

# INFORMATION SYSTEMS DEVELOPMENT ASPECTS FOR THE MOBILE WEB TECHNOLOGIES

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## Abstract

**Purpose** – *The paper goes through and outlines the developments of IS methodologies as well as certain research approaches applied. In addition, the technical aspects of the ICT architectures are discussed for purposes of the development and implementation of the mobile web technologies for the industrial domain.*

**Design/methodology/approach** – *The author organizes the relevant literature findings in three sections named the ICTs in the industrial maintenance domain, web oriented architecture and the IS development methodologies. The findings are analysed and discussed while highlighting aspects of the ICT architectures, IS methodologies and different approaches that one needs to be aware of for successful design and implementation of the mobile web technologies.*

**Findings** – *The results reveal that mobile technologies have been developed mainly with the prototype and design approach where emphasis has been on the technical aspects. For the above mentioned reason the author reviews the area of the IS development methodologies as well as the ICT architectures, which shows rapid and dynamic process over time. In addition, it was found that for successful planning, implementation and use of the mobile web technologies it is important to emphasize other aspects and not just the technological ones. The research approaches that shed light on the IS development process are the Action design research as well as Participatory design approach.*

**Research limitations/implications** – *The current work presented in this paper shows that to develop sustainable ICTs, especially mobile web technologies for the industrial domain, there is a need to consider various aspects which put an emphasis on*

not just the technological aspects of the developed systems but also, for instance, on the organizational context as well as the user's needs and various stakeholders. It is, therefore, important to choose proper IS methodologies, tools, techniques and approaches for sustainable ICTs in the domain of interest.

**Practical implications** – The current work pinpoints important aspects to understand and consider when choosing the IS methodology, tools and techniques for the mobile web technologies.

**Originality/Value** – The paper pinpoints important characteristics to consider when planning to develop and implement mobile web technologies into the industrial maintenance engineering domain.

**Keywords:** Web technologies, web 2.0, mobile technologies, industrial maintenance engineering, IS methodologies, participatory design, action design, design research.

**Research type** – general review.

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## 1. Introduction

Information and communication technologies (ICTs) are a significant enabler for enhancing decision-making and supporting knowledge creation within an organization. Companies that are not able to keep up with the pace of the latest ICT developments may lose their competitive advantage and the ability to compete under the same conditions as their competitors, leading to shrinking market share and profitability (Turban, et al. 2011). Consequently, there are many industrial efforts regarding the development of mobile devices in the area of industrial maintenance, which are in the experimental phases, such as the prototype named IBM Smart Mobility ([www.ibm.com](http://www.ibm.com); [www.qualitydigest.com](http://www.qualitydigest.com) 2013). The prototype possesses a few functions, namely finding the right machine, making sure an engineer gets the right task sheet as well as providing possibilities to call an expert if needed. However, there is no market penetration of the mobile devices in the industrial maintenance (Backman & Helaakoski, 2011). In addition, in a recent paper it has as well been highlighted that the mobile technologies have not been fully adapted yet, especially in the maintenance department (Campos, et al. 2015).

In addition, recently such web technologies as the web 2.0 have appeared. It's a concept and social media technology that are composed of a set of independent services, which provides rich user interaction. Moreover, this new technology with its applications and services enables and facilitates the collaboration as well as information and knowledge sharing between employees in an organization. It becomes possible to apply the web 2.0 through the platform of Semantic web, Web services and the use of ontologies, etc. Examples of the web 2.0, i.e. media technologies, are the wikis and blogs. However, it does not refer to new technical standards, but to new ways of using the Internet as a platform for interactive applications (Battle and Benson, 2008). The web 2.0, even called the social media technology, facilitates the capture, storage and sharing of not only information and knowledge (explicit knowledge), but also the tacit

knowledge that a person or group possesses. Crucial for successful implementation and use of the web 2.0 technology is the organizational design, which needs to be seen as a socio-technical system. This in its turn depends on the interaction between employees, organization and its technical systems for its effectiveness effect.

The web technologies such as the web 2.0 and the Semantic web have entered various sectors and the recent emergence of the e-maintenance concept is something to consider when developing modern mobile maintenance applications based on the web technologies (Campos, 2009; Campos & Jantunen, 2011). The area of industrial maintenance engineering can benefit from the implementation of the mobile web technologies for different purposes to support the maintenance staff in their daily work tasks such as mobility, access to the right information anywhere, anytime, etc. It is, therefore, important to understand how the integration of the mobile web technologies can be facilitated in the area of industrial maintenance engineering, since they convey numerous ways to resolve the business and maintenance problems. Thus, this paper aims to discuss and develop an understanding of the complexity and multidimensional aspects that should be considered to develop and implement successfully mobile web technologies in the maintenance department taking into account its needs.

For the above mentioned reasons the author presents in the work under consideration a brief review of the area of software application modelling and approaches that should be taken into account when developing mobile web technologies. In the next section a brief overview of the ICTs in the domain of interest is presented. In section 3 various characteristics of the web architectures and especially the web oriented architecture are gone through. Next in section 4 the IS methodologies and approaches are presented and discussed. Finally the discussion and conclusion section is given.

## 2. The ICTs in the industrial maintenance domain

In a review it was shown that the artificial intelligence (AI) for decision making in maintenance department started to appear in the 1980s in the form of expert systems (Campos, 2009). In the 90s such technologies as artificial neural networks and fuzzy logic appeared. Distributed artificial intelligence (DAI) started to be vastly implemented in condition monitoring after the advent of Internet during the late 1990s. The commercialization of the Internet occurred in the early 1990s and the web was introduced in 1993. ICT in conjunction with these developments offered the opportunity of doing it comprehensively and the concept of e-business was born. Next the concept of e-manufacturing arose followed by the e-maintenance concept. The e-maintenance concept is characterised by the complete integration of data, system and processes, which are seen as an important requirement when the assets are geographically distributed. Consequently, ICTs can play a vital role in achieving this objective.

The e-maintenance approach is an approach that emphasizes the use of information technologies such as the web technologies in the maintenance area (Levrat, 2008).

According to Iung (2006) e-maintenance is a sub discipline of e-manufacturing and e-business for the support of next generation with manufacturing practices. Accordingly, he defines e-maintenance as “the ability to monitor plant floor assets, link the production and maintenance operation systems, collect feedbacks from remote customer sites, and integrate its upper level enterprise applications.” Iung (2006) believes that it is a revolutionary change rather than an evolutionary advancement. Muller et al. 2007 mention that this development takes us to a new maintenance generation, which has emerged since early 2000, in which the mobile technologies have started to appear lately. Year 2006 saw a few applications developed with the embedded technology (Wang, 2007). In 2007 the first mobile device based on the web technologies, i.e. ICTs such as web and wireless technologies, came forth (Campos et al. 2007).

However, the impact of mobile technologies has been almost non-existent in the industry, especially in maintenance. In addition, the approaches that have been used to develop the ICT systems such as the mobile devices in the industrial domain, especially maintenance, have been more or less developed through the prototype approach and with the help of the design science (Campos, 2009; Holmberg et al. 2010). These approaches test the technological aspects of mobile devices. However, when developing the mobile web technologies it is crucial to not only consider the technical aspects, but also to take into account the user and the context, which results in a better understanding of the needs of a mobile device and its software. This in its turn enables an increased acceptance level and adaption of the mobile devices for different work tasks within the maintenance department.

### 3. Web oriented architecture

To be able to monitor the machine condition there is a need to gather a huge amount of data. The gathered data facilitate, for instance, deterioration trends of the machines and enable the user to analyse maintenance history and manage its trends. For the above mentioned purposes serve the databases and their various tiers of the architecture. The databases, middleware, client machines, i.e. ICT architectures, which are an important tool for gathering, storing and sharing the data and information with the right user at the right time following the right format, etc., for the purposes of foreseeing the health of machines, have been changing over time. Consequently, with the rapid developments of the ICTs new architectures have emerged such as the SOA architecture, which is a combination of services that have interaction with each other by the transfer of data and information. The Service Oriented Architectures (SOA) differ from well-known object oriented approaches, since they have different services that are loosely coupled, standard based and interoperable (Papazoglu and Van den Heuvel, 2007). In addition, there are various components reusable and independent of platform, i.e. Microsoft or Java. An emerging architecture and concept is the Web oriented architecture (WOA) and a sub part of the SOA with the emphasis on web 2.0 technologies and standards, i.e. such as the HTTP, SSL or XML. In addition, in contrast to SOA, WOA is clearly directed towards web technologies, thus WOA can be seen as a

subset or specialization of SOA for the web technologies. WOA is, as mentioned, a sub part of SOA, however, there are some differences since SOA uses WS-security while WOA, for instance, HTTPS. In addition, it is believed that WOA in conjunction with the web 2.0 technologies can facilitate what was expected of SOA to deliver, i.e. code reusability, cost and complexity reduction, as well as high flexibility (Thies and Vossen, 2008). The web services (WS) are the application software that is designed to support interoperability among the distributed applications over a network (World Wide Web Consortium (W3C), [www.w3.org](http://www.w3.org)). WS facilitates conveying of the messages from and to the client machines. The potential of WS is that it can be consumed through the web to any application program independent of the language used. It consists of three basic components (Newcomer 2002, Meyne & Davis 2002, Lee et al. 2003, Venkatraman 2004). The first component is the XML. It is language that is used across various layers in the web services. The second is the SOAP listener. It works with packaging, sending and receiving messages over the HTTP. The third component is the web services Description Language (WSDL), which is the code that the client machine uses to read the messages it receives. Other important component in the WS is the Repository for Universal Description, Discovery and Integration (UDDI) protocol. The UDDI produces a standard platform that the WS can use and provide various applications to find access and consume the WS over the internet ([www.uddi.org](http://www.uddi.org)). However, for WOA there is no available or generally accepted modelling technique. Haron et al. (2014) indicate that this is a common situation, since different modelling techniques have been used over time, which were anticipated to be favourable and have proved to be no more than case-by-case oriented methods. However, it is important that a proper IS methodology is chosen for the ICTs development, since if not, it might result in software that does not meet the demand of different stakeholders. In this case the web applications have characteristics that differ from regular software. It is, therefore, important to choose the right methodology and modelling technique for the proper development of ICTs.

#### 4. The IS development methodologies

In this section the author briefly goes through the methodologies for developing information systems and their development during history as well as the current state of practices when it comes to the developments in web based methodological information systems, etc. Avison and Fitzgerald (2006) study the history of information systems development (ISD) as well as development and concerns regarding the ISD. The authors identify four eras, i.e. the pre-methodology, early methodology, methodology and post- methodology. They mention that they could be seen as a “maturity model for ISD”, since some companies might be in different stages as well as the countries can differ in their location in the maturity model for ISD. In the pre- methodology era the emphasis was on programming and due to the lack of methodology, problems occurred because of, for instance, overworked programmers and software that needed corrections resulting in few operational applications, which led in its turn to the birth

of the early methodology era, i.e. as a reaction to the failures of the pre-methodology one. The factors that were vital in the early methodology era were concerned with the awareness of the need of analysis and design to be part of the Information Systems (IS). In addition, people working in the domain became aware that the integrated IS was needed for big size companies. Moreover, there was a desire of the IS developers as well as customers to have an IS methodology for the developments of the IS. Consequently, these developments led to the widely known System Development Life Cycle (SDLC), also known as the waterfall model. However, even if this led to positive effects, there were some problems such as user dissatisfaction, due to the fact that they were able to see the final product only when it was finished. These and many other limitations and problems brought about the appearance of the methodology era. In this later era some tried to develop further the SDLC while others sought for some new methodologies. Different themes were covered with the help of the following approaches, i.e. system, strategic, participative, prototyping, etc. All this led to the emergence of new methodologies such as the general systems theory with an emphasis on the nature of the systems. A well-known approach within the latter is the soft systems methodology (SSM) of Checkland (1990) and later during the 1990s the Object oriented methodologies. Furthermore, there were some other useful methodologies created for the purposes of specific kind of applications such as the knowledge management applications, ERP applications and WISDM for the web applications, etc. The post-methodology era is distinguished from the era of contemplation of different opinions when it concerns different methodologies and the difficulties of choosing the most appropriate ones. The rapid and agile approaches are now widely used. They are characterized by user involvement where different interest groups are taken into account when it comes to flexibility. The ISs are delivered to the customer in small parts instead of the whole ones. Moreover, there is also a trend to adapt methodologies to the needs and characteristics of each circumstance based on the exigencies in a specific situation. In addition, the recent developments, research experiences of new software methodologies and techniques in the area are highlighted in Haron et al. (2014). The authors mention that the emphasis has been on several aspects such as human-centric software methodologies, end-user development practices and emotional reasoning, for a coherent performance between the design tool and the user. Continuously, the emergence of new ICTs such as the Service oriented architectures, Web Oriented Architectures (WOA) and web technologies, such as the Web services, the semantic framework, web 2.0 technologies and a boom in the use of web applications for different purposes have led to a new situation and a need for new methodologies that consider the characteristics of the emergent architectures such as the Service Oriented Architecture (SOA), WOA and emergent web technologies. For SOA there are some methods suggested for its developments, for instance the IBMs Service oriented for modelling and architecture as well as the UML is used for this purpose (Arsanjani & Allam, 2006; Lopez-Sanz et al. 2008). Nevertheless, for web applications based on WOA, i.e. especially for applications with the use of web 2.0 technologies, there is no standard. However, there are many suggested tools and methodologies in academia and industry. Consequently, the authors Battle

& Betton,(2008) mention that the Representational State Transfer (Rest) design methodologies, which is a W3C recommendation, can be a useful approach when designing and developing the latest Web technologies since, for instance, Web 2.0 has a wealth of data, however its semantics is poor resulting in integration difficulties. In addition, they mention that the Semantic web solves the integration issues, but suffers in terms of users who lack the corresponding knowledge. The authors show in their work how both issues mentioned earlier can be solved with the use of Rest, which considers interoperation of both OWL and RDF, while also serving as access point for semantically enabled clients or query architectures. Continuously, the work of Thies & Vossen, (2009) suggests a methodology which considers the characteristics of the web 2.0 technologies. It uses well known and accepted tools such as the Business Process Model and Notation (BPMN) to highlight the processes of interest. In addition, they propose the use of well-known and accepted standards, for instance the Web Services Description Language (WSDL), which is a XML format applied for describing network services and the Web Application Description Language (WADL) to illustrate the services of the application ([www.w3.org](http://www.w3.org)).

#### 4.1 Action and Participatory design approaches

There is a more broad understanding of the need of other approaches for different phases of system development than the emphasis on just technological aspects for successful implementation of the ICTs. The Scandinavian approach, i.e. participatory design (PD) which emerged during 70's, and involves several stakeholders into the development process. It emphasizes the ICT development process of joint learning where the participants, i.e. designer and users, learn from and about each other (Löwgren and Stolterman (2004). The authors mention that the complexity of the IS development has increased. There is, therefore, a need of a more thoughtful approach for IS development which they discuss in (Löwgren and Stolterman (2004). A short review of the PD area can be found in Bodker and Pekkola, (2010). However, to be able to use the PD approach optimally one should share social and cultural background as well as language. Moreover, it requires that not only the users participate in the design, but also the designers in the use, i.e. it is important that the designer shares practice with the user. Furthermore, it requires more collaboration, participation and involvement of the designers and users in their context to support the developments of the ICTs. Consequently, it has been shown that it is important to consider this kind of methodological features to grasp other less technical aspect from the ICT developments such as the contextual organizational features, users, etc., which becomes crucial for the successful implementation of the ICTs. These aspects are highlighted in, for instance, the Participatory design as well as in the Action research, as mentioned before. The authors Sein et al., (2011) propose to combine the Action design approach with the Design Science, i.e. ADR, since the Design research takes a technological view of the IT artefact and overlooks its shaping by the organizational context (Hevner et al. 2004a; Hevner et al. 2004b; Hevner and March, 2003; Myers and Avison, 2002; Baskerville, 1999; Lee et al. 1997). For the ICT

development it is important to understand what an IT artefact is within the ADR. Orlikowski and Iacono 2001 mention that it is an ensemble, i.e. "those bundles of material and cultural properties packaged in some socially recognizable form such as hardware and/or software". In addition, it can be seen as an emergent thing "neither fixed nor independent, instead, emerges from ongoing social and economic practices" (Orlikowski and Iacono 2001). The emergence comes from the interaction between technology and an organizational context shaped by interests, values, and assumptions of a variety of communities, i.e. developers and users. Hence, the artefacts are only partly the work of a designer, which cannot be anticipated by reference to any prior design. Consequently, the development and implementation of the mobile IT artefact is a result of material and cultural aspects bringing about growing needs for hardware and/or software, which is materialized from the interaction between the technology and the organizational context shaped by the factors such as interests, values and assumptions of the developers and the users, which cannot be anticipated to any other former development. Nevertheless, the Action Design Research (ADR) is a research method to generate prescriptive design knowledge by building and evaluating the mobile IT artefact in the organisational setting. It involves first of all addressing the problem situation in a specific organization context by intervening and evaluating, and secondly by the construction and evaluation of the mobile IT artefact, which addresses the situation that can be supported by a mobile IT artefact. These two parts result in a method with focuses on aspects such as the building, intervention, and evaluation of the mobile IT artefact that reflects not only theoretical aspects and objectives of the researchers, but also the users and their function in the context. Consequently, it is important, as mentioned earlier, to use a combination of Action Research (AR) and Design Research (DR), i.e. Action Design Research as stated by Sein et al., (2011) there is a need for a research method, namely the Design Research that recognizes the emergence of an artefact from the interaction with the organizational context even when the initial design is guided by the researchers' intent. The ADR methods suggested by the authors is illustrated through a case of competence management at Volvo IT (Sein et al., 2011)

Moreover, there are other approaches as mentioned earlier where researchers suggest, for instance, a Participatory design approach to understand IS development process important factors to consider during the ICTs developments. The participative design (PD) approach brings new aspects into the IS developments such as the direct participation of the users in the co-design of the ICTs (Robertson and Simonsen, 2012). The authors mention that several tools and approaches have been created to support the development of the ICTs which has also become a standard practice. In addition, Bodker et al. (2009) say that the goal of the PD approach is to set functional, all-purpose effective guiding principles for the introduction and development of new ICTs into organizations. Moreover, Saunders (2002) indicate that the IS development has changed from user-centred design process to understand various participatory experiences when designing the ICTs. It is important to identify the stakeholders of the intended ICT system for its successful implementation and use. However, it has been shown that, for instance, the agile methods fail to support the stakeholders



identification (Ballejos and Montagna, 2008) while the stakeholder identification is well developed in the PD IS development methods (Bødker, et al. 2010). In conclusion, the participatory approach has been used for the development of mobile learning technology with successful results (Cochrane, et al. 2011). In another work of the same author the Participatory action design is used for mobile learning where they identified six critical success factors for implementing mobile web 2.0 for learning purposes (Cochrane, et al. 2014).

## Discussion and conclusions

The paper has highlighted several aspects that need to be considered as for the mobile web technologies. It becomes crucial to understand certain problems that can occur in the development phases. A wide range of architectures such as the Service Oriented Architectures (SOA) or even Web Oriented Architectures (WOA) has none ISD methodologies as standards for their IS development process. It is, therefore, important to understand what is available when it comes to approaches, methods, methodologies, etc., and chose the proper one. Thus, while developing the ICTs it is necessary to consider several aspects such as the specific ICT architecture to be used, for instance WOA and its different characteristics, which is important to be able to utilize them in an optimal manner. Haron et al. (2014) mention that many of the software methodologies, tools and techniques, which were expected to be promising have proved to be no more than case-by-case oriented methods. This becomes apparent when new techniques, tools, languages and methodologies are developed to match the requirements of new technologies such as, for instance, mashup development. It is, however, wise to use recommendations or standards like the WSDL, but even the WADL for the modelling of the services provided in the web architectures. Consequently, the standardization efforts and recommendations of new developed methodologies and techniques, such as the W3C recommendation are important, resulting in higher software quality that can be integrated to already existent and future systems.

However, the use of the UML and sequence diagram is another alternative to design the first phases of the services, which is easy to understand even for a non-expert. In addition, it has been shown that the UML has been widely used in many software application developments. In a comprehensive review different aspects such as the UML model refactoring as well as the use of the UML are presented (Misbhauddin and Alshayeb, 2015). However, there are still efforts to be made to try to improve certain aspects of the UML such as an approach to transform Use Case Models into UML sequence diagrams (Khan and Mahmood, 2015). Nevertheless, another approach that can be considered is the Representational State Transfer (Rest) design methodology. It is a W3C recommendation and can be a useful approach to use when developing applications based on the web 2.0. It has been shown that in the ICTs area the advances area rapid and dynamic because of the speed with which the technologies are developing, which has brought new aspects and characteristics

of the ICT architectures that need to be reflected in the design, modelling and other phases, i.e. the use of a proper IS methodology to be able to use these technologies in an optimal manner. Moreover, the historical development of the ISD methodologies shows that there are many methods to choose from and that all have their own features and emphasis on different aspects of the development phases and organizational aspects such as the SSM or business driven approaches, etc. In addition, the aspects highlighted and suggested by Sein et al. (2011) with the ADR approach as well as the PD utilized by Cochrane, et al. (2014) and Bødker, et al. (2010) are extremely significant for the implementation of the mobile web technologies, since they highlight other aspects rather than just the technology which need to be considered for sustainable ICTs. These approaches promise successful design, implementation and use of these technologies, since they consider among other things the user in their specific context and a collaborative IS development where all the important stakeholders are present. Moreover, it is important to be aware and understand the factors that might impede the full integration of the mobile technologies into the industrial maintenance engineering domain. In Campos et al. (2015) among other things the acceptance models of Venkatesh et al (2003) are presented and the factors to understand the factors that might impede the mobile technologies acceptance in the domain of interest are highlighted.

As a final point, if the mobile technologies in conjunction with the web technologies such as the web 2.0 are utilized in the industrial maintenance engineering domain, then the utilization of the web will be in line with the state of the art solutions. However, the rapid pace of the development of web technologies holds more to promise. In conclusion, it should be noted that different approaches such as the participatory and action design research are crucial to consider, since they highlight different needs of various stakeholders as well as important features of the organizational context.

## References

- Avison, D; Fitzgerald, G. 2006. Methodologies for developing information systems: a historical perspective, in: D. Avison, S. Elliot, J. Krogstie, J. Pries-Heje (Eds.), *The Past and Future of Information Systems: 1976–2006 and Beyond*, Springer, Heidelberg, pp. 27–38.
- Backman, J; Helaakoski, H. 2011. Mobile Technology to Support Maintenance Efficiency - Mobile Maintenance in Heavy Industry, in *Industrial Informatics (INDIN)*, 2011 9th IEEE International, pp. 328-333.
- Ballejos, L. C.; Montagna, J. M. 2008. Method for stakeholder identification in interorganizational environments. *Requirements engineering*, Vol. 13, No. 4, pp. 281-297.
- Baskerville, R.L., 1999. Investigating Information Systems with Action Research. *Commun. AIS*, Vol. 2. pp. 1-32.
- Battle, R., Benson, E., 2008. Bridging the semantic Web and Web 2.0 with Representational State Transfer (REST). *Web Semantics: Science, Services and Agents on the World Wide Web*, Semantic Web and Web 2.0 Vol. 6, pp. 61–69. doi:10.1016/j.websem.2007.11.002
- Bødker, K., Kensing, F., Simonsen, J., 2010. Participatory Design in Information Systems Development, in: Isomäki, H.,

- Pekkola, S. (Eds.), *Reframing Humans in Information Systems Development, Computer Supported Cooperative Work*. Springer London, pp. 115–134.
- Bodker, S.; Pekkola, S. 2010. A Short Review to the Past and Present of Participatory Design. *Scandinavian Journal of Information Systems*, Vol. 22, Issue 1, pp. 45-48.
- Bodker, K.; Kensing, F.; Simonsen, J. 2009. *Participatory IT Design – Designing for Business and Workplace Realities*, MIT Press.
- Campos, J.; Jantunen, E.; Baglee, D.; Gilibert, E.; Fumagalli, L.; Emmanouilidis, C. 2015. *The Use of Mobile Technologies and Their Economic Benefits in Maintenance*, The 10th World Congress on Engineering Asset Management (WCEAM 2015).
- Campos, J.; Jantunen, E. 2011. The Semantic Web and Web 2.0 social media technologies for e-maintenance applications, *Proceedings of the 24th International Congress on Condition Monitoring and Diagnostics Engineering Management, COMADEM 2011*, Det Norske Veritas, Norway & Centre for Industrial Asset Management (CIAM), University of Stavanger, Norway. Kolkata, India (2011), pp. 463-473.
- Campos, J.; Jantunen, E.; Prakash, O. 2009. A web and mobile device architecture for mobile e-maintenance, *Int Journal of Advanced Manufacturing Technology*, Vol. 45, Springer, pp. 71–80.
- Campos J.; Jantunen E.; Prakash O. 2007. Keynote paper: Development of a Maintenance System Based on Web and Mobile Technologies. *Journal of International Technology and Information Management*, Vol. 16 No. 4, pp. 1-8.
- Checkland, P.; Scholes, J. 1990. *Soft Systems Methodology in Action*. Wiley, Chichester.
- Cochrane, T.D. 2011. Beyond the Yellow Brick Road: Mobile Web 2.0 Informing a New Institutional E-Learning Strategy, *Journal of Asynchronous Learning Networks*, Vol. 15, No. 4, pp. 60-68.
- Cochrane, T. D. 2014. Critical success factors for transforming pedagogy with mobile Web 2.0. *British Journal of Educational Technology* Vol. 45, pp. 65–82. doi:10.1111/j.1467-8535.2012.01384.x
- Haron, H.; Selmat, A.; Fujita, H. 2014. *New Trends in Software Methodologies, Tools and Techniques: Proceedings of the Thirteenth SoMeT\_14, Frontiers in Artificial Intelligence and Applications*. IOS Press, Amsterdam.
- Hevner, A.R.; March, S.T. 2003. The information systems research cycle, *Computer*, Vol 36, No. 11, pp 111-113.
- Hevner A. R.; March, S. T.; Park, J.; Ram, S. 2004a. Design science in information systems research, *MIS Quarterly*, Vol 28, no 1, pp 75-105.
- Hevner A. R.; March, S. T.; Park, J.; Ram, S. 2004b. Design science in information systems research, *MIS Quarterly*, Vol 28, no 1, pp 75-105
- Holmberg, K.; Adgar, A.; Arnaiz, A.; Jantunen, E.; Mascolo, J.; Mekid, S. 2010. *E-maintenance*, Springer, ISBN 978-1-84996-205-6.
- Khan, Y.A.; Mahmood, S. 2015. Generating UML Sequence Diagrams from Use Case Maps: A Model Transformation Approach. *Arab J Sci Eng* pp. 1–22. doi:10.1007/s13369-015-1926-0.
- Iung, B. 2006. Research and development on e-maintenance: Survey of some recent advances and directions
- International Conference on Maintenance Management, 27-28 April 2006, Italy, pp. 95-100.
- Lee, A.; Liebenau, J.; DeGross, J.I. 1997. *Information Systems and Qualitative Research*. Springer.
- Lee, H.; Etnyre, V.; Chen, K.L. 2003. A Study of .Net Framework, XML Web Services and Supply Chain Management, *Journal of International Technology and Information Management*, Vol.12, no. 1, pp. 137-153.
- Levrat, E.; Iung, B.; Marquez, A.C. 2008. E-maintenance: review and conceptual framework. *Production Planning & Control* Vol. 19, pp. 408–429. doi:10.1080/09537280802062571.

- López-Sanz, M., Acuña, C.J., Cuesta, C.E., Marcos, E. 2008. Modelling of Service-Oriented Architectures with UML. *Electronic Notes in Theoretical Computer Science*, Proceedings of the 6th International Workshop on the Foundations of Coordination Languages and Software Architectures (FOCLASA 2007), Vol. 194, pp. 23–37. doi:10.1016/j.entcs.2008.03.097
- Löwgren, J.; Stolterman, L. 2004. *Thoughtful Interaction Design: A Design Perspective on Information Technology*, The MIT Press.
- Myers, M. D., & Avison, D. (Eds.). (2002). *Qualitative Research in Information Systems*. London: Sage Publications.
- Meyne, H.; Davis, S. 2002. *Developing web applications with ASP.NET and C#*, Wiley Computer Publishing, John Wiley & Sons, Inc.
- Misbhauddin, M.; Alshayeb, M. 2013. UML model refactoring: a systematic literature review. *Empir Software Eng* Vol. 20, pp. 206–251. doi:10.1007/s10664-013-9283-7.
- Muller, A.; Crespo Marquez, A.; Iung, B. 2008. On the concept of e-maintenance: Review and current research. *Reliability Engineering & System Safety* Vol. 93, pp. 1165–1187. doi:10.1016/j.res.2007.08.006
- Newcomer, E. 2002. *Understanding Web Services: XML, WSDL, SOAP, and UDDI*, Addison Wesley Professional.
- Orlikowski W J, Iacono C S .(2001).Desperately seeking the “IT” in IT research – a call to theorizing the IT artifact, *Information Systems Research*, Vol 12, No. 2, pp. 121-134.
- Pakdeetrakulwong, U.; Wongthongtham, P. 2013. State of the art of a multi-agent based recommender system for active software engineering ontology. *International Journal of Digital Information and Wireless Communications* Vol. 3, pp.29–42.
- Papazoglou, M. P.; Heuvel, W.J. 2007. Service oriented architectures: approaches, technologies and research issues, *The VLDB Journal*, Vol. 16, No. 3, pp. 389–415.
- Robertson, T.; Simonsen, J. 2012. Challenges and Opportunities in Contemporary Participatory Design. *Design Issues* Vol. 28, pp. 3–9.
- Sanders, E.B.N. 2002. From user-centered to participatory design approaches. In Frascara, J. (ed.), *Design and the Social Sciences: Making Connections*. London: Taylor and Francis, pp. 1–8.
- Sein, M.K.; Henfridsson, O.; Purao, S.; Rossi, M.; Lindgren, R. 2011. Action design research”, *MIS Quarterly*, Vol. 35, Issue 1, pp. 37- 56.
- Thies, G.; Vossen, G. 2008. Web-oriented architectures: On the impact of web 2.0 on service-oriented architectures, *Asia-Pacific Conference on Services Computing*. 2006 IEEE, pp. 1075–1082.
- Turban, E.; Sharda, R.; Denlen, D. 2011. *Decision support and business intelligence systems* (9th ed.). Upper Saddle River, NJ: Pearson Prentice Hall.
- Venkatesh, V., Morris, M.G., Davis, G.B., Davis, F.D., 2003. User Acceptance of Information Technology: Toward a Unified View. *MIS Quarterly* 27, pp. 425–478.
- Venkatraman, S.S. 2004. Web-Services – The Next Evolutionary Stage Of E-Business, *Journal of International Technology and Information Management*, Vol.13, no 2, pp. 111-122.
- Vizcaino, A.; Garcia, F.; Caballero, I.; Villar, J.C.; Piattini, M. 2012. Towards an ontology for global software development. *IET Software* 6, 214–225. doi:10.1049/iet-sen.2011.0087.
- Wang, W., Tse, P.W., Lee, J., 2006. Remote machine maintenance system through Internet and mobile communication. *Int J Adv Manuf Technol* 31, 783–789. doi:10.1007/s00170-005-0236-1