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Research Article

The Success Implementation Factors for Mobile Collaboration Technology in Asset Maintenance

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Abstract

Mobile maintenance is evolving as an area of major prominence in engineering asset. This paper addresses the issue of why many engineering asset management organizations have experienced major problems implementing mobile collaborative maintenance systems (MCMS) that can maximize asset operation. Unsuccessful implementation of MCMS and computerized maintenance management systems (CMMS) has been widely reported in the literature. There is, however, a lack of research on the requirements for successful implementation. Several specialised computerise maintenance systems have been invested by engineering asset organisations to enhance their asset management and maintenance systems. Nevertheless, there is no common ground among engineering asset organisations about what sorts of collaborative maintenance are required for adoption/implementation. The lack of a systematic approach, together with the lack of specific requirements for implementing mobile collaborative maintenance, needs a comprehensive framework. For this study, we elicited and organized the opinions of 18 expert panellists through a-three round email-based Delphi study. A rank-order list of 31 requirements was identified, and ranked lists of the top five requirements in each dimensions. Highest consensus on existing technology/features and current mobile technology supported were also identified.

Keywords: Engineering asset, collaborative maintenance, mobile technology.

Introduction

One of the most important aspects of engineering asset management (EAM) is maximising an asset's operational time. Sun et al. (2006) and Yao et al. (2005) claim that operating and maintaining today's physical assets is more complicated due to their having more functions than ever before. Moreover, current working circumstances are more complex and therefore need to be managed by multiple and interlinked activities (Camacho et al., 2008). Hence, an integrated high-level maintenance system

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which contains multiple sub-systems requires the collaboration of multiple stakeholders. These include, for example departments or units to improve resources, information sharing and maintenance practices. In today's maintenance practices, CMMS is widely employed by engineering organizations (Tam & Price, 2006). However, around 70% of total system implementation is reported as failing. The main reasons for unsuccessful implementation of computerized maintenance systems include the following: selection errors, insufficient commitment, lack of training, failure to address organizational implications, underestimating the project task, lack of project resources, and lack of demonstrable use of system output (Olszwesky, n.d). Briefly, the main reasons for unsuccessful implementation are organizational and personnel factors. Unfortunately, studies have mostly focused on the technological concerning hardware, software, and networking, with a lack of attention paid to the systematic approach or the specific requirements to implement computerize maintenance information systems including the mobile collaborative asset maintenance system. The aim of this research is therefore to develop a framework to guide engineering organizations implementing new mobile collaborative maintenance and aimed to address the following three research questions:

RQ1: What are the mobile collaboration requirements in engineering management organizations for asset maintenance activities?

RQ2: What is the existing state of collaboration technologies being used in engineering management organizations for asset maintenance activities?

RQ3: What is the current role of mobile technologies in the above collaboration technologies?

Collaborative Asset Maintenance

A system to support collaboration and information management should be able to offer a shared information work space; a communication space to negotiate collective interpretations and shared meanings; and a coordination space to support cooperative work action. In other words, it should engender a shared information work space that facilitates access to information content, organizational communications, and group collaboration (Pereira & Soaresa, 2007).

Collaboration consists of four pillars which are collectively known as the continuum of collaboration. The first pillar is *networking*, which refers to the exchange of communication and information to support individual tasks across organizational boundaries. The second pillar is *coordination* which is extending the networking for communication and information exchange to alter or adjust tasks so that they are done more effectively. The third one is *cooperation* where the allocation of resources is compatible with certain achievable goals. This pillar extends the prior pillar, coordination. The last (key) pillar is *collaboration*. The collaboration building block extends cooperation, enabling collaborators to share information and communication, resources, and tasks in order to achieve a common goal. The goal is to achieve a mutual benefit or compatible objective, (Himmelman, 2001). To improve quality and reliability of asset maintenance work, maintenance personnel are required to access information related to maintenance from anywhere, anytime through a mobile device.

Mobile Technology to Support Asset Maintenance

Mobile technologies and solutions are very popular in consumer applications and the exploitation of mobile technologies is expanding. In heavy industry, the maintenance use of mobile solutions has not yet been widely adopted. One reason might

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be that there is a lack of competence and knowledge for adopting mobile solutions successfully in professional use. Many companies have poor experiences in adopting mobile solutions in their maintenance due to previously inoperative telecommunication connections, lack of suitable devices or insufficient prepared adoption process. Another reason may be that the benefits of mobile solutions are not seen or not known, for example, in maintenance domain. Mobile technologies are now mature enough to face the challenge and requirements of professional use in the engineering industry.

The use and adoption of mobile services has been studied globally and extensively from the perspective of context-driven organizational problem solving (Bardram & Bossen, 2005; Burley & Scheepers, 2002; Cass, Shove & Yrry, 2005; Charterjee et al., 2009; Haaparanta & Ketamo, 2005; Lamming et al., 2000; Malladi & Agrawal, 2002; O'connell & Bjorkback, 2006; Perry et al., 2001; Sarker & Wells, 2003; and Sheng, Siau & Nah, 2010). When considering employing mobile solutions in industry and especially in maintenance, the available studies focus mainly on e-maintenance (Marquez & Iung, 2008; Muller, Marquez & Iung, 2008, Koc et al., 2004, and Campos, 2009). The term e-maintenance is a broad concept where mobile solutions constitute a part of it. Some e-maintenance specific case studies focus on mobile device architectures where a mobile device can assist the maintenance engineer to do maintenance tasks (Campos, Jantunen & Prakash, 2009). Mobile solutions can lead to more efficient maintenance operations and practices.

Method

This study was conducted to identify collaboration requirements, current collaborative maintenance practice and mobile technology roles in support of collaborative engineering asset maintenance. The Delphi technique was employed to more accurately build consensus among panel experts. The Delphi study is a group process designed to solicit expert responses to reaching consensus on a particular problem, topic, or issue by subjecting them to a series of in-depth questionnaires, interspersed with controlled feedback (Dalkey & Helmer, 1963). Among participants, consensus agreement can vary from 51% (Loughlin and Moore, 1979), 70 % (Sumsion, 1998) to 80% (Green et al., 1999). The Delphi method was employed for several reasons: 1) the topic 'Mobile collaboration technology in engineering asset maintenance' is a relatively new, and complex issue, 2) there is only limited literature on the topic, and 3) not much empirical data is available. The Delphi study carried out in this research comprised three rounds (Linstone & Turoff, 1975).

***Nomination of experts*:** Expert in this instance was defined as someone who has knowledge, experience and the ability to influence policy and can provide valuable insights into a specific subject related to mobile maintenance. A total of 47 experts who have strong academic backgrounds, research experience and professional careers in mobile asset maintenance were invited via e-mails to participate in the Delphi survey. Of these, 20 were willing to participate in the research project. Eight of them were academics and 12 were professionals from 10 different countries.

Delphi Design: A three-round Delphi email-based questionnaire was designed. **The first round** (generating ideas/issues) was an initial collection of requirements, technical functions and features of current collaboration technology being used, the roles of mobile technology in support of the current collaborative asset maintenance. During this round, we did not receive responses from one of any of the twenty experts, after two reminders. In total, 19 experts participated in Round one. **The second round** (Eliciting agreement) was validating the categorized list of requirements. The experts were asked to verify the list that the researcher had correctly interpreted and place them in an appropriate category/group based upon their first round responses. These experts

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were also requested to remove, add or regroup the item (s) into other groups or categories. **The third round** (obtaining consensus**)** was about ranking relevant requirements. The consensus in the ranking order of the relevant group/category about requirements was achieved in this final iteration. The experts were also asked about the importance of the existing technology/features of collaborative maintenance systems, and their agreement for mobile technology support to the existing systems. Another one respondent withdrew from the final round.

***Data Analysis*:** **Round one** (Categorisation and reduction of statements). The Researcher collated all the requirements, ideas/issues generated during Round one, and removed any that were duplicated or ambiguous. Similar ones were condensed into one. List of requirements, statements were then sent to experts to be rated in terms of their importance. **Round two and three** (Ranking, Rating of the requirements or statements). For each requirement or statement, the mean, and standard deviation of the ratings were calculated. Those with the highest mean were considered to be the highest ranking, similarly those with the highest ratings and smallest standard deviations were considered to have the greatest consensus (Jones & Hunter, 1995). The consensus level of agreement was set at 70% to 100% agreement or disagreement.

Findings and Discussions

A Top 5 Ranking of Mobile Collaborative Maintenance Requirements

During the second round, 31 Technology, Organization and People requirements were verified as being critical for implementing mobile collaborative maintenance in engineering asset organizations (Syafar et al., 2013). This set was ranked by 18 expert panel members in the final round of the Delphi study. Due to limit of space, we listed and discussed the top 5 ranked requirements concerning each dimension.

Technology:

1. Mobility-Data and service access through contextualized and mobile interfaces. The mobility of the maintenance crews on a physical environment depends on current environment conditions where they are located.

2. Linking maintenance planning and dispatching. Maintenance collaborates across different sites. The system mechanism must be able to support discussion, negotiation and decision-making with regards to integrated asset maintenance.

3. Accessible-Data and service functionality are porting to the cloud (cloud service for collaborative facility maintenance). The cloud computing platform supports online interaction, without the intervention of local IT staff, of condition monitoring, automatic diagnosis/prognosis of a physical asset's health and performance and communication between maintenance crews including experts.

4. Autonomous information/communication exchange. Characterized by which group of maintenance crews work independently on loosely-shared artefacts. They come together to share results of work that collaborators have undertaken.

5. Interoperability-support interoperability between maintenance roles modes. The ability of two or more mobile collaborative maintenance systems, devices or applications to exchange data information between them and to use the information so exchanged.

Organization:

1. Clear maintenance vision (maintenance strategy-business objective),
2. Simplified (business-maintenance) process flow,

3. Maintenance must be profit and customer-centred,
4. Using unified communication,
5. Involving maintenance stakeholders in the system/technology selection process.

People

1. Common understanding of maintenance process,
2. Organizational commitment,
3. Common understanding of the system,
4. Skill and training (technology competence),
5. Collaborative work culture, trust and motivation.

Highest Consensus on Existing Technology/Features of Collaborative Maintenance Systems

The following technologies and features were verified as technologies/features being used in engineering asset practice in the second round of the Delphi study. In the final round, this list was further rated about on their importance by 18 expert panel members. The highest level of consensuses is documented as follow.

Format data:

Text, Visual, Audio, Graphic and Document

Technologies:

Portability, Wireless, Display, Voice Communication, and Video captures.

Features:

1. Scheduling: generate work order, preventive maintenance wizard, task library and work order list,
2. Managing: retrieve asset performance information (e.g. historical performance, work order history, etc.),
3. Productivity: retrieve job-related information (e.g. previous job, training, etc.), retrieve asset specification (for example drawing, configuration diagrams, etc.),
4. General: system security.

Highest Consensus on Mobile Technology Support

These were verified as the current roles for mobile technology in supporting maintenance collaboration technologies/systems in round two. Eighteen expert panel members were asked to rate their agreement concerning the set areas/categories in the final round. The highest consensus is:

Flexibility:

1. Critical for response time for data or information that failures can be identified and corrected early,
2. Visualizing of collected data, parameter history and trending,
3. Provide notification for instances of failure.

Empowering management

1. Enhancing accuracy of critical data entry for maintenance history,
2. Off-site (not in office) notifications and live feeds,
3. Question and Answer decisions.

Overall, a total of 33 requirements were identified both from the literature and Delphi study, specifically 15, 12 and 6 for Technology, Organization and People, respectively (Table 1). The literature review identified 23 requirements whereas 31 requirements were found in the Delphi study. Of the 33 requirements, 21 were noted in the literature and confirmed in the Delphi study (to be common) while 12 were specific to one analysis – two (2) are unique to the literature and 10 are unique to the Delphi study.

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Table 1: Requirements Identified

TOP	Literature	Delphi	Common	Total per Group	Literature Only	Delphi Only
Technology	11	13	9	15	2	4
Organisation	8	12	8	12	0	4
People	4	6	4	6	0	2
Total	23	31	21	33	**2**	**10**

A further comparison of the requirements from the literature with those derived for the development of the MCMS framework is shown in Table 1 and is summarized in Figure 1. The figure highlights the similarities and the differences between the two sets of requirements from the literature and the Delphi study.

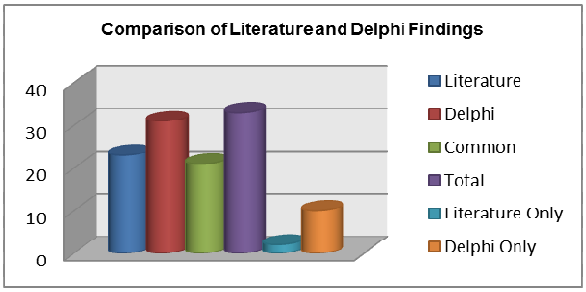

Figure 1: Comparison of the Number of Requirements Identified by Literature and Delphi Study

Conclusion

Due to the strong connection between the collaboration technology and the engineering asset maintenance process, such systems have become an important strategy for improving the way in which information is gathered, managed, distributed and presented to maintenance people. By developing and improving mobile technologies, information processing can be done by technical personnel away from the central production office or site.

It is expected that the framework provides a comprehensive structure for identifying and understanding MCT requirements in an organised way. The framework of requirements provides rich insight of selection criteria, benefits and mobile collaborative issues in asset maintenance, and highlights the important requirements that engineering organisations need to focus on for their asset management improvement efforts. The framework is also expected to bring significant beneficial to engineering organisations in several ways. First, maintenance managers will be better able to identify critical requirements for successfully implementing new mobile initiatives and for prioritising and nurturing existing maintenance activities. Second, managers will be better able to understand the relationships among these key requirements. They can use their improved understanding to develop or improve their organisational maintenance policies.

For organisations that have initiated collaborative or mobile collaborative maintenance improvement systems, the results of the research are expected to serve as a point of reference for comparison and improvement. For IT and asset maintenance professionals, this research identifies the required functional requirements of MCT specific technologies, which will aid software designers in developing the required mobile collaboration enabling tools specific for engineering asset maintenance.

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