Requirements for the Successful Implementation of Mobile Collaborative Maintenance: An International Delphi Study

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Abstract

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. This framework should guide engineering organisations to implement new mobile technologies. In this International Delphi study, 31 requirements were found to be critical to creating successful MCMS implementation, covering aspects of technology, organization and personnel.

Keywords*:* Engineering asset, collaborative maintenance, mobile technology.

Introduction

Optimizing the amount of time an asset may be used is a top priority in engineering asset management (EAM). 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). As a result, a system of integrated high-level maintenance including many sub-systems necessitates the participation of a wide range of parties. Examples of such entities include divisions charged with bettering such things as resource management, data dissemination, and upkeep procedures. 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). In a nutshell, issues with the implementing organization and its people are usually to blame for failed initiatives. The systematic approach and the particular requirements to implement computerize maintenance information systems, such as the mobile collaborative asset maintenance system, have not received nearly as much attention in the literature as the technological aspects of hardware, software, and networking. Therefore, the purpose of this study was to answer the following three research questions in an effort to provide the groundwork for a framework that might be used by engineering firms considering the introduction of new forms of mobile collaborative maintenance.

RQ1: What are the needs for mobile collaboration in engineering management organizations for operations involving asset maintenance?
RQ2: What is the current status of the collaboration technologies that are being utilized in engineering management organizations for the tasks related to asset maintenance?
RQ3: What place does the use of mobile technology now have in the aforementioned types of collaborative technologies?

Collaborative Asset Maintenance

A system that is designed to facilitate collaboration and the management of information ought to be capable of providing a shared information work space, a communication space designed to facilitate the negotiation of collective interpretations and shared meanings, and a coordination space designed to facilitate 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).

The four cornerstones of cooperation make together what is known as the continuum of collaboration. The first pillar is making connections with people and resources outside of one's own company to help with specific projects. Coordination, the second pillar, involves expanding communication and information-sharing networks to better adapt or modify existing activities. The third option is working together to achieve common objectives in a way that makes efficient use of available resources. This foundational element builds upon the work done in the coordinating phase. Collaboration is the last (essential) pillar. Collaboration is expanded in this way as well, since partners may now coordinate on the planning, execution, and assessment of an activity schedule. The end game is to help each other out or work toward a shared goal (Himmelman, 2001). Maintenance workers should use mobile devices at the point of performance rather than a central location to obtain maintenance-related data on physical assets in order to boost quality and dependability.

Mobile Technology to Support Asset Maintenance

Consumers' enthusiasm for mobile technology and solutions is driving a rise in their widespread use. Mobile solutions for maintenance in the manufacturing sector are still in their infancy. One such explanation is an absence of necessary skills and expertise to implement mobile technologies in a business setting. Due to unreliable or nonexistent cellular connections, a lack of compatible devices, or an inadequately planned adoption procedure, many businesses have had negative experiences implementing mobile solutions for their maintenance. Another explanation might be that the advantages of mobile solutions are not recognized or understood. The engineering sector is currently at the point where mobile technologies are sophisticated enough to handle the challenge and needs of professional usage.

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 word "e-maintenance" refers to an umbrella phrase that includes mobile solutions. 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). The use of mobile solutions can improve the effectiveness of maintenance procedures.

Method

The purpose of this research was to determine the kind of cooperation needed for engineering asset maintenance, the state of the art in collaborative maintenance, and the role that mobile technology plays in this field. By using the Delphi method, the experts on the panel were able to more effectively reach an agreement. Experts are polled via a series of in-depth questionnaires and controlled feedback sessions in a Delphi research, which aims to obtain agreement on a problem, topic, or issue (Dalkey & Helmer, 1963). Consensus among participants ranges from 51% (Loughlin & Moore, 1979), 70% (Sumsion & 1998,) to 80%. (Green et al., 1999). A number of factors led to the decision to use the Delphi technique: There is a lack of empirical data and a dearth of literature on the subject of "Mobile collaboration technology in engineering asset maintenance" for a few reasons: 1) it is a novel and difficult problem; 2) there is little research on the topic; and 3) the topic is still in its infancy. In this study, we conducted a three-round Delphi poll to get at our conclusions (Linstone & Turoff, 1975).

Nomination of experts. Here, the term "expert" refers to a person who has the aforementioned qualities as well as the capacity to influence legislation and give insightful commentary on a particular topic linked to mobile maintenance. The Delphi poll included the participation of 47 experts with significant backgrounds in academia, research, and mobile asset maintenance who were invited through email. The study project was able to recruit 20 of them. They hailed from 10 different nations and included 8 academics and 12 professions.

Delphi Design. A questionnaire with three rounds of email-based Delphi was created. In the **first phase**, we gathered needs, technical and feature details about the existing collaboration technology in use, and information about the roles played by mobile technology in aiding the existing collaborative asset maintenance. After two reminders, none of the twenty experts responded during this round. There were a total of 19 specialists that took part in the first round. For the **second phase**, "Eliciting agreement," we validated the sorted list of criteria. In this second stage, experts were requested to double-check the list that the researcher had accurately read and classify them accordingly. These professionals were also asked to modify the list by excluding, adding, or rearranging the item(s) in question. In the **third phase** (achieving agreement), we ranked the most important criteria. In this last iteration, everyone agreed on a unified priority list for the relevant set of criteria. Experts were also polled on the significance of current collaborative maintenance system technology/features and their agreement with the use of mobile technologies in these systems. One more responder did not show up for the last round of voting.

Data Analysis. The first round (Categorisation and reduction of statements). Researcher collected all criteria, ideas/issues from Round 1 and eliminated those that were duplicates or unclear. The number of similar ones was reduced to one. Experts were given the list of needs and asked to prioritize the assertions. This is the second and third go-around (Ranking, Rating of the requirements or statements). Mean and standard deviation were determined for each criterion or statement. Results with the highest mean were deemed the best, as were those with the highest ratings and the lowest standard deviations, indicating widespread agreement (Jones & Hunter, 1995). The agreement threshold was established at a range of 70% to 100%.

Findings and Discussions

An Ordered List of the Top Five Requirements for Mobile Collaborative Maintenance

During the second round, 31 needs pertaining to technology, organization, and people were validated as being absolutely necessary for the implementation of mobile collaborative maintenance in engineering asset organizations. In the final round of the Delphi research, there were 18 experts that participated in the ranking process for this set. Because of the limitations of the available room, we selected the top five needs for each dimension and then listed and debated them.

Technology:

1. Mobility-Context-aware and mobile interfaces to data and services. A maintenance crew's ability to move about in a physical setting is influenced by the circumstances there right now.
2. Integration of maintenance scheduling with scheduling. The maintenance team works together across locations. The system's mechanism should allow for IAM-related discourse, bargaining, and decision-making.
3. There is a shift toward storing data and providing services on the cloud (cloud service for collaborative facility maintenance). Condition monitoring, autonomous diagnosis/prognosis of a physical asset's health and performance, and communication amongst maintenance teams including specialists are all made possible via the cloud computing platform with no involvement from local IT employees.
4. Independent passing of data and verbalization. Identified by the number of autonomous maintenance personnel working on a set of semi-common assets. Participants at this gathering discuss the outcomes of a collaborative effort.
5. Facilitate communication and coordination amongst various forms of maintenance assistance. Connectivity between and interoperability of two or more mobile collaborative maintenance systems, devices, or apps for the transfer and use of data.

Organization:

1. Straightforward Perspective on Upkeep (maintenance strategy-business objective).
2. Streamlined procedures for (company) upkeep.
3. Profitability and customer focus are essential in maintenance.
4. Employing a single method of contact
5. Maintenance stakeholders participation in system/technology evaluation and selection.

People

1. A consensus on the maintenance procedure
2. Dedication from inside an organization
3. All parties involved have a common knowledge of how the system works.
4. Capabilities and education (technology competence)
5. Culture of trust, motivation, and cooperation in the workplace.

Highest Agreed-Upon Collaborative Maintenance System Technology/Features

During the second phase of the Delphi research, the following technologies and characteristics were confirmed as technologies/features actually utilized in engineering asset practice. This list was then graded by 18 experts on how important they were. The following represents the most widely held agreements.

Format data:

Text, Visual, Audio, Graphic and Document

Technologies:

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

Features:

1. Task libraries, work order lists, a preventative maintenance wizard, and a work order generator are all part of the scheduling process.
2. Access past data on an asset's performance (such as its rate of return or the number of service calls it's received) for management purposes.
3. Productivity: obtaining job-related data (past employment, education, etc.) and obtaining asset specifications (for example drawing, configuration diagrams, etc.)
4. Concerning the whole, we have the issue of system security.

Strongest Agreement Regarding Mobile Technology

The second round of research confirmed these as the primary functions of mobile technology in facilitating maintenance cooperation systems and technologies. In the final round, 18 experts were asked to assess how much they agreed or disagreed with the predetermined topics/classifications. In general, people agree that:

Flexibility:

1. Having access to data or information quickly is crucial for seeing problems and fixing them quickly.
2. Showing the evolution of parameters and other acquired data.
3. Deliver alerts when anything goes wrong.

Empowering management

1. Improving the precision of the input of essential data for maintenance history,
2. off-site (not in office) alerts, and live feeds
3. Choices between the Question and the Answer

Both the research in the literature and the results of the Delphi survey combined to provide a total of 33 criteria, with 15, 12, and 6, respectively, falling under the categories of technology, organization, and people (Table 1). When compared to the findings of the Delphi research, which uncovered 31 criteria, the literature analysis only uncovered 23 requirements. Of the 33 criteria, only two (2) are unique to the literature, while ten (10) are unique to the Delphi research. Twelve (12) of the requirements were particular to one analysis. Of the 33 requirements, 21 were identified in the literature and verified in the Delphi study (to be common).

The use of keywords is encouraged in this area. Both the context of the study and the impetus for the investigation should be presented here.

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**

Table 1 and Figure 1 demonstrate a comparison of the literature's criteria with those used to create the MCMS framework. The diagram illustrates the correlations and discordances between the two lists of needs, which were derived from the literature and the Delphi survey, respectively.

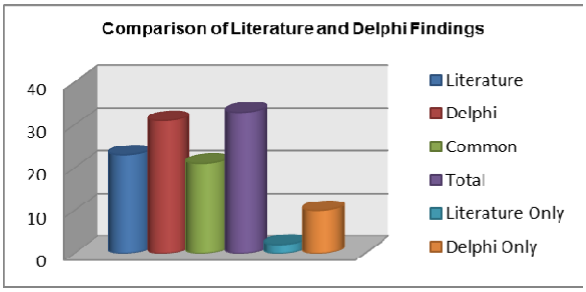

Figure 1. Literature vs. Delphi Study Requirements.

Conclusion

Because of the inextricable link between collaboration technology and the engineering asset maintenance process, implementing such a system is a crucial tactic for enhancing the collection, organization, dissemination, and display of data for maintenance workers. Information processing may be done by technical staff away from the main production office or site thanks to the development and improvement of mobile technologies.

In conclusion, it is hoped that the results of this study will contribute to the creation of a novel framework that addresses the following problems: (1) Engineering asset management with a focus on the most crucial process — asset maintenance; (2) Business process alignment at all three levels (strategic, tactical, and operational) in company activities through the variable of mobile collaboration technologies; and (3) A comprehensive framework that meets all technological, regulatory, and legal requirements.

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