# Integration of Knowledge Management Systems and End-user Interfaces for MPMM

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*Abstract* – **Maintenance can be considered as a combined information and knowledge processing and management system. Effective knowledge, practices and experiences management is growing in importance, especially in advanced processes and management of advanced and expensive assets. Efforts of integrating maintenance knowledge management (MKM) processes with MKMM will be increasingly more important due to the increasing complexities of these overall systems – the context in which the performance measurements has been performed is also important input in the performance analysis. Integration of MKM in MPMM can result in higher quality of the decisions and actions in the maintenance processes and in the overall work to increase efficiency and decreasing costs in the organizations.**

**Integration of MKM (Maintenance Knowledge Management – knowledge, experiences and practices management) with collaborative structures and interfacing abilities with qualified services for simulation, modeling and computations can be regarded as Intelligence-based Maintenance (iMaintenance). These infrastructures present in iMaintenance can further improve MPMM efforts due to possible utilization of more accurate property and context information and services – changes in installations, environmental factors etc. not easily integrated in current MPMM implementations.**

**Integration of MPMM with iMaintenance solutions can also improve the interaction between management and the maintenance operators and also allow improved interaction and integration with production operators in the organization. MPMM can with this approach be integrated as a natural component in the overall ICT-based maintenance and collaboration solutions – the performance status reporting will be seen as a natural extension to the normal routines. In this context the usability of the end-user environments will be very important – especially when designing systems for mobile use by maintenance operators in the field.**

*Keywords* − **eMaintenance, iMaintenance, MKMM, CMMS, CM, Collaboration Structures, End-user Interfaces, Mobile solutions**

## I. Maintenance Knowledge Management and iMaintenance

The production and process industry are passing through a continuous transformation and improvement for last couple of decades, due to the global competition coupled· with advancement of information and communication technology. (ICT). The business scenario is focusing more on e-business intelligence to perform transactions with a focus on customers needs for enhanced value, improvement in asset management and improving productivity. Such prognostic business requirement compels the organizations to minimize the production and service downtime by reducing the machine performance degradation and minimize risks. The above organizational requirements necessitate developing proactive maintenance strategies to provide optimized and continuous process performance with minimized system breakdowns and maintenance. With these changing systems of the business world in the 21st century, a new era of e-intelligence, e-factory, e-automation, e-maintenance, e-marketing and e-service have emerged.

CMMS and CM are the most popular repositories of information in maintenance, where most of deployed technology is installed. The combination of the strengths of a top-notch CMMS (preventive maintenance (PM) scheduling, automatic work order generation, maintenance inventory control, and data integrity) with the wizardry of a leading edge CM system (multiple-method condition monitoring, trend tracking, and expert system diagnoses) can allow work orders to be generated automatically based on information provided by CM diagnostic and prognostic capabilities. Just a few years ago, linking CMMS and CM technology was mostly a vision easily dismissed as infeasible or at best too expensive and difficult to warrant much investigation. Now, the evolved technology in CMMS and CM has made it possible to achieve such a link relatively easily and inexpensively (figure 1).
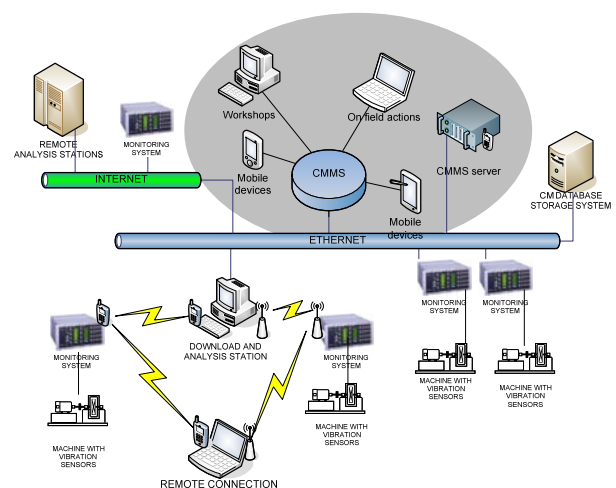


Fig.1 ICT architectures in maintenance – CMMS, CM. [1]

CMMS (and MPMM) environments do not today effectively support integration of advanced competence resources like multimedia and integrated collaborative environments useful for effective remote support and interaction with internal / external specialists. Core functionalities for effective experience capture are not present in current CMMS / MPMM environments - the main challenge is the lack of effective meta-data management and ontologies management supporting effective searches and management of the experience resources. Thus, CMMS, CM, MPMM and Knowledge Management have to be linked.

Knowledge management is evolving as an increasingly important factor in the operations and maintenance of processes and use of advanced technical systems and components. The complexity of processes and equipment increases together with an ever-increasing fragmentation of products, variants and versions of hardware and software in combination with ever increasing competition for knowledgeable staff and specialists. The increased complexity of equipment, processes and solutions increases risks at different levels of the organizations and in the processes, risks that can have a substantial impact on performance and costs and reduced ability to sustain efficient production. Integration of systems for standard knowledge management (training and education, competence databases) with systems for practices and experience capture management specifically adapted for maintenance solutions can be named Maintenance Knowledge Management (MKM). What also characterizes a Maintenance Knowledge Management system in comparison to a more standard knowledge management systems is the ability to handle a larger number of variants of knowledge resources – due to the very large number of types of equipment and variants in production and other processes and their properties and connected information and data (figure 2).

Fig. 2 Properties and resources connected to an asset etc.

Integration and inclusion of maintenance knowledge management (MKM) into the processes and infrastructures of e-maintenance creates the foundation for a more comprehensive approach to ICT-based maintenance solutions which one can call iMaintenance ("Intelligence-based Maintenance"). The iMaintenance approach do not only aim at integrating maintenance knowledge management into the integrated CMMS / CM / MPMM solutions but also offer integration of collaborative environments, access to simulation / computation engines & services, ontologies for effective tagging of resources, solutions etc. all designed to be effectively used across different levels of the organization and interacting with external actors. This integration lends itself well to ICT environments implementing cloud networks – an architecture aiming at integrating existing ICT systems and limiting the redundancies of data between systems (figure 3).
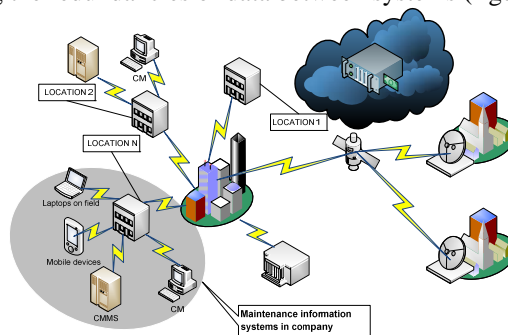
Fig. 3 Schematic presentation of an ICT maintenance cloud environment [2]

The main advantage of a maintenance cloud environment is the elimination of duplicated data and potential access to highly qualified computational services like simulations and analysis of very large datasets. A highly functional iMaintenance solution can integrate these different sources and services at the end-user level and thus allowing more effective and efficient maintenance and management processes and results.

One such example of a potential iMaintenance solution is presented in figure 4 where each component and module in the system can be connected to different unique parts of a maintenance cloud solution. By a modular approach the end-user are also capable of designing their own unique setup of tools and modules for their own unique needs and processes, account take to their unique access control profiles and work roles.

## II. MPMM – Maintenance Performance Measurement and Management Integration With iMaintenance

One of the most vital parts of an advanced iMaintenance solution is the Maintenance Performance Measurement & Management (MPMM) – both in the case of planning / follow-up and analysis on the management side and the in-situ involvement of the maintenance operators in their status updates, planning and follow-up. By integrating the needed status reporting as a natural part of other activities, the quality of the data improves, thus increasing the accuracy of the

following analysis and conclusions. The quality of the status information and data delivered into the systems for maintenance performance management can be increased further by improved in-situ support in the form of practices / experiences documentation etc. in direct connection to the status and data reporting activities, thus minimizing the risk of faulty data inserts and modifications.

To improve the quality of the MPMM activities the managers and operators often need to integrate different information and knowledge elements in their analysis and final conclusions. In the case of status and data entry in the field the operators might need to include properties describing changed conditions, changes in configurations and especially in the case of ICT-based equipment installed software patches and configurations. Most of the current ICT-systems in the maintenance field do not allow this information to be entered in a structured manner allowing more specific and advanced analysis. The analysis of maintenance performance can become more accurate if the overall end-user environment allows for integration and access to most of the assets / resources / processes properties, specifications, experiences, fault records etc. in parallel to the evaluated performance data. Examples of such "externalities" can be repair events, changes in specifications, changed external conditions, earlier documented human errors etc.

Another challenge for effective maintenance performance measurement and management beyond the need for accurate data and information access and analysis is the effective dissemination of the results of the analysis to the different levels of the organization and to speed up implementation of corrective actions and their feedback. Actively involving the maintenance operators in the maintenance performance management processes can increase the quality of the data collection, data analysis and conclusions by integrating experiences and observations from different parts of the organization.

## III. END-USERS INTERFACES FOR iMAINTENANCE AND MPMM

There are mainly three different approaches when utilizing of fragmented information / data spaces – using different tools to handle each individual information source, integrating by implementing advanced cloud approaches (integrating at the server level) or creating solutions that integrate the different information spaces at the end-user / application server level. In the last two cases regardless if the integration is performed at the server level or the end-user level it is vital that the end-user environments are flexible and modularized enough to effectively integrate, access and manage the data and information from the different sources.
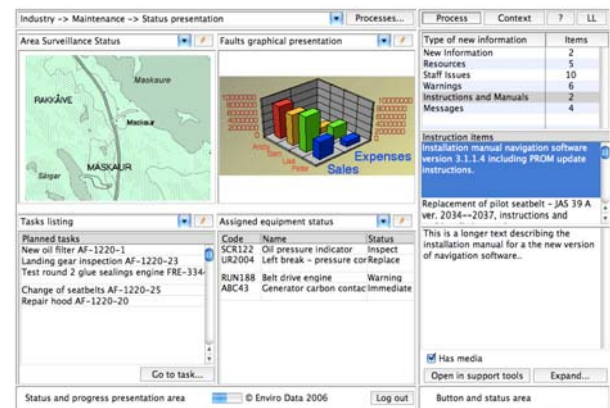


Fig. 4 Demonstrator of integrated end-user desktop environment (iMaintenance), courtesy of Enviro Data, Sweden

The example presented in figure 4, is a demonstrator of an integrated end-user environment supporting modular and work context-centric approach to information management for multiple organizational layers in an iMaintenance structure. This demonstrator presents ability to support end-user adaptation of the overall work environment depending on work roles, deployment environment and user access control structures. End-user controlled mash-up of information from many disparate information sources and services – all presented in one unified end-user environment. This demonstrator is based on research covering end-user environments for qualified maintenance of advanced technical systems (military fighters) allowing integration of knowledge / practices / experiences / standards management into a unified and integrated support environment for the maintenance operators. This type of environments allows integration of maintenance performance measurement, status reporting and management as integrated part of the normal work processes and contexts, both for management and for maintenance operators. The ability of the environment to be adapted for the specific end-user work contexts is very important – close to every organization is unique in their asset stock, their internal maintenance processes and their external environmental and market contexts. Another vital component in a ICT environment aiming at integrating MPMM and knowledge management is the ability to effectively manage experience capture – both at managerial and work floor levels and to utilize these experiences effectively in the performance analysis stages.

Mobile solutions like tablets and pads can be used allowing for relatively cost-effective deployment in large numbers across an organization, increasing the involvement of additional active actors in the maintenance performance management processes. This allows for new approaches in MPMM – increased direct involvement of maintenance operators when performing status, repair and error reporting, feedback structures for environmental and other feature data that will improve the accuracy of the performance analysis etc.

Mobile solutions can also assist in mitigating the ever-existing challenge of how to disseminate the results of the

performance analysis to the maintenance operators in a format and context that will allow them to act and implement improvements and corrections in their area of expertise and access rights. iMaintenance solutions offers the potential to give access to more tools for different staff to actively and effectively evaluate different approaches for improvements and corrections and to more effectively communicate with relevant specialists and experienced staff in their efforts to achieve the planned performance levels.



Fig. 5 Demonstrator of integrated end-user iPad environment (iMaintenance), courtesy of Enviro Data, Sweden (Montage)

The iPad demonstrator presented in figure 5 shows a simple example of multi-modal and modular interfaces for iPads and in adapted form also for modern smartphones / Android-based units and personal computers using modern web-browsers. With these tools easily accessible to close to all staff in an organization the concepts and solutions in MPMM can be vastly extended regards taken to the organizations policies, access control infrastructure and internal organizational culture. With these more advanced end-user support tools the access to supporting information and resources will be drastically improved and the ability of the individual to contribute with vital information for the performance management processes will also be drastically improved.

Similar to the demonstrator in figure 4 the mobile terminals can access a multitude of services and information sources in the maintenance cloud environment and also allow them to adapt their own unique system according to their own unique needs and work processes. Mobile solutions can also be the foundation for collaborative environments with external specialists involved in advanced performance management analysis or being accessed as specialists on the equipment used in the production processes. Involvement of external specialists in the efforts to analyse breakdowns or lacking performance can improve the accuracy of the planned mitigated efforts and solutions and also increase the accuracy when estimating the performance of the equipment and/or overall processes. Finally, mobile solutions integrating iMaintenance (Maintenance Knowledge Management integrated with collaborative environments and access to services etc.) with MPMM structures can also contribute to mitigate the strongest threat to a systems performance –

accidents and incidents that disrupts the normal execution and process flows.

## IV. CONCLUSIONS

By integrating advanced and extended knowledge management structures and resources into the maintenance performance measurement and management processes the quality of the analysis can improve. Both in terms of higher quality of the data used in the analysis and in terms of more effective dissemination mechanisms to the operational staff and structures. By utilization of the more advanced structures present in concepts like iMaintenance the ability of operational and managerial staff to improve the processes can increase. Additionally, new features, properties and experiences can more effectively be integrated into the analysis processes and interactively be managed by a wider selection of internal and external specialists.

This type of integration between iMaintenace and MPMM structures and processes demand highly advanced approaches in end-user interfaces and process flows. Performance data by itself is often not enough – also the data underlying the analysis also has to include environmental / contextual and configuration status information of different types, information that often evaluated through a prism of detailed knowledge about the surrounding environment around the processes and equipment. Supporting the end-users with integrated tools for information management and local analysis can be a vital tool for improved and effective maintenance performance management.

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