

*Full Length Research Paper*

# Service oriented architecture and advancement of maintenance management information systems: A review

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**Global competitive environment among enterprises requires efficient business interactions with external and internal entities in companies. Maintenance management systems are one of the critical business units in companies that play a key role in reducing the downtime of machinery and equipment. Therefore, the maintenance management interactions need to be optimized. The new era of information technology lead to apply information system in wide extends in maintenance management. Maintenance management systems have been improved by information technology to facilitate the accessibility, storing, and retrieving information. This article reviews the recent trends in maintenance management information systems and various maintenance applications. Applying service oriented architecture (SOA) and e-maintenance strategy in industries shows that integration trend in maintenance management information technology grows rapidly. Suggestion has been made on classifications of services which can be handled in an SOA enabled maintenance management system.**

**Key words:** Maintenance management, e-maintenance, plant maintenance, service oriented architecture.

## INTRODUCTION

The maintenance management approach has been changed over the last decades. Maintenance strategy in 1940s was about providing corrective maintenance which means unavoidable cost. The evolution of operation research during World War II resulted in appearance of new approaches in maintenance management and using preventive maintenance in industries and optimization in maintenance strategies (Murthy et al., 2002). Maintenance has become a profit center to improve the organizations businesses rather than a cost center (Sherwin, 2000; Stephens, 2004; Bagadia, 2006). Various practices have been employed in maintenance management. These practices including; reliability centered maintenance (RCM), failure mode and effect analysis (FMEA), total productive maintenance (TPM), and condition based maintenance (CBM) have been emphasized on applying sophisticated maintenance

management practices in organizations. RCM was introduced in aircraft industries in US to manage the reliability of systems (Moubray, 1991). TPM was applied in Japanese industries as a successful strategy in maintenance management to improve productivity (Tajiri and Gotoh, 1992). CBM as a proactive maintenance practice is a set of maintenance activities carried out to monitor and prevent failures in equipment according to its operating status (Gulledge et al., 2010). Information technology has played a key role in all these maintenance practices as one of the main pillars in maintenance management (Crespo et al., 2006).

The author believes that the new trends of information technology in maintenance management systems is in fast growing and need to be reviewed as a helpful source of information to be taken into account by technicians for selection and implementation of suitable maintenance management systems in organizations. After reviewing literature about maintenance management systems, the author concluded that a literature review describing the recent approaches in maintenance management

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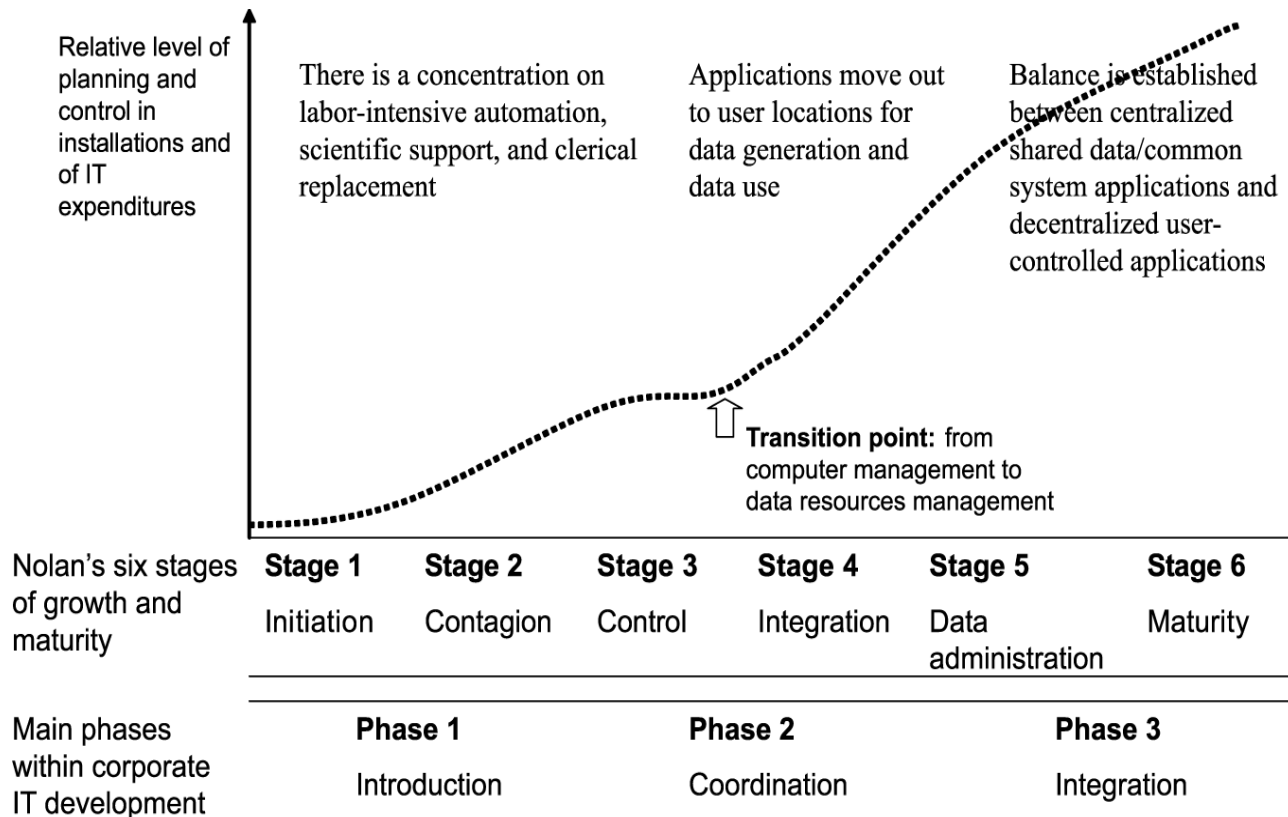


Figure 1. Advancement stages of information technology (Kans, 2009).

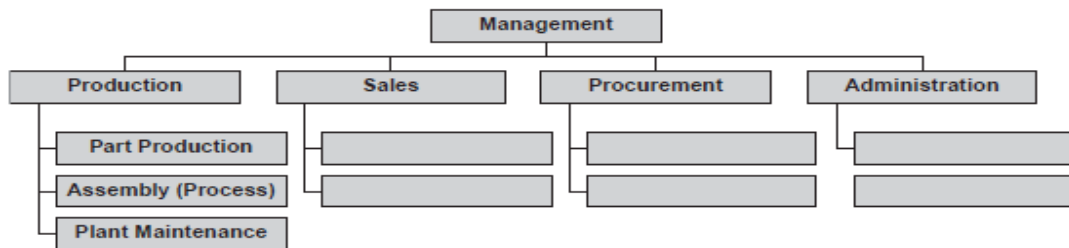
information technology such as service oriented approach has not been found and need to be prepared. To fill this gap, this article reviews the advancement and recent trends of information technology in maintenance management. In addition, a classification of services in an SOA information system for maintenance management has been provided.

This review was conducted through academic literatures, Elsevier, Emerald, and IEEE databases, and also commercial maintenance applications. Keywords related to maintenance management, computerized maintenance management system, plant maintenance, e-maintenance, and service oriented architecture were applied in this research. In first section of article, there is a review on trends of maintenance management information technology. It shows that current practices are aligned with integration phase and this trend has been continued by applying e-maintenance. In next section, the various maintenance management information systems and applications that can be involved in integration with other businesses in enterprises have been reviewed. The next section devoted to review on e-maintenance as one of the strategies which is backbone of SOA-enabled information system. The various maintenance management services that can be supported through SOA are discussed in subsequent section.

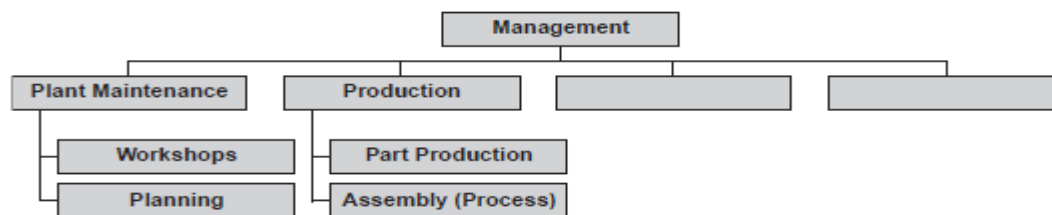
## INFORMATION TECHNOLOGY AND MAINTENANCE MANAGEMENT SYSTEMS

Information technology has been applied in maintenance management for about 40 years. There are six main stages in IT maturity model for development of IT in a business. Compare to the Nolan's IT maturity model, the advancement of general corporate IT and trends in maintenance management information technologies are similar over the last decades. This advancement can be divided into three main phases (Kans, 2009) (Figure 1):

**Introduction:** According to Wilder and Cannon (1993) the first stage of computerized maintenance management systems can be seen from 1970s while mainframes used for limited tasks to support scheduling for preventive activities. By minicomputers advent as new technology in 1980s, the number of computerized maintenance management systems increased to more than 60 in 1985 (Raouf et al., 1993). New functions were developed to manage the inventory, budget, stock control, and even expert systems to decrease the downtime and diagnosis of fault based on maintenance data. This improvements led to evolution of CMMSs in this stage and preparing the state-of-the-art CMMS by late 1980s at Ford (Mullin, 1989).



**Figure 2.** Plant maintenance as a subarea of production in line organization in SAP (Stengl and Ematinger, 2001).



**Figure 3.** Plant maintenance as a separate area in line organization in SAP (Stengl and Ematinger, 2001).

**Coordination:** In this stage, cooperation and exchange of information were significantly employed in organizations in early 1980s to improve business processes. Data repository, relational model databases, and central databases in this stage were exploited to handle data heterogeneity and facilitating interchange of data in organizations (Dahlbom, 1997; Kelly et al., 1997).

**Integration:** In late 1990s and after evolution of material resource planning (MRP), integrated solutions such as enterprise resource planning (ERP) received a lot of attention in companies (Leon, 2008). At this stage, information systems were applied to integrate the whole parts of organizations together. The collaboration and exchange of information between all parts of organizations played a key role to provide cost-effective systems especially in maintenance management. Moreover, new models of decision support systems led to more utilities to have predictive and proactive strategies rather than preventive maintenance (Labib, 1998).

Integration phase in information technology have been significantly improved over recent years and is growing too fast. As of 2000, advancement of e-maintenance and applying SOA approach in development of maintenance management systems emphasized this fact that integration between systems even different platforms is very important to facilitate the communication of various systems together (Muller et al., 2008; Karim, 2008).

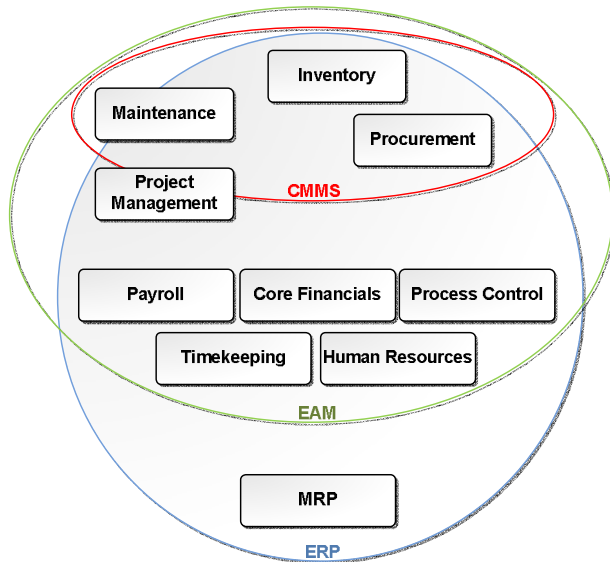
### Maintenance management in integrated systems

Maintenance management systems are in wide variety

according to types of included functions and modules. These systems can be found as off-the-shelf packages especially for maintenance which is called computerized maintenance management system (CMMS) or as an integrated asset management module in ERP (Wireman, 2004). CMMS is an integrated set of computer programs to support the data and files of maintenance, purchasing, and inventory control in a sophisticated cost-effective means for supporting the maintenance functions in an organization. CMMS has been considered as a tool to improve the efficiency of maintenance activities in enterprises (Cato and Mobley, 2002). Different strategies in organizations result in different organizational structure for asset management module. Plant maintenance (PM) is a maintenance module in ERP of SAP Company. According to types of activities in SAP, maintenance management can be considered as a subarea of production (Figure 2) or as a separate area from production (Figure 3) (Stengl and Ematinger, 2001).

In comparison to other maintenance management packages, CMMS can be considered as a professional software package for maintenance management. In other words, CMMS have more features and functionalities especially for maintenance management (Figure 4). Enterprise asset management (EAM) is one of the other packages which can be found for supporting maintenance management. EAM includes inventory, financial, human resource management, and all features and functions of maintenance management in CMMS (Barratt, 2004).

Although Figure 4 shows that human recourse management is in separate area from CMMS and it is not



**Figure 4.** Maintenance management in integrated information systems (Barratt, 2004).

included in CMMS, Bagadia (2006) emphasized that there are limited human resource functions in CMMS to manage the availability, utilization, and other indexes. Furthermore, CMMS has features, tools, and facilities in management of assets as much as EAM in organizations and can be used specifically for maintenance. EAM covers the whole functions of human resource and financial beside maintenance management (Barratt, 2004) whereas ERP strives to put the whole integrated businesses including maintenance management into a comprehensive system. Human resource module in ERP has exchange of information with maintenance module to share information and effects of it on the whole enterprise (Wireman, 2004). Although maintenance management can be a supportive function in computer integrated manufacturing (CIM) system, Al-Najjar (1996) emphasized that in CIM everything except maintenance planning are integrated.

## E-MAINTENANCE

Along advancement in information and communication technology (ICT) in early 2000, e-maintenance has been appeared as one of the useful strategies to control and maintenance of machinery in companies. With Applying wireless systems and web-based software programs in order to implement e-diagnostic systems (Hung et al., 2003) for monitoring systems off the work places, e-maintenance emerged along other concepts such as e-manufacturing and e-business (Muller et al., 2008). Collaboration between e-maintenance as one of the main elements in asset management and other layers of organizations including e-operations and e-business has

been depicted in Figure 5 (Lee and Ni, 2004). Condition based monitoring (CBM) is a maintenance program for decision making based on collected information of condition monitoring and proactive strategy which is enhanced extensively through e-maintenance (Jardine et al., 2006). Leveraging remote maintenance technology with artificial intelligence has been suggested to support the e-manufacturing systems through monitor and control of real-time data in enterprises for next generation of e-automation (Ucar and Qiu, 2005). E-maintenance can be applied in wide variety to take advantages of reducing cost, time, or risk of monitoring equipment in hazardous situations (Hamel, 2000).

On the other hand, still some needs and issues remain in obtaining of e-maintenance which is classified by Muller et al. (2008). These issues such as providing security for transactions of data in internet, cross-platforms communications, selection of data transmission protocols (Hung et al., 2003), and distributed computers and synchronization of them to develop a dynamic decision-making environment (Koc et al., 2003) are considerable and need to be weighed up in implementation of e-maintenance system.

## SERVICE ORIENTED ARCHITECTURE (SOA) IN MAINTENANCE MANAGEMENT

Service oriented architecture (SOA) is an architectural framework and approach to support the business functions which is known as services to satisfy the requirements of a business (Chen, 2006). The hype cycle of SOA in Gartner report shows that SOA has gained much attention since 2005 (Fenn and Linden, 2005). SOA can support an integrated environment to provide services among different platforms. Integrated database between maintenance and other businesses in organization has been recommended to enjoy cost effective strategy (Al-Najjar, 1996; Kans and Ingwald, 2008). Also, this common database can provide decision support system (DSS) in maintenance management (Labib, 2004). This integration is a necessity for real-time data in order to implement DSS (Fernandez et al., 2003) and CBM (Jardine et al., 2006). Systems based on SOA can be integrated through web-services with other information systems such as human resource (HR), ERP, or finance. Leveraging SOA in maintenance management systems can provide possibility of interaction with other information systems such as ERP, customer relation management (CRM), and supplier relationship management (SRM) through services (Schneider, 2010). Recent efforts have been carried out to provide frameworks for e-maintenance based on SOA in maintenance management (Karim, 2008; Candell et al., 2009).

Although SOA can provide integration with other systems, the governance over SOA processes can be considerable to have seamless and secure environment.

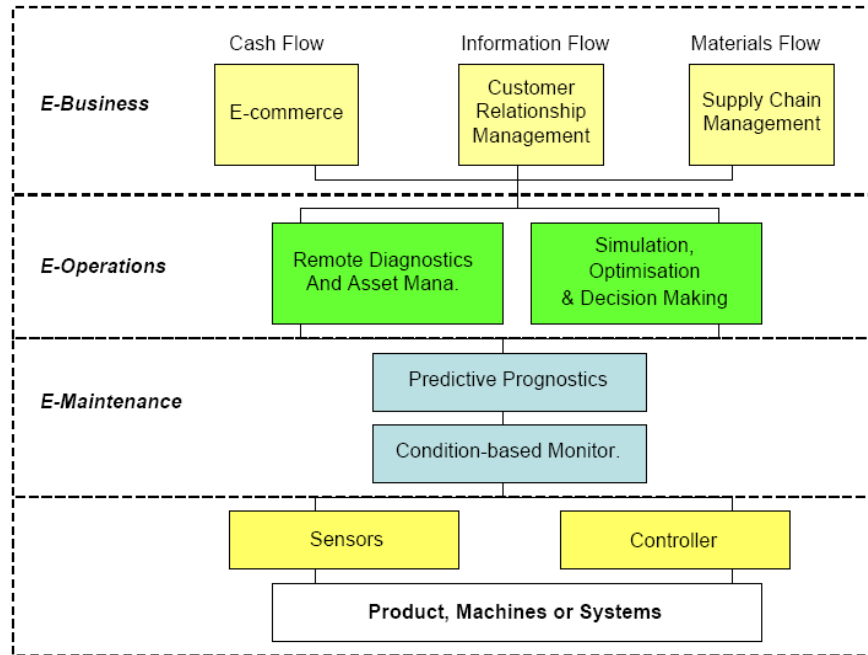


Figure 5. An enterprise view of e-maintenance (Lee and Ni, 2004).

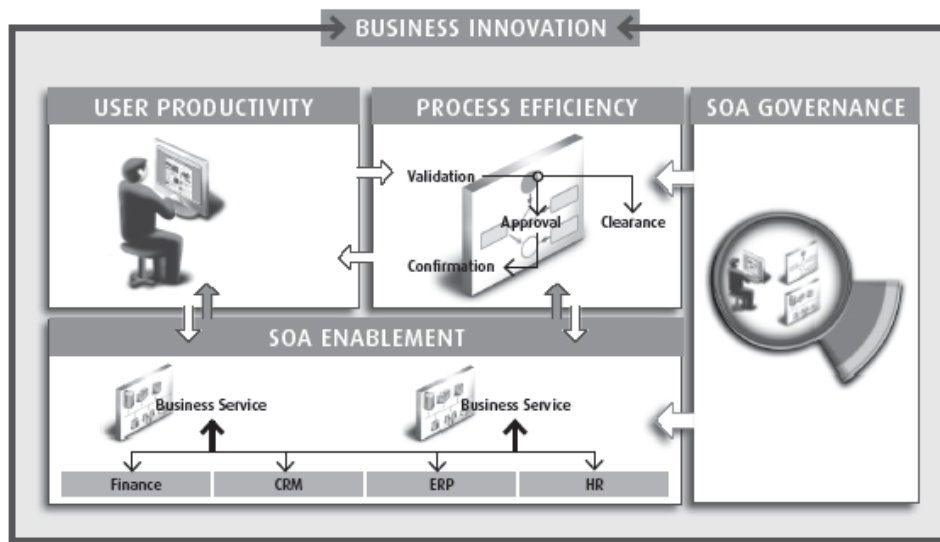


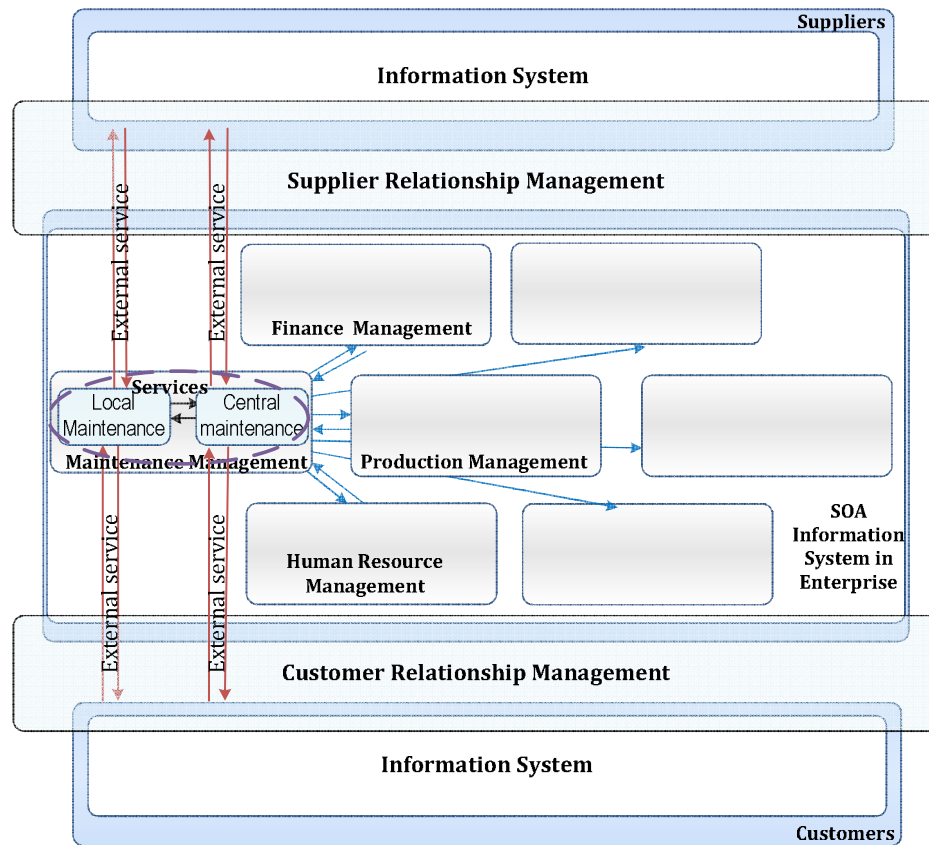
Figure 6. SOA governance (Schneider, 2010).

Figure 6 shows an SOA-enabled environment whereby ERP, CRM, HR, finance, and other business services can communicate in a seamless environment along governance over processes.

**DISCUSSION**

According to the main functionalities of maintenance management systems and their interactions with external

and internal business units in organizations, various services can be found in maintenance management systems and have been depicted in Figure 7. With comparison to functional approach, services are main elements of maintenance systems in service oriented approach (Karim et al., 2008). Maintenance management system includes a collection of services in order to facilitate interaction of maintenance with external or internal entities and have been suggested with following classification:



**Figure 7.** Proposed perspective of internal and external interactions through services in maintenance management system

**Interaction with external entities:** These services can be applied to handle the maintenance requirements with external entities rather than business units inside enterprise. These services include functions of maintenance which can be provided for suppliers through contract management or even raising work request by supplier for maintenance department. External services can be applied to cover some services for customers and suppliers through customer relationship management (CRM) and supplier relationship management (SRM) (Rehan and Akyuz, 2010).

**Interaction with internal entities:** These services can be applied to handle the maintenance requirements with internal entities in enterprise. Different types of organizational structure for maintenance department such as centralized or decentralized (Hajshirmohammadi and Wedley, 2004) require accessibility from different places or have transaction of data with contractors from their sites. These services include work orders assigned to maintenance department or work requests which are raised by local or central department.

For instance, in case of insufficient skills in local maintenance, a work request will be raised through service to central maintenance. The work request is one

of the services in maintenance that can be applied for interaction with both external and internal entities. In an SOA-enabled maintenance system, services are not limited to support the internal interactions and can be extended to CRM and SRM. Work request service can be used by central maintenance, production planning department, human resource department, or even external customers and suppliers. Work request is one of the services in SOA maintenance management which is discussed here. Other services in an SOA-enabled maintenance management are valuable to study for further research.

This review reveals that recent trends in maintenance management systems tend to be more flexible in integration with other businesses even in different platforms. In addition, e-maintenance based on SOA can facilitate long distance communication, contract management, CBM with real-time data, and interaction with other integrated systems through web services. SOA-enabled CMMS is a helpful tool in maintenance management systems to have integration with other parts of organizations but concerns about governance of services, reliability, and securities still remain. SOA is a new approach in information systems and maintenance management information systems certainly pave this



road. In this paper, the trends of maintenance management and applying recent information technology in maintenance management have been reviewed to make a helpful source of information for trends of e-maintenance and service oriented architecture in maintenance management.

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