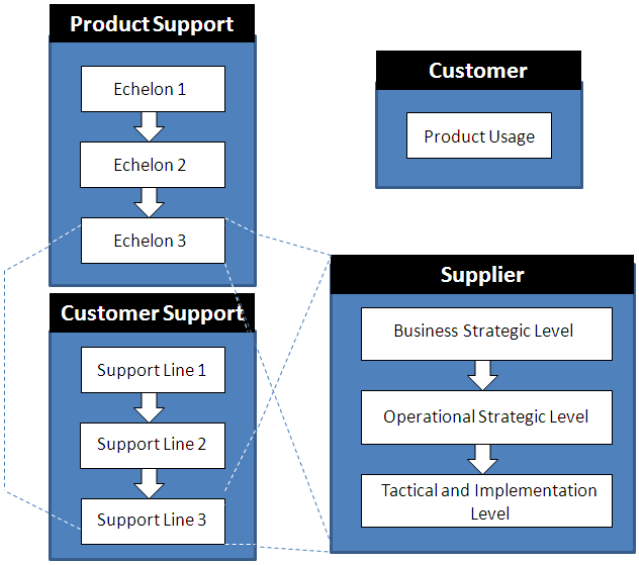

Figure 5. Organizational scope relevant within *eMaintenance.*

The common denominator to all these *eDomains* is the fact that they are all managed and performed via computing. Another common denominator is the fact that they reflect current state-of-mind, a way of thinking, an attitude, and a global approach towards improving their underlying domains. All of them are multidisciplinary domains having one main parent domain and several sub-domains, such as for instance, health management is the parent domain to be supported by other sub-domains coming from various disciplines. Their common goal is to improve the efficiency and cost of the management and performance of their underlying parent domain.

5. Business and Organization

Introducing *eMaintenance* requires identification of all the organizational units, their structures and stakeholder groups that are involved in either creating *eMaintenance* services or in consuming them. As shown on the organizational roadmap in Figure 5, this includes both support, supplier and customer organizations. The suppliers mainly develop and maintain their products and/or services with or without the aid of third-party suppliers. The support organizations either provide product support or customer support. Finally, the customers use the product and/or services.

In this section, we first present each of the roadmap's organizational structures. We then describe how they may be related and/or partnered in the context of *eMaintenance*.

5.1 Support Organizations

Complex products are usually supported by two different support organizational structures. These are *Product Support* and *Customer Support*.

5.1.1 Product Support

Organizations providing maintenance on the complex products organize themselves into three *Echelon* levels. In the context of product support, they attend to all types of proactive and reactive maintenance tasks. Different levels have different goals and responsibilities. [13; 14]

Maintenance at *Echelon 1* is conducted directly on the product in the field where the product operates. Here, maintenance is conducted at pre-determined intervals or after having experienced a failure. Due to the fact that the tasks performed at this level are less complicated, they are conducted directly on the product. These tasks include inspections, adjustments, calibration, cleaning, lubrication, repair and replacement of *Line Replaceable Units (LRUs).*

At *Echelon 2*, more qualified tasks are performed mainly off-the product, in maintenance shops. Examples of tasks are the removal and replacement of faulty *Shop Replaceable Units (SRU*s), and their repair. Finally, support at *Echelon 3* is performed by the *Supplier*, or its third-party allies. Here, highly specialized personnel overhaul items and major product assemblies.

5.1.2 Customer Support

Just as *Product Support* consists of three levels so does *Customer Support.* These levels are however called *Support Line Levels 1-3.* In the context of customer support, they attend to all types of demands stated by their customers, where different levels have different goals and responsibilities. [13; 14]

Regarding the first two levels, they correspond to pure customer support. Regarding the third line support, it is usually conducted by the product supplier or its third-party supplier.

Support Line 1 is the customers' first and preferably the only point of contact. Its main role is to guarantee the continuity of customers' daily business operation. The remaining demands, those requiring further attention and higher expertise (due to their complex character) or those concerning, for instance, corrective software maintenance, are channeled to the *Support Line 2* process level.

At the *Support Line 2* level, the support engineers are more competent with respect to the supported products. Their main role is to assist *Support Line 1* in attending to more difficult tasks such as investigation of reported problems and suggestions for how to work around them. Within corrective software maintenance, for instance, they should escalate them to the *Support Line 3* level, the *Supplier's* level.

5.2 Product Supplier

Supplier is the organization that develops, evolves and maintains products and services. It is usually organized into several strategic levels. When describing them, we use the terminology as used by Johnsson [11].

Large company groups organize themselves into four levels: *Corporate Strategic Level, Business Strategic Level, Operational Strategic Level* and finally, *Tactical and Implementation Level* [11].

Corporate Strategic Level is the overarching strategy of a diversified company. It establishes the purpose and scope of its business or a set of businesses, the nature of the environment in which it operates, its position in the marketplace, and the competition it faces [2]. *Corporate Strategy* is often explicitly stated in a mission and vision statement [11].

Business Strategic Level focuses on how to compete in a particular industrial business. It concerns strategic decisions about the choice of products or services, choice of customers and meeting their needs, gaining advantage over competitors, exploiting or creating new opportunities and the like [11]. An example of a business strategy is a decision on whether to move to an adjacent market, whether to extend the customer portfolio, or whether to choose an *eMaintenance* concept.

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Operational Strategic Level is concerned with how the business is organized to deliver the corporate and business strategic goals. It focuses on issues of products, services, resources, processes, people, and the like [11]. Finally, *Tactical and Implementation Levels* develop or evolve the products and services.

In our roadmap, we merge two of above-described strategic levels, *Corporate* and *Business*, into one or two levels. This is because, in most of the non-corporate companies, the main strategic levels are *Business*, *Operational Strategic* and *Tactical* levels. For this reason, our framework does not consider the *Corporate* level.

All business levels in our roadmap deal with *eMaintenance*. However, *Business Strategic* level is not much involved. The management and performance of *eMaintenance* is pushed down to the lower levels. The *Business Strategic* level is, however, somewhat impacted by it. It must at least determine that *eMaintenance* is one of its strategic goals.

Regarding the lower levels, the *Operational Strategic* level creates the *eMaintenance* strategy and provides a high-level planning and management of the transition to the *eMaintenance* mode. The *Tactical* and *Implementation* levels, on the other hand, make low-level plans and implement the transition to *eMaintenance* and perform *eMaintenance* after it got implemented.

6. Product, Services, Information and Methodologies

Management of products and services is *Number One* activity. It may however be easier said than managed in big organizations. Many times, the organizations do not have any overview of their systems, products and services [15; 20]. Hence, a prerequisite for introducing *eMaintenance* is to record the assets such as products and services supporting them. Another prerequisite is to create an organization-wide list of products and services.

Listing products and services is not enough however. Organizations need to track the complex relationships among maintenance processes, strategies, information systems, services, roles involved, and the like. For this reason, a traceability base should be established. It should allow maximal visibility into the whole *eMaintenance* process. It is only in this way, one may see which products have been supported by which services, during which lifecycle processes, by which roles and what information was used for this purpose.

7. Technology

Technology needs to be considered when considering an establishment of *eMaintenance* solutions. This is one of the most challenging essentials. Due to fast technological changes, it is not always clear which technological solutions to choose. When doing it one must always consider the following:

- The *dependability* aspect addressing characteristics such as reliability, availability, maintainability, safety, and security, in all components. The dependability aspect is essential for defining technology-related requirements for the solution.
- The *integration* aspect addressing the integration models for *eMaintenance* services. It provides fundamentals, conventions, rules and guidelines for how different services can be integrated depending on the characteristics of the service (e.g. internal services or external services). It also deals with other integration-related aspects such as content transferring, safety, security, authentication, and authorization.
- The *communication* aspect referring to conventions, rules and guidelines for service communication, such as protocols, wired/wireless communication, and synchronous/ asynchronous communication.
- The *real-time* aspect addressing conventions, rules and guidelines for the establishment of real-time infrastructures, and guidelines for the services requiring real-time execution. It can include aspects of robustness and physical environment.

8. Customer

Understanding customers and their value-generating processes is highly important when establishing and performing an *eMaintenance* solution. For this reason, one should put substantial effort into understanding customer processes and needs. This can be realized in the following:

- The *value-in-use* aspect referring to the use of methodology enabling *eMaintenance* service providers to understand the value of *eMaintenance* services when being invoked by the customer.
- The *efficiency* and *effectiveness assets* referring to inquiring perspectives and strategies of maintenance that in the short run and long run may influence the business, its services and objectives.

9. Education and Training

To manage and perform *eMaintenance* requires initial and continuous education and training of all the roles involved in it. If not properly educated and trained, they will not be able to perform their duties in a satisfactory way. This encompasses roles such as developers and consumers of *eMaintenance* services.

The *Education and Training* component contains activities for providing education and training to the stakeholders of the system. It is one of the most resource consuming and most complex components. The complexity depends on who is trained in what, for what purpose, when and who should be trained before who.

All education and training consists of two main parts, the preparation part and the training part. Preparation for education and training is one of the most complex, painstaking and time-consuming processes. Hence, it may start as soon as one has decided to go over to *eMaintenance*. Provision of education and training is still a very complex process, however, not as painstaking as its preparation. It should at least consist of four phases during which different groups are trainers and trainees [16]. These are:

- *Education and training of software professionals:* These are the roles involved in developing *eMaintenance* services. It encompasses developers and managers managing the development effort. Due to the system complexity and for pedagogical reasons, system training of developers may be conducted in several sub-stages, where each sub-stage is dedicated to a specific part such as general orientation, OS and DBMS, system-specific matters or new technology. This type of education and training requires complex and difficult preparations such as creation of a training environment, migration of data to this environment and creation of education and training material.
- *Education and training of super users:* These are the roles performing *eMaintenance* services. Education and training of super users is conducted right before the users start using the

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system. This education and training and its preparations are not as complex as the education and training of software professionals. However, it still requires complex and difficult preparations. Super users play the role of educators within their organizations. Hence, they have to be thoroughly trained for this task.

- *Education and training of managers:* These roles correspond to high-level managers. They need to have an overview of *eMaintenance* in order to make the right decisions. This type of education and training is the least complex one. Provision of the education and training may be based on simple system demonstrations that do not always require meticulous preparations of the education and training data.
- *Refresher education and training:* Due to the evolution of the *eMaintenance* services, underlying technologies and methodologies, all the above-mentioned roles need to undergo refresher education and training.

10. Challenges

eMaintenance is the facilitator of a maintenance process. It represents services that are aimed for managing maintenance-related information. The *eMaintenance* services can be utilized during all system lifecycle phases for different purposes, such as maintenance preparation, execution, assessment and also knowledge management. Hence, it is believed that a proper *eMaintenance* solution should be approached from a holistic perspective. Its design should be based on appropriate strategies, methodologies and technologies (e.g. service-orientation). To identify them is a very challenging task. This is because all the components as identified in Figure 1 will have to be considered, properly managed and interconnected. Some of the challenges to be met are the following:

- Restructuring of the organizations involved in *eMaintenance*
- Restructuring of the lifecycle processes used for developing and maintaining *eMaintenance* services,
- Transitioning to *eMaintenance* mode,
- Planning of eService resources,
- Management, interaction and interactivity of eServices,
- Enablement of configuration awareness in eServices,
- Management of heterogeneous organizations,
- Management of heterogeneous eService-environments,
- Integration of enterprise applications,
- Management of documentation and archiving,
- Management of lifecycle stages of *eMaintenance* services,
- Alignment and structure of content format,
- Enablement of context- and situation-awareness in eServices,
- Enablement of integration capability across a multi-platform and technologies in eServices,
- Establishment of an overarching architecture for development of eServices.

11. Conclusions

In this paper, we have explored the fundamental elements underlying the *eMaintenance* domain and materialized our work in the *eMaintenance* concept: (1) *Definition*, (2) *Business*, (3) *Organization*, (4) *Product*, (5) *Service*, (6) *Methodology*, (7) *Technology*, (8) *Information*, (9) *Customer*, and (10) *Education and Training*. Our contribution is manifold. First, to be able to pass the test of time, it provides a definition of *eMaintenance* on two abstraction levels. Second, it identifies nine additional *eMaintenance* constituents forming the essential part of the *eMaintenance* domain. Third, it places *eMaintenance* in the context of other *eDomains*. Fourth, it provides insight into the state of the *eMaintenance* art and identifies intellectual opportunities and challenges to be met by both the academia and industry when researching on or transitioning to the *eMaintenance* mode. Finally, it voices the first call for action to the *eMaintenance* community to gather their forces and commonly improve and extend our *eMaintenance* concept.

Our concept is only preliminary. We strongly advise the *eMaintenance* community to use it as a platform for improving it and to use it as a roadmap for creating their *eMaintenance* research suggestions and solutions. However, we wish to raise a piece of warning. A lot of challenging work remains to be done!

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